Aeronautical Engineering with Indexes

National Aeronautics and Space Administration

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### ACCESSION NUMBER RANGES

Accession numbers cited in this Supplement fall within the following ranges.

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### **AERONAUTICAL ENGINEERING**

# A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 257)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in September 1990 in

- Scientific and Technical Aerospace Reports (STAR)
- · International Aerospace Abstracts (IAA).



National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Division
Washington, DC
1990



### INTRODUCTION

This issue of Aeronautical Engineering -- A Continuing Bibliography (NASA SP-7037) lists 560 reports, journal articles and other documents originally announced in September 1990 in Scientific and Technical Aerospace Reports (STAR) or in International Aerospace Abstracts (IAA).

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category.

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cumulative index will be published.

Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

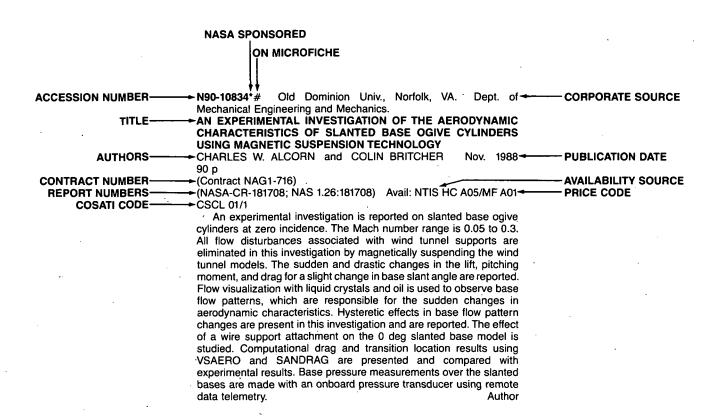
### **TABLE OF CONTENTS**

	Page
Category 01 Aeronautics (General)	617
Category 02 Aerodynamics Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.	619
Category 03 Air Transportation and Safety Includes passenger and cargo air transport operations; and aircraft accidents.	635
Category 04 Aircraft Communications and Navigation Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.	637
Category 05 Aircraft Design, Testing and Performance Includes aircraft simulation technology.	641
Category 06 Aircraft Instrumentation Includes cockpit and cabin display devices; and flight instruments.	651
Category 07 Aircraft Propulsion and Power Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and onboard auxiliary power plants for aircraft.	654
Category 08 Aircraft Stability and Control Includes aircraft handling qualities; piloting; flight controls; and autopilots.	667
Category 09 Research and Support Facilities (Air) Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tubes; and aircraft engine test stands.	672
Category 10 Astronautics Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; space communications, spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.	674
Category 11 Chemistry and Materials Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; propellants and fuels; and materials processing	675

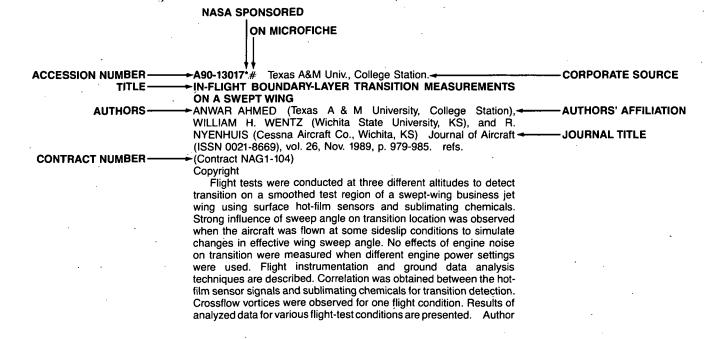


Category 12 Engineering Includes engineering (general); communications and radar; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.	679
Category 13 Geosciences Includes geosciences (general); earth resources and remote sensing; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.	692
Category 14 Life Sciences Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and space biology.	N.A.
Category 15 Mathematical and Computer Sciences Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.	693
Category 16 Physics Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.	695
Category 17 Social Sciences Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law, political science, and space policy; and urban technology and transportation.	N.A.
Category 18 Space Sciences Includes space sciences (general); astronomy; astrophysics; lunar and planet- ary exploration; solar physics; and space radiation.	N.A.
Category 19 General	699
Subject Index	B-1 C-1 D-1 E-1
Accession Number Index	

### TYPICAL REPORT CITATION AND ABSTRACT



### TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



# AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 257)

OCTOBER 1990

### 01

### **AERONAUTICS (GENERAL)**

### A90-40345

TRANSPORT AIRCRAFT CORROSION CONTROL

Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, July 2, 1990, p. 60-64, 66, 68 (4 ff.).

Copyright

Ongoing efforts to monitor and control corrosion damage to commercial aircraft are reviewed, with a focus on the activities of the Airworthiness Assurance Task Force (AATF) established by the airline and manufacturing industries. Topics addressed include (1) the AATF standard classifying repairs made on transport aircraft before 1978 (when damage-tolerance design standards were initiated) into four categories: (2) the recommendation by the AATF Subcommittee on Corrosion that the Airworthiness Directives proposed by the FAA for B-707/720, B-727, B-737, and B-747 aircraft be softened to allow more flexibility to operators and manufacturers in responding to the corrosion problem; (3) a shortage of replacement parts for older aircraft and its potential delaying effect on the repair effort; (4) the problems encountered by the FAA in finding additional inspectors; (5) the possibility that new regulations may force most of the current narrow-body transport fleet out of service by the year 2000; and (6) new design approaches being adopted by aircraft manufacturers to control corrosion.

### A90-40648#

# RATIONALE FOR DETERMINING INFORMATION ASSOCIATED WITH AIRCRAFT GAS TURBINE ENGINES THAT IS OF HISTORICAL IMPORTANCE

A. STUART ATKINSON (Management Consulting and Research, Inc., Falls Church, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 21 p. refs

(AIAA PAPER 90-2754) Copyright

A rationale is developed for the selection of the most important information associated with the design features and performance characteristics of aircraft gas turbine engines (AGTEs) in the U.S., with a view to the compilation of a historical data base that will facilitate the projection and analysis of performance trends and perhaps suggest avenues to future development. The AGTE data base must encompass turbojet, turboprop, and turboshaft configurations; it is envisioned as including engine-generated noise and pollution data, as well as radar and IR detectability, visual exhaust emission detectability, and resistance to combat damage, in the case of military AGTEs.

### A90-41110#

### TECHNOLOGICAL PREPARATIONS OF CIVIL AIRCRAFT PROGRAMS

HUBERT LIESE Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 6, 7.

Copyrigh

Civil aircraft development programs must be closely tied to

competitive criteria such as mission fulfillment, economics, environmental control and safety. Economics is certainly one of the most important criteria for the commercial operator. Fuel and maintenance costs, depreciation of aircraft unit price, along with interest rates and insurance costs, are all critical factors in the economic analysis. Technological considerations in civil aircraft development studies include aerodynamics, configuration, structures and designs, propulsion, and equipment, including avionics and controls. Finally, all of these criteria must be used to identify relevant fields of technology and to evaluate them with respect to their effects on future aircraft utilization.

### A90-41112#

### EUROMART - THE EUROPEAN AVIATION RESEARCH AND TECHNOLOGY PROGRAM

JOHANNES SPINTZYK Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 22, 23.

Copyright

A study was required by the EEC in 1987 on the status of the European aeronautics industry and its future requirements. Follow-on studies were developed into five areas of work: (1) technologies for advanced materials, (2) design methods and quality assurance for products and procedures, (3) application of production technologies, (4) technology for production methods, and (5) special aviation activities. More than 50 aviation-specific projects have been selected within the five major work areas. Helicopter, engine, and equipment companies, as well as Euromart companies and research institutes and universities are all participating in this research and technology program.

### A90-41177

### CONCEPT DEMONSTRATION OF THE USE OF INTERACTIVE FAULT DIAGNOSIS AND ISOLATION FOR TF30 ENGINES

GRAHAM F. FORSYTH and MICHAEL D. LARKIN (Department of Defence, Aeronautical Research Laboratories, Canberra, Australia) IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 1. Tullahoma, TN, University of Tennessee, 1989, p. 15-20.

Copyright

A prototype interactive fault diagnosis and isolation system (IFDIS) has been developed for the TF-30 turbofans powering the F-111 aircraft, with a view to troubleshooting functions while the engine is mounted on the aircraft. IFDIS is designed to suggest a possible 'fault' for a known problem. Two related methods, the 'fault model' produced by the engine manufacturer and the 'qualitative model' generated by defining the symptoms associated with failure modes of all replaceable items. The proper role of the knowledge supervisor used will depend on the verification procedure chosen.

### A90-42156#

### TREND ANALYSIS AND DIAGNOSTICS CODES FOR TRAINING PURPOSES

G. TORELLA (Accademia Aeronautica, Naples, Italy) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-2394) Copyright

The development of theoretical techniques and numerical

computer codes for training of personnel in new maintenance techniques based on 'on condition' criteria is discussed. Those techniques most suited for trend analysis studies are examined along with the development and use of codes for diagnostics. Examples are presented.

A90-42475#

### THE PLACE OF KNOWLEDGE BASED SYSTEMS IN HELICOPTER DYNAMIC SYSTEM CONDITION PROGNOSIS

IAN C. CHEESEMAN (Stewart Hughes, Ltd., Southampton, Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 33 p. refs

Applications are made of rule-based prognostic programs to several diagnostic problems associated with helicopter rotor head, transmission, and gas turbine problems. The various applications are discussed and their problems and successes are reviewed. The programs have proved useful in allowing hypotheses to be tested and have made it relatively easy to accommodate the wide-ranging quantities and quality of data available in the field. For program efficiency the code has been written in FORTRAN or in C. An essential feature of the development system is a powerful interface between the two languages and Prolog or Lisp. Among the topics addressed are the modification of the traditional view of the value of knowledge-based systems by the ability of the general mechanical or aeronautical engineer to think numerically, and the importance of the representation of data in the most suitable form. Roles in which the engineer can profitably interact with the knowledge-based system are considered, along with the ability of allowing a system to 'self-learn' from a data base.

### A90-42476# THE MODULAR HUM SYSTEM

PETER J. GOODCHILD (Stewart Hughes, Ltd., Southampton, Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p.

Investigations are carried out in what is called health and usage systems (HUMS), to improve the safety and reliability of rotor wing aircraft. This system consists of permanently installed digital devices which continuously monitor the integrity and life of components within the rotor wing mechanism. Some of the problems that must be addressed when designing a HUMS and how these ideas are used to develop a practical demonstrator, are discussed. This computer system architecture, with its built-in expansion capability and flexibility, means that current techniques can work in the current S61-N tests, and that the system can be adapted for other aircraft and new analysis techniques.

### A90-42478# THE FRANCO-GERMAN HELICOPTER PROGRAMME HAP. PAH-2/HAC

A. HORLEBEIN (Eurocopter GmbH, Munich, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 13 p.

The HAP, PAH-2/HAC, the first joint Franco-German helicopter. development, is discussed. The scope of the development phase of this antitank aircraft is outlined and the sharing of work between France and Germany is shown in a block diagram and summarized. The roles of integrated teams are pointed out and the activities of the two governments and industry are discussed. Cost aspects and schedules are addressed, and the state of the program as of August 1988 is reviewed. C.D.

A90-42489#

### **EH-101 MAIN ROTOR HUB APPLICATION OF THICK CARBON** FIBER UNIDIRECTIONAL TENSION BANDS

L. CARONI, G. ACAMPORA, F. BORGNOLO, O. ROSSI, and M. FARIOLI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Cascina Costa di Samarate; Elicotteri Meridionali S.p.A., Frosinone, Italy)

Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 19 p.

The design and manufacture of the hub assembly of the EH-101 main rotor including a number of graphite loop windings are described. The principal defects of the graphite loop windings and the hub assembly are identified using nondestructive evaluation methods, and improvements to the fabrication process designed to eliminate the typical defects are described. Acceptance limits for the hub assembly are established.

### A90-42492# **DESIGN AND MANUFACTURING OF COMPOSITE MATERIALS BLADE MODELS**

F. DUPRIEZ, P. GEOFFROY, and B. PALUCH (Lille I, Universite, Villeneuve-d'Ascq, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 21

Methods and tools used in the design of helicopter rotor blade models in structural composites for wind tunnel testing are briefly reviewed. In particular, attention is given to structural design using finite beam and shell elements, aerodynamic methods, dynamic methods, and the material data base. The discussion also covers design software, blade model instrumentation, and quality control.

### N90-23340 Mauter (George A.), Huntington Station, NY. AIRCRAFT DRAWINGS INDEX

GEORGE A. MAUTER, comp. 1989 68 p Copyright Avail: George A. Mauter, 268 East Seventeenth Street, Huntington Station, NY 11746

This is an index to a collection of cutaway or 3-view drawings of specific aircraft collected from aviation periodicals by the Fairchild Republic Company Librarian during his tenure there. Drawings of commercial and military aircraft from over 25 countries are indexed. The data elements presented include aircraft designation; name; manufacturer; country; type of drawing; journal title, date and page numbers. Access to this information is provided via two listings: one arranged by aircraft designation and one by name (or NATO codename). This index enables anyone to obtain individual drawings from his library or through inter-library loan.

Author

N90-24225# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.

### TEST AND MEASUREMENT TECHNIQUE IN HYPERSONICS [VERSUCHS- UND MESSTECHNIK IN HYPERSCHALL]

J. SZODRUCH, ed. and W. NITSCHE, ed. Jun. 1989 In ENGLISH and GERMAN Congress held in Goettingen, Fed. Republic of Germany, 2-3 Mar. 1989 Original contains color illustrations LIMITED REPRODUCIBILITY: More than 20% of this document may be affected by color photographs

(ILR-MITT-225(1989); ETN-90-96480) Avail: NTIS HC A07/MF

Hypersonics often appear in current projects such as Hermes and Sanger. The partners in the 1989 Goettingen congress agreed that the status of the technique does not enable economical developments of transporters. Topics include: a wind tunnel for the investigation of compressible flows until M equals 6; a gun-tunnel for flow mechanics; high enthalpy hypersonic wind tunnel; LARVE mission; hypersonic vacuum wind tunnels; flow field measurements in the retaining point area of a half spheric cylinder by thin hypersonic flow with electron radiation; short-time force measuring system for shock wave channels; calculation of accuracy for force and moment measurements in radial flow field of hypersonic conic nozzles; and infrared thermography in hyper-

### 02

### **AERODYNAMICS**

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A90-38915#

AEROELASTIC ANALYSIS OF A LOW ASPECT RATIO WING P. RAJAGOPAL, N. G. V. VITTALA, and T. S. RAMANI (National

Aeronautical Laboratory, Bangalore, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 42, Feb. 1990, p. 51-56. refs

Analytical predictions of aeroelastic behavior like flutter and divergence of a typical wing configuration are presented in this paper. To facilitate the calculation of steady or unsteady airloads, the modal data of the wing configuration in the form of a limited number of low frequency mode shapes and their associated generalized masses and stiffnesses are generated CSA/NASTRAN. Unsteady airloads required to perform flutter analysis are evaluated for a set of natural modes using piston theory. The flutter model formulated combining the structural and aerodynamic models is solved using KE method available in CSA/NASTRAN. Critical flutter Mach number and flutter frequencies are calculated from the condition that the damping of the whole system should be zero. To calculate steady air load in the supersonic regime, the normal mode shapes are expressed in the form of polynomials. Then the divergence equation, formulated by combining the steady airload and stiffness matrix, is solved as an eigenvalue problem to obtain the divergence Mach number for the wing.

A90-39049\*# National Aeronautics and Space Administration.

Ames Research Center, Moffett Field, CA.

CALCHIATION OF HYPERSONIC FOREBODY (IN ET ELOW

CALCULATION OF HYPERSONIC FOREBODY/INLET FLOW FIFLDS

BRADFORD C. BENNETT and THOMAS A. EDWARDS (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 21st, Seattle, WA, June 18-20, 1990. 11 p. refs

(AIAA PAPER 90-1493) Copyright

The National Aero-Space Plane (NASP) is unique in its integration of the airframe and propulsion system. The performance of the NASP propulsion system (scramjet) is dependent upon the quality of the flow into the scramjet inlet. Hence, the calculation of the inlet flow field must be coupled to the forebody flow field for accurate performance predictions. The Compressible Navier-Stokes code has been extended to perform both external and internal hypersonic flow fields. Computations are presented that validate these changes and demonstrate the capability to perform coupled forebody/inlet computations for hypersonic flows.

A90-39465

NUMERICAL SOLUTION OF THE PROBLEM OF SUPERSONIC FLOW OF A VISCOUS GAS PAST A CONCAVE CONICAL WING [CHISLENNOE RESHENIE ZADACHI OB OBTEKANII VOGNUTOGO KONICHESKOGO KRYLA SVERKHZVUKOVYM POTOKOM VIAZKOGO GAZA]

N. M. BELIAEV, V. L. BORSHCH, and V. V. KRAVETS (Dnepropetrovskii Gosudarstvennyi Universitet, Dnepropetrovsk, Ukrainian SSR) Gidromekhanika (ISSN 0367-4088), no. 60, 1989, p. 31-37. In Russian. refs

Copyright

Supersonic viscous flow past a concave conical wing at Mach 3 and angles of attack. 0.5 and 10 deg is analyzed in the quasi-conical approximation for the Navier-Stokes equations using an explicit McCormack's scheme. It is shown that the approach used here provides sufficiently detailed information on the kinematic characteristics of flow past the wing and on the dynamics of formation, convergence, and coalescence of suspended shock

waves on the concave side with an increase in angle of attack, making it possible to add new elements to the structural scheme of the flow.

V.L.

A90-39475

MATHEMATICAL MODELING OF PLANE PARALLEL SEPARATED FLOWS PAST BODIES (MATEMATICHESKOE MODELIROVANIE PLOSKOPARALLEL'NOGO OTRYVNOGO OBTEKANIIA TEL]

SERGEI M. BELOTSERKOVSKII, VLADIMIR N. KOTOVSKII, MIKHAIL I. NISHT, and ROMAN M. FEDOROV Moscow, Izdatel'stvo Nauka, 1988, 232 p. In Russian. refs Copyright

The theory of plane parallel flow past a body is presented in a systematic manner. In particular, attention is given to the principal classes of aerodynamic problems for plane parallel flows past bodies, stationary and nonstationary aerodynamic characteristics of bodies, and statistical characteristics of wake flows. A numerical method is presented which is based on the synthesis of nonviscous incompressible flow and boundary layer models. The discussion also covers algorithms for solving aerodynamic problems, examples of flow calculations, and comparisons with experimental data.

V.L.

A90-39514

BOUNDARY LAYER STABILITY IN THE CASE OF TRANSONIC EXTERNAL FLOW [OB USTOICHIVOSTI POGRANICHNOGO SLOIA PRI TRANSZVUKOVYKH SKOROSTIAKH VNESHNEGO POTOKA]

O. S. RYZHOV and I. V. SAVENKOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Mar.-Apr. 1990, p. 65-71. In Russian. refs

The classical theory of free interaction predicts the stability of direct waves propagating in the incoming flow direction in the case of supersonic flow velocities. The available equations for the transonic range, however, are not applicable to stability problems for viscous flows, although they do predict correctly flow separation. Here, an additional analysis of the initial system of Navier-Stokes equations is carried out in order to preserve the terms determining the loss of boundary layer stability in the transonic region. V.L.

A90-39516

PERTURBATIONS OF HIGHER MODES IN A SUPERSONIC JET [VOZMUSHCHENIIA VYSOKIKH MOD V SVERKHZVUKOVOI STRUE]

N. A. ZHELTUKHIN and N. M. TEREKHOVA PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Mar.-Apr. 1990, p. 75-83. In Russian. refs Copyright

The objective of the study was to test the hypothesis of the existence of longitudinal vorticity in free supersonic jets in the form of stationary vortices confined to the compressed layer region and oriented along the flow. In particular, attention is given to two types of structures associated with instabilities of different types. The structures examined are Taylor-Goertler vortices and longitudinal vortices resulting from the nonlinear interaction of large-scale instability waves with the jet mixing layer, which are similar to the Benny-Lin vortices.

A90-39518

WAVE STRUCTURE OF ARTIFICIAL PERTURBATIONS IN A SUPERSONIC BOUNDARY LAYER ON A PLATE [VOLNOVAIA STRUKTURA ISKUSSTVENNYKH VOZMUSHCHENII V SVERKHZVUKOVOM POGRANICHNOM SLOE NA PLASTINE]

A. D. KOSINOV, A. A. MASLOV, N. V. SEMENOV, and S. G. SHEVEL'KOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Mar.-Apr. 1990, p. 95-98. In Russian. refs

Artificially produced perturbations in a boundary layer on a plate were investigated experimentally in a supersonic wind tunnel with a test section of 200x200 mm at Mach 2. Perturbations were

introduced either internally using a point source or externally using acoustic waves. The wave structures of perturbations produced by the two excitation methods are discussed and compared.

VΙ

#### A90-39519

THE PROBLEM OF SUPERSONIC FLOW PAST A THIN WING OF FINITE SPAN WITH FULLY SUBSONIC LEADING EDGES [K ZADACHE OBTEKANIIA SVERKHZVUKOVYM POTOKOM TONKOGO KRYLA KONECHNOGO RAZMAKHA S POLNOST'IU DOZVUKOVYMI PEREDNIMI KROMKAMI]

N. F. VOROB'EV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Mar.-Apr. 1990, p. 105-111. In Russian. refs Copyright

The problem of supersonic flow past a slightly curved wing with fully subsonic leading edges is solved by assuming a zero perturbation potential on the basis plane outside the wing projection plane. The problem is reduced to an integral Volterra equation of the second kind, and the possibility of solving this equation by the method of successive approximations is demonstrated. The solution has the form of a series whose terms are multiple integrals of known functions.

#### A90-39538

## VORTEX THEORY FOR THE SCREW PROPELLER WITH A HUB [VIKHREVAIA TEORIIA GREBNOGO VINTA SO STUPITSEI]

L. F. KOZLOV Bionika (ISSN 0374-6569), no. 23, 1989, p. 1-12. In Russian. refs Copyright

A vortex theory for the screw propeller is presented which allows for the effect of the propeller hub on the induced velocity field. It is shown that the consideration of additional velocities associated with the hub in propeller design does not lead to significant changes in its integral hydrodynamic characteristics but may affect local hydrodynamic effects at the blade root. The theory is found to be in good agreement with experimental data.

### A90-39539

RELATIONSHIP BETWEEN VELOCITY CIRCULATION AROUND A WING PROFILE AND VORTICITY DISPERSION IN A BOUNDARY LAYER [O SVIAZI TSIRKULIATSII SKOROSTI VOKRUG PROFILIA KRYLA S DISPERSIEI ZAVIKHRENNOSTI V POGRANICHNOM SLOE]

V. A. KOCHIN (AN USSR, Institut Gidromekhaniki, Kiev, Ukrainian SSR) and L. F. KOZLOV Bionika (ISSN 0374-6569), no. 23, 1989, p. 12-17. In Russian. refs Copyright

The generalized Zhukovskii-Chaplygin postulate is derived for determining velocity circulation around a wing profile with allowance for viscosity effects in the boundary layer approximation. Some known particular cases are examined.

V.L.

## A90-39780\*# Vigyan Research Associates, Inc., Hampton, VA. NAVIER-STOKES SOLUTIONS FOR VORTICAL FLOWS OVER A TANGENT-OGIVE CYLINDER

PETER-M. HARTWICH (Vigyan, Inc., Hampton, VA) and R. M. HALL (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1171-1179. Previously cited in issue 09, p. 1279, Accession no. A89-25284. refs

(Contract NAS1-17919) Copyright

### A90-39782#

TRANSONIC FLOW AROUND AIRFOILS WITH RELAXATION AND ENERGY SUPPLY BY HOMOGENEOUS CONDENSATION GUENTER H. SCHNERR and ULRICH DOHRMANN (Karlsruhe, Universitaet, Federal Republic of Germany) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1187-1193. Research supported by the Klein, Schanzlin und Becker Stiftung. Previously cited in

issue 18, p. 2755, Accession no. A89-42062. refs (Contract DFG-ZI-18-31) Copyright

#### A90-39801#

### LIFT RESPONSE OF A RECTANGULAR WING UNDERGOING A STEP CHANGE IN FORWARD SPEED

R. STEVEN SAWYER and JOHN P. SULLIVAN (Purdue University, West Lafayette, IN) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1306, 1307. refs Copyright

The indicial lift response function of a rectangular wing due to a step change in forward speed is investigated experimentally to verify the formulations derived by Jones (1939) and Dore (1964). Tests were carried out on a 9-in. chord 36-in. aspect-ratio-4 wing at a nominal angle of attack of 10 deg to which motive force was supplied by a large-bore short-stroke air cylinder connected to the table which also supported the wing with its force transducers. Data acquisition consisted of performing a least-squares fit on the position vs time data. The results showed the response of the wing to a rapid acceleration at a constant speed. The wing showed the correct steady-state lift, indicating that the finite size and influence of the rectangular wing wake is correctly accounted for by the theory.

### A90-39814#

### COMMENTS ON 'EFFECT OF NOSE BLUNTNESS AND CONE ANGLE ON SLENDER-VEHICLE TRANSITION'

KENNETH F. STETSON (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1336, 1337; Author's Reply, p. 1337. refs

#### A90-40181#

### CALCULATION OF STABILITY DERIVATIVES FOR SLENDER BODIES USING BOUNDARY ELEMENT METHOD

SHINJI SUZUKI (Tokyo, University, Japan) and KIZUKI FUKUDA Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 763-765. refs Copyright

The boundary element method is presently used to calculate the stability derivatives of a slender body, on the basis of apparent-mass coefficients of the crossflow section. This technique furnishes a computer-aided design tool for aerospace engineers requiring stability derivative estimates at the initial design stage. Since the stability derivatives related to the drag force cannot be calculated by the preceding potential-flow theory, a semiempirical formula is used for drag estimation..

A90-40495\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### SUPERCOMPUTER APPLICATIONS IN GAS TURBINE FLOWFIELD SIMULATION

NATERI K. MADAVAN, PAUL KELAITA (NASA, Ames Research Center; Sterling Federal Systems, Inc., Moffett Field, CA), and SHARAD GAVALI (Amdahl Corp., Sunnyvale, CA) International Journal of Supercomputer Applications (ISSN 0890-2720), vol. 4, Summer 1990, p. 81-95. Research supported by the U.S. Navy. refs
Copyright

The numerical simulation of the unsteady three-dimensional viscous flow in a gas turbine stage is considered. Results from a three-dimensional time-accurate Navier-Stokes simulation of rotor-stator interaction in an axial turbine stage are presented. The present study uses a fine grid in the spanwise direction to better resolve the complex three-dimensional flowfield, and complements earlier reported coarse-grid calculations. Several different features of the flowfield are analyzed and compared to earlier calculations and to experimental data whenever possible. Computer animation techniques are used to visualize various unsteady three-dimensional features of the flow. The results demonstrate the capabilities of current computing hardware in obtaining accurate simulations of unsteady flows in turbomachines.

Author

#### A90-40501#

### NUMERICAL SOLUTION OF 3-D HYBRID PROBLEMS IN TURBOMACHINERY

NAIXING CHEN, MING DONG, and JIALIN ZHANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 97-102. In Chinese, with abstract in English. refs

A new numerical method for solving aerodynamic hybrid problems of fully 3-D flow in turbomachinery is presented. This method is based on a nonorthogonal coordinate system and contravariant components and employs the approximate factorization-multigrid scheme in conservative form. It has been proved that this scheme improves the numerical computation convergence speed and the computational precision. The computer program written by this method for numerical solution of the 3-D hybrid problem has been applied to modify a single rotor compressor with satisfactory results.

#### A90-40504#

## THE INFLUENCE OF THE INLET MACH NUMBER ON THE BOUNDARY LAYER DEVELOPMENT ON TURBOMACHINERY BLADE SURFACES

NIANGUO ZHU and LIPING XU (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 118-122. In Chinese, with abstract in English.

Keeping the Reynolds number and the blade surface pressure coefficient distribution constant, the influence of the inlet Mach number on the boundary-layer development on the blade surfaces of turbomachinery is studied with numerical simulation as well as an order-of-magnitude analysis, based on the integral boundary-layer equation. The effects of surface curvature and the free-stream turbulence intensity on the development of the boundary layer are also estimated by the numerical simulation. The results show that the variation of the nondimensional integral parameters with the inlet Mach number is very small; up to the critical Mach number, the changes are usually within the engineering tolerance. The variation caused by the surface curvature differences is of the same order as that due to Mach number; however, the freestream turbulence level can cause remarkable changes in the development of the boundary layer.

### A90-40513#

## AN EXPERIMENTAL INVESTIGATION OF ROTATING STALL IN A CENTRIFUGAL COMPRESSOR WITH VANELESS DIFFUSER

WULI CHU (Northeastern Polytechnical University, People's Republic of China) and TONG JIANG (Xian Jiaotong University, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 163-165. In Chinese, with abstract in English.

This paper deals with experimental investigation of unsteady flow in a radial vaneless diffuser. The circumferentially uniform discharge at the exit of the diffuser changes into a periodic circumferentially fluctuating flow state. The results of the investigation indicate that two types of rotating velocity patterns occur successively as the flow rate decreases. Their rotational speeds are different, and the pattern with low rotational speed appears first.

Author

### A90-40555#

### SIMULATION OF INVISCID BLADE-ROW INTERACTION USING A LINEARISED POTENTIAL CODE

A. SUDDHOO and P. STOW (Rolls-Royce, PLC, Derby, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-1916) Copyright

A linearized unsteady finite-element blade-to-blade potential flow code used for flutter predictions is modified to simulate the inviscid (potential) interaction between two adjacent blade rows in a turbomachine. In particular, the inlet and exit boundary conditions are modified in order to model an incoming pressure wave.

Comparisons of the present unsteady flow results with those of semianalytical and time marching methods show good agreement. A comparison with an exact test case shows important dependence of the solution on the grid fineness, Mach number of the steady flow, and the frequency of the wave. Results presented for blade row interaction demonstrate the importance of blade numbers in the design of a single stage.

Author

### A90-40592#

### COMPUTATIONAL MODELING OF INLET HAMMERSHOCK WAVE GENERATION

ISMAIL O. HINDASH, ROBERT H. BUSH, and RAYMOND R. COSNER (McDonnell Aircraft Co., Saint Louis, MO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p.

(AIAA PAPER 90-2005) Copyright

A two dimensional computational fluid dynamics study was conducted to evaluate existing prediction capabilities of the inlet duct pressure rise occurring during an engine stall/hammershock event. Results were compared to analytical shock tube predictions and to available flight data. Good accuracy was obtained at a reasonable cost. The model was extended to predict a nonuniform stall/hammershock pressure rise. The impact of two dimensional geometric variations also was studied.

### A90-40596#

### AERODYNAMIC DETUNING FOR CONTROL OF SUPERSONIC ROTOR FORCED RESPONSE

KAREN M. SPARA and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-2018) Copyright

A mathematical model is developed to analyze the aerodynamically forced response characteristics of a detuned rotor operating in a supersonic inlet flow field with a supersonic axial component. Alternate blade aerodynamic detuning is considered, with the aerodynamic detuning accomplished by alternating the circumferential spacing of adjacent blades. The unsteady aerodynamics are determined by developing an influence coefficient technique which is appropriate for both aerodynamically tuned and detuned rotor configurations. Rotor forced response is then analyzed by combining this unsteady aerodynamic model with a single-degree-of-freedom structural model. The effects of this detuning on the forced response characteristics of supersonic axial flow rotors is then demonstrated by applying this model to baseline twelve bladed rotors.

### A90-40599#

### SUPERSONIC RECTANGULAR ISOTHERMAL SHROUDED

H. L. BOWMAN, E. GUTMARK, K. C. SCHADOW, K. J. WILSON, and R. A. SMITH (U.S. Navy, Naval Weapons Center, China Lake, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (AIAA PAPER 90-2028)

The entrainment characteristics of shrouded flows utilizing supersonic shrouded circular or rectangular converging/diverging jets were investigated using a free jet test facility with interchangeable supersonic circular or 3 to 1 aspect ratio rectangular nozzles with a design Mach number of 2.0. Entrained flow velocity was measured at the shroud inlet, and the mass flow ratios were computed for different shroud lengths and diameters. It was found that rectangular jets with supersonic divergence on the major axis or on both axes induced higher entrained flow velocities and mass flow ratios compared to the circular jet, or a rectangular jet with divergence only on the minor axis.

### A90-40612#

### A NUMERICAL INVESTIGATION OF SUPERSONIC INLET USING IMPLICIT TVD SCHEME

JUNJI SHIGEMATSU (Ishikawajima-Kogyo Co., Ltd., Tokyo, Japan), KAZUOMI YAMAMOTO (National Aerospace Laboratory, Tokyo,

Japan), KAZUO SHIRAISHI, and ATSUSHIGE TANAKA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (AIAA PAPER 90-2135) Copyright

The compressible Navier-Stokes equations were solved to investigate supersonic inlet flowfield. In two-dimensional analysis, the mass flowplug which control the back pressure was modeled numerically for close modeling of experimental case. The three-dimensional computation was done to predict threedimensional flow behavior such as corner vortex and interaction between oblique shock wave and side wall turbulent boundary layer. The two-dimensional numerical analysis could predict the complicated flowfield on various mass flowplug condition respectively. The results by three-dimensional computation could show the viscous effects caused by the interaction between ramp oblique shock wave and the side wall turbulent boundary layer. The computations were compared with the experimental results of wind tunnel test. The numerical solutions were successfully agreed with the experimental results. Author

**A90-40678\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### STRAKE CAMBER AND THICKNESS DESIGN PROCEDURE FOR LOW ALPHA SUPERSONIC FLOW

JAMES L. PITTMAN, DARYL L. BONHAUS (NASA, Langley Research Center, Hampton, VA), and MICHAEL J. SICLARI (Grumman Aerospace Corp., Bethpage, NY) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 481-487. Previously cited in issue 21, p. 3336, Accession no. A87-49059. refs Copyright

#### A90-40679#

### **VARIOUS SOURCES OF WING ROCK**

L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 488-494. Previously cited in issue 21, p. 3484, Accession no. A88-50610. refs

### A90-40681#

### PRELIMINARY CHARACTERIZATION OF PARACHUTE WAKE RECONTACT

JAMES H. STRICKLAND and J. MICHAEL MACHA (Sandia National Laboratories, Albuquerque, NM) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 501-506. Previously cited in issue 14, p. 2115, Accession no. A89-35214. refs (Contract DE-AC04-76DP-00789)

# A90-40682\*# Texas A&M Univ., College Station. DETERMINATION OF AERODYNAMIC SENSITIVITY COEFFICIENTS BASED ON THE TRANSONIC SMALL PERTURBATION FORMULATION

HESHAM M. ELBANNA and LELAND A. CARLSON (Texas A & M University, College Station) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 507-515. Previously cited in issue 09, p. 1282, Accession no. A89-25426. refs (Contract NAG1-793)

A90-40683\*# Naval Postgraduate School, Monterey, CA. FLOW VISUALIZATION STUDIES OF THE MACH NUMBER EFFECTS ON DYNAMIC STALL OF AN OSCILLATING AIRFOIL M. S. CHANDRASEKHARA (U.S. Naval Postgraduate School, Monterey, CA) and L. W. CARR (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 516-522. Research supported by the U.S. Army, USAF, and U.S. Navy. Previously cited in issue 09, p. 1270, Accession no. A89-25019. refs

A90-40686\*# United Technologies Corp., Windsor Locks, CT. INVESTIGATION OF THE NEAR WAKE OF A PROPFAN D. B. HANSON (United Technologies Corp., Hamilton Standard

Div., Windsor Locks, CT) and W. P. PATRICK (United Technologies Research Center, East Hartford, CT) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 536-542. Research supported by United Technologies Corp. Previously cited in issue 13, p. 1940, Accession no. A89-33735. refs (Contract NAS3-23720) Copyright

### A90-40690#

### DRAG REDUCTION BY CONTROLLING FLOW SEPARATION USING STEPPED AFTERBODIES

JAMES A. KIDD, DENNIS WIKOFF, and CHARLES J. COTTRELL (USAF, Armament Laboratory, Eglin AFB, FL) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 564-566. refs

Results are presented from investigations of stepped missile afterbodies incorporated for the sake of base drag reduction on both fin- and spin-stabilized projectile configurations at subsonic, transonic, and supersonic speeds. Free-flight tests of these configurations, with various stepped, flat, and boattailed bases, indicate that the boattailed base is the most effective passive drag reduction technique available for typical munitions and missile configurations at frequently encountered flight conditions. O.C.

A90-40692\*# Lockheed Engineering and Sciences Co., Hampton, VA.

## COMPARISON OF HIGH-ANGLE-OF-ATTACK SLENDER-BODY THEORY AND EXACT SOLUTIONS FOR POTENTIAL FLOW OVER AN ELLIPSOID

MICHAEL J. HEMSCH (Lockheed Engineering and Sciences Co., Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 569-571. refs (Contract NAS1-18000) Copyright

The accuracy of high-alpha slender-body theory (HASBT) for bodies with elliptical cross-sections is presently demonstrated by means of a comparison with exact solutions for incompressible potential flow over a wide range of ellipsoid geometries and angles of attack and sideslip. The addition of the appropriate trigonometric coefficients to the classical slender-body theory decomposition yields the formally correct HASBT, and results in accuracies previously considered unattainable.

A90-40693\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### EFFECT OF DETAILED SURFACE GEOMETRY ON RIBLET DRAG REDUCTION PERFORMANCE

MICHAEL J. WALSH (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 572, 573. refs Copyright

A comparison is made of the effect of small changes in v-groove geometry, for several riblet films applicable for drag reduction to commercial transport aircraft, whose nominal v-groove dimension is of the order of 0.002 inch. The films were tested in a water towing-tank facility. The results obtained indicate that small riblet peak geometry variations can result in a deterioration of riblet drag-reduction efficacy of as much as 40 percent, while interriblet valley curvature was found not to be critical to riblet performance.

### A90-40694#

### FLOW STRUCTURE GENERATED BY OSCILLATING DELTA-WING SEGMENTS

THOMAS UTSCH and DONALD ROCKWELL (Lehigh University, Bethlehem, PA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 574-576. Research supported by USAF. refs Convigable.

An effort is made to characterize the features of the unsteady flow structure past symmetrical delta-wing segments forced to oscillate about a common axis, using for this characterization a novel flow-visualization technique involving laser-induced reflection from a grid of hydrogen bubbles. Attention is given to the complex situation of wing segments having swept leading edges, which

are undergoing a harmonic version of the clap-and-fling mechanism in the presence of axial flow. For both the clap and fling motions, the irrotational flow near the midplane of the wing segments interior is in a direction that promotes vortex formation.

A90-40749 COHERENT VORTEX STRUCTURES IN THE WAKE OF A SPHERE AND A CIRCULAR DISK AT REST AND UNDER FORCED VIBRATIONS

E. BERGER, D. SCHOLZ, and M. SCHUMM (Berlin, Technische Universitaet, Federal Republic of Germany) Journal of Fluids and Structures (ISSN 0889-9746), vol. 4, May 1990, p. 231-257.

(Contract DFG-BE-343/17)

Copyright

Results are presented from a study of the near-wake of a circular disk in the Reynolds number range 15,000 to 300,000 at low values of Mach number. It is found that the wake is dominated by three instability mechanisms: asymmetric pulsation of the recirculation bubble at very low frequency, antisymmetric fluctuations induced by a helical vortex structure at a natural frequency, and a high frequency instability of the separated shear layer. The wake of the cylinder is analyzed and compared with the wake of a sphere.

A90-40926#

INVESTIGATION OF SUPERSONIC MIXING LAYERS

J. P. RENIE, J. C. DUTTON, H. KRIER (Illinois, University, Urbana). N. L. MESSERSMITH, and S. G. GOEBEL Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 353, 354. Abridged. Previously cited in issue 07, p. 941, Accession no. A88-22527. refs (Contract N00014-86-K-0434)

Copyright

A90-40937\*# Purdue Univ., West Lafayette, IN.
COUNTER-ROTATING PROPELLANT ANALYSIS USING A FREQUENCY DOMAIN PANEL METHOD

MARC H. WILLIAMS (Purdue University, West Lafayette, IN) and JINSOO CHO Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 426-433. refs (Contract NAG3-499)

Copyright

The unsteady aerodynamic coupling between the front and rear rotors in a counter-rotating propeller system is analyzed using a frequency-domain panel method based on linear compressible aerodynamic theory. The periodic loads are decomposed into harmonics, and the harmonic amplitudes are found iteratively. Each stage of the interation involves the solution of an isolated propeller problem, the interaction being done through the Fourier transform of the induced velocity field. The method was validated by comparing mean performance parameters with measured data and by comparing the predicted velocity field with detailed laser Doppler velocimeter measurements. Comparisons have also been made between the fluctuating loads predicted by the present method and a time-domain panel method. Author

A90-40941# NUMERICAL SIMULATION OF THE GROWTH OF INSTABILITIES IN SUPERSONIC FREE SHEAR LAYERS

W. TANG, N. M. KOMERATH, and L. N. SANKAR (Georgia Institute of Technology, Atlanta) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 455-460. Previously cited in issue 09, p. 1280, Accession no. A89-25319. refs (Contract N00014-87-K-0132) Copyright

A90-40942#

REVERSE FLOW IN MULTISTAGE AXIAL COMPRESSORS

R. N. GAMACHE (USAF, Arnold Engineering Development Center, Arnold AFB, TN) and E. M. GREITZER (MIT, Cambridge, MA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 461-473. Research supported by USAF and United Technologies Corp. Previously cited in issue 20, p. 2917, Accession no. A86-42825. refs

A VISUALIZATION STUDY OF THE INTERACTION OF A FREE **VORTEX WITH THE WAKE BEHIND AN AIRFOIL** 

J. SWIRYDCZUK (Polska Akademia Nauk, Instytut Maszyn Przeplywowych, Gdansk, Poland) Experiments in Fluids (ISSN 0723-4864), vol. 9, no. 4, June 1990, p. 181-190. refs Copyright

The two-dimensional interaction of a single vortex with a thin symmetrical airfoil and its vortex wake has been investigated in a low turbulence wind tunnel having velocity of about 2 m/s in the measuring section. The flow Reynolds number based on the airfoil chord length was 4500. The investigation was carried out using a smoke-wire visualization technique with some support of standard hot-wire measurements. The experiment has proved that under certain conditions the vortex-airfoil-wake interaction leads to the formation of new vortices from the part of the wake positioned closely to the vortex. After the formation, the vortices rotate in the direction opposite to that of the incident vortex. Author

A90-41203#

COUPLED AERODYNAMIC FORCES DUE TO UNSTEADY STALL ON A HIGH-ASPECT-RATIO WING OSCILLATING AT HIGH AMPLITUDE [FORCES AERODYNAMIQUES COUPLEES DUES AU DECROCHAGE INSTATIONNAIRE SUR UNE AILE DE GRAND ALLONGEMENT OSCILLANT A GRANDE **AMPLITUDE**1

J.-J. COSTES and D. PETOT (NATO, AGARD, Specialists' Meeting on Aircraft Dynamic Loads due to Flow Separation and Workshop on Analytical Qualification of Aircraft Structures, Sorrento, Italy, Apr. 1-6, 1990) ONERA, TP no. 1990-24, 1990, 16 p. In French.

(ONERA, TP NO. 1990-24)

Experimental results obtained on a rectangular wing oscillating in pitch around the quarter chord line are discussed. Tests have been conducted for normal flow situations as well as for skewed flow cases. Comparing the data obtained with the usual theory applied in helicopter studies indicated the influence of the wing tip vortex and the importance of the wind velocity component, directed along the wing span, in the skewed flow case.

A90-41740#

INVESTIGATIONS OF THE INFLUENCE OF SLOT BLOWING FROM THE UPPER WING SURFACE ON THE FLOW AROUND THE WING AND ITS AERODYNAMIC CHARACTERISTICS **IBADANIA WPLYWU SZCZELINOWEGO WYDMUCHU Z** GRZBIETOWEJ POWIERZCHNI PLATA NA JEGO OPLYW I CHARAKTERYSTYKI AERODYNAMICZNE]

ROBERT JOZWIAK Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 117, 1989, p. 12-57. In Polish. refs

Results of experimental investigations of the influence of blowout angle and its intensity on aerodynamic lift and boundary layer flow are presented. Air is blown from a slot in the upper wing surface. It is shown that the location of the blowing slot just behind the point of the maximum negative pressure on the profile simultaneously leads to the rise of the lift coefficients, its derivative with respect to the angle of attack, and the critical angle of attack. Control zones of circulation and boundary layer, zones of subcritical, critical, and supercritical angles of the blowing and the criteria of flow separation expansion are determined. Author

A90-41751#

VORTICITY DISTRIBUTION OF VORTEX STREET IN THE WAKE OF A CIRCULAR CYLINDER

MUNESHIGE OKUDE (Meijo University, Nagoya, Japan) and TATSUYA MATSUI Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 33, May 1990, p. 1-13. refs

The hot-wire technique was used to measure the vorticity distributions in the vortex street behind a circular cylinder in a low-speed wind tunnel. The distribution of a vortex in the vortex street at intermediate distances from the cylinder resembled that of an isolated viscous vortex with the Gaussian distribution and nearly concentric circular equivorticity lines in the vortex cross-section. At distances farther downstream, where two consecutive vortices in the primary vortex street merged, the circulation of the resulting vortex had a value of about twice that of the original vortices.

#### A90-41983#

### DESIGN AND PERFORMANCE OF A SMALL, HIGH SPEED AXIAL COMPRESSOR

T. M. TYNER and J. P. SULLIVAN (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p. refs (AIAA PAPER 90-1911) Copyright

This paper describes the design and performance of a small axial compressor developed under a Pratt & Whitney small engine program. Results from both rig and gas generator tests are presented to show that the performance of the two stage compressor is outstanding, despite its small size, high speed, and aggressive loadings. This exceptional performance was achieved by using a quasi-3D/3D design system to efficiently incorporate three-dimensional features into the high reaction, low aspect ratio blading of the compressor. Results are also presented which show the compressor's sensitivity to hub clearance in the variable first vane, and the impact of variable geometry on the performance and flow capacity of the machine.

**A90-41988\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

## APPLICATION OF A NEW ADAPTIVE GRID FOR AERODYNAMIC ANALYSIS OF SHOCK CONTAINING SINGLE JETS

S. PAUL PAO (NASA, Langley Research Center, Hampton, VA) and KHALED S. ABDOL-HAMID (Analytical Services and Materials, Inc., Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 16 p. refs (AIAA PAPER 90-2025) Copyright

A fast and robust solution-adaptive grid generation method has been developed for the three-dimensional numerical analysis of shock containing supersonic jets. The adaptive grid algorithm, which is based on the equidistribution principle and the alternate direction method, has been fully integrated with the space marching scheme developed by Abdol-Hamid (1989). The capability of the approach proposed here is illustrated by numerical solutions for circular, square, and elliptic jet plumes.

### A90-41989#

## THREE DIMENSIONAL TRANSONIC AND SUPERSONIC FLOW PREDICTION IN AXI-VECTORED NOZZLES USING A FINITE VOLUME METHOD

R. K. ROUT, R. K. ROWE, and JOHN FEDERSPIEL (General Electric Co., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990.

(AIAA PAPER 90-2026) Copyright

This paper addresses application of the PHOENICS code based on the finite volume method to predict complex flows and performance parameters for a number of three-dimensional axi-vectored nozzles. A systematic approach to efficiently generate the three dimensional grids for flow computations in complex geometries is presented through example problems. Analyses were performed for different operating conditions for two different geometries. The results of the analysis such as pressure distributions and performance parameters, are compared with test data. The results of two dimensional analysis as opposed to a full three-dimensional analysis for one case is also presented to demonstrate why a full three-dimensional analysis is necessary for vectored nozzle geometries. Finally, the use of advance color graphics to provide a better understanding of the complex flow

field in an axi-symmetric nozzle is demonstrated through illustrations.

### A90-42018#

### CALCULATION OF THREE-DIMENSIONAL JET INTERACTION FLOWFIELDS

R. R. CHAMBERLAIN (Lockheed Missiles and Space Co., Inc., Huntsville, AL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (Contract DASG60-85-C-0122)

(AIAA PAPER 90-2099) Copyright

An upwind relaxation algorithm for the solution of the compressible Navier-Stokes equations is described and applied to the problem of a lateral control jet injected into a hypersonic crossflow. The numerical procedure uses Roe's flux difference splitting technique for the pressure and convective terms and central differencing for the viscous terms. The resulting time linearized system of algebraic equations is solved using approximate factorization in each crossflow plane and relaxation with nonlinear updating in the streamwise direction. Numerical solutions to the hypersonic jet interaction problem are obtained and compared to experimental data for a generic interceptor configuration at zero degrees angle of attack. Surface pressure results are found to be in good agreement with the data. Detailed flow visualization studies also highlight the complex nature of the three dimensional interaction phenomena and provide insight into the physics of the flow structure.

### A90-42019#

### MEASUREMENTS OF TURBULENT DUAL-JET INTERACTION

M. J. SHEU (National Tsing Hua University, Hsinchu, Republic of China) and Y. F. LIN AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs

(AIAA PAPER 90-2105) Copyright

The experimental results of the parallel plane turbulent free twin-jet flows are presented in this paper. The measurements of mean velocity components, flow direction, turbulent intensities and Reynolds stress were made by using a constant temperature hot wire anemometer. Due to the sensitivity of the split film probe to the flow direction, the entrainment of the surroundings into the jet flow could be investigated. The formation of the reverse flow between the two jets upstream of the merging point could be observed by using a split film probe. However, these reverse flows were not found in the earlier literatures in which the measurements were made by using an X-wire probe. The effect of nozzle spacing, which is the distance between the centerlines of the nozzles, on the flow structure is given in this paper.

### A90-42032#

# VISCOUS-INVISCID INTERACTION METHOD FOR CALCULATING THE FLOW IN COMPRESSOR CASCADE BLADE PASSAGES AND WAKE WITH SEPARATION

GERALD J. MICKLOW (Florida, University, Gainesville) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 16 p. refs (AIAA PAPER 90-2125) Copyright

A method is presented for the efficient analytical prediction of the two-dimensional laminar or turbulent compressor or turbine cascade flow field and wake. The scheme utilizes a viscous-inviscid interaction routine combining a two-dimensional full potential cascade flow solver with a two-dimensional compressible boundary layer analysis. The boundary layer analysis can compute in the direct mode with pressure gradient specified or in the inverse mode with 'boundary layer mass flux' specified. When calculating with the inverse mode, flow separation can be handled easily. Turbulent flow is treated using an algebraic eddy viscosity model with the modified Levy-Lees transformation applied to capture the growth of laminar and turbulent boundary layers. The boundary layer solution is fully implicit and formally second order accurate. The current viscous inviscid coupling is performed utilizing thin airfoil theory for subsonic and supersonic flow. Numerical solutions

are presented for several test cases and compared with published test data. Author

#### A90-42033#

### QUASI-3D VISCOUS FLOW COMPUTATIONS IN SUBSONIC AND TRANSONIC TURBOMACHINERY BLADINGS

C. VUILLEZ (SNECMA, Moissy-Cramayel, France) and J.-P. VEUILLOT (ONERA, Chatillon, France) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. Research supported by DRET. refs

(AIAA PAPER 90-2126) Copyright
A method is adopted to develop industrial codes solving the Reynolds-averaged Navier-Stokes equations to improve the prediction accuracy of aerodynamic performance in turbomachinery blading. This requires numerical methods that take into account phenomena due to fluid viscosity. The quasi-3D Navier-Stokes solver jointly developed by SNECMA and ONERA uses an explicit, time-matching, centered finite-volume scheme with multigrid convergence acceleration. The flow in a supersonic compressor cascade with stream tube contraction was calculated and the results compared with experimental data. Finally, calculations performed on near-hub, midspan and near-tip sections of an experimental wide-chord fan are discussed. R.E.P.

#### A90-42034#

### INVISCID AND VISCOUS FLOWS IN TRANSONIC AND SUPERSONIC CASCADES USING AN IMPLICIT UPWIND **RELAXATION ALGORITHM**

HANNES BENETSCHIK and HEINZ E. GALLUS (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 14 p. refs (AIAA PAPER 90-2128) Copyright

This paper presents a numerical algorithm for calculating inviscid and viscous flows in transonic and supersonic turbomachinery cascades. Of particular interest is the prediction of shock induced boundary layer separation and the comparison with experiments. The numerical procedure uses upwind-biased differencing with an approximate Riemann solver for the inviscid Euler fluxes. The viscous fluxes are discretized with a careful treatment of cross derivatives. Convergence to a steady state is accelerated by use of an impicit relaxation strategy. The Baldwin-Lomax eddy-viscosity model is used for turbulent flows. Details of the numerical method are presented along with an appropriate grid generation procedure. Computed results show that the method can predict very complicated viscous flow phenomena in cascades.

### A90-42035#

### APPLICATION OF 3-D NAVIER-STOKES COMPUTATION TO **BOWED STACKING TURBINE VANE DESIGN**

K. MATSUNAGA, A. TANAKA, T. MAYA, R. HASHINO, H. TAKEUCHI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, AIAA, SAE, ASME, and ASEE, Joint Propulsion Japan) et al. Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (AIAA PAPER 90-2129) Copyright

The design of a turbine vane cascade is presently undertaken on the basis of three-dimensional Navier-Stokes computations, first giving attention to the introductory case of a simple cascade geometry with straight endwalls and then to a curvilinear, leaned stator vane originally designed on the basis of Euler codes. It is found that, while endwall aerodynamics are improved, midspan flow is degraded; this phenomenon is ascribable to the flow viscosity and three-dimensionality near the endwalls. A computational study is then made of the effects of the degree of airfoil bowing and thickness distribution.

#### A90-42044\*# Vigyan Research Associates, Inc., Hampton, VA. 3-D EULER CALCULATIONS FOR AFT-PROPFAN INTEGRATION

DINESH A. NAIK (Vigyan Research Associates, Inc., Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs

(Contract NAS1-17919)

(AIAA PAPER 90-2147) Copyright

The problem of reducing engine-airframe installation drag for a transport aircraft with an aft-mounted propfan or turboprop engine is investigated. A three-dimensional Euler code is used for the analysis. Installation drag effects are inferred from a qualitative analysis of the computed velocity and pressure distributions. The basic design philosophy is to alleviate flow acceleration near the strut/nacelle junction by aerodynamic means. This involves minor reshaping and relocation of the propulsion system.

#### A90-42045#

### THE SENSITIVITY OF NEAR-FIELD ACOUSTICS TO THE **ORIENTATION OF TWIN TWO-DIMENSIONAL SUPERSONIC NOZZLES**

DAVID E. ZILZ (McDonnell Aircraft Co., Saint Louis, MO) and (McDonnell Douglas Research ) AIAA, SAE, ASME, and ASEE, WLEZIEN RICHARD W Laboratories, Saint Louis, MO) Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs

(AIAA PAPER 90-2149) Copyright
The acoustic near-field generated by jets from twin two-dimensional (2-D), convergent/divergent nozzles is examined experimentally as a function of nozzle geometry and integration parameters. Geometric parameters investigated include splay angle, spacing, aspect ratio, cant angle, and antisymmetric pitch vector. Acoustic measurements obtained at six locations near the nozzle exit plane provide an indication of acoustic amplitude and directivity. Phase-conditioned schlieren flow visualization is used to identify the twin jet interaction modes which result from plume coupling. Four distinct jet interaction modes are identified which characterize the entire test matrix over the range of parameters tested. Each interaction mode is shown to produce a unique acoustic directivity. The largest reduction in acoustic amplitude is observed for geometries which cause the twin jets to merge rapidly. Noise reduction is achieved by weakening plume coupling during screech or by fully suppressing screech. **Author** 

#### A90-42094# TURBULENCE MODEL PERFORMANCE IN V/STOL FLOW FIELD SIMULATION

E. P. CHILDS and B. R. PATEL (Creare, Inc., Hanover, NH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research sponsored by USAF. refs

(AIAA PAPER 90-2248) Copyright

The numerical simulations of two V/STOL jet configurations containing regions of turbulence anisotropy near the impingement plane are compared. Both experimentalists use laser Doppler anemometry systems to measure instantaneous velocities in round jets in water tank setups. It is shown that the match between data and numerical prediction is not good in the impingement zone, however, the distortions are only local and there are no consistently incorrect trends. The spreading rate of single and twin source jets and a fountain jet are predicted adequately. Prediction of the Reynolds shear stress is also good, except near the impingement zone of the single jet.

### A90-42102#

### **BOUNDARY-LAYER TRANSITION AND SEPARATION ON A** TURBINE BLADE IN A PLANE CASCADE

T. H. OKIISHI (Iowa State University, Ames), D. C. WISLER (GE Aircraft Engines, Cincinnati, OH), and D. E. HALSTEAD SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p. Research sponsored by GE Aircraft Engines. refs

(AIAA PAPER 90-2263) Copyright

Several patterns of boundary layer development observed along the suction surface of a turbine blade in a plane cascade using surface-mounted hot-film sensors are addressed. Test results from this well-defined boundary layer flow indicate the validity of the measurement technique in anticipation of its incorporation into a research program involving unsteady boundary layers in a multistage turbine. The condition of the boundary layer is determined along the airfoil from leading to trailing edge. Data for transition from laminar to turbulent flow through laminar separation and turbulent reattachment, through a combination of natural transition and weak separation, and through solely natural transition with no separation, are inclined. A method for comparing experimental data with computational boundary layer results is proposed.

A90-42132\*# Virginia Polytechnic Inst. and State Univ., Blacksburg.

### DIRECT MEASUREMENTS OF SKIN FRICTION IN A SCRAMJET COMBUSTOR

D. J. DETURRIS, J. A. SCHETZ (Virginia Polytechnic Institute and State University, Blacksburg), and R. F. HELLBAUM (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 14 p. Research supported by USAF. refs (AIAA PAPER 90-2342) Copyright

A direction experimental measurement was made of the skin friction in the turbulent boundary layer of three-dimensional supersonic combustor flows. A floating element configuration was designed to detect two components of the small tangential shear forces due to the flow passing over a nonobtrusive instrument. A cantilevered sensing head extending from a very sensitive piezoresistive displacement transducer simultaneously measured displacement in the axial and transverse directions to the flow. The small overall deflection means that no self-nulling is required. Consistently repeatable output from the gage during testing show the skin friction with supersonic combustion is higher than for a corresponding noncombusting flow. The results are probably accurate to within 10 percent for the mean streamwise component.

# A90-42136# Purdue Univ., West Lafayette, IN. FLOW INDUCED FORCED RESPONSE OF AN INCOMPRESSIBLE RADIAL CASCADE INCLUDING PROFILE AND INCIDENCE EFFECTS

W. BARRY BRYAN and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p. Research supported by the U.S. Army and NASA. refs (AIAA PAPER 90-2352) Copyright

An unsteady aerodynamic radial cascade model is developed to predict flow induced vibrations of radial flow airfoil cascades. This is accomplished by developing a conformal transformation and a radial wake model in conjunction with existing axial cascade unsteady aerodynamic flow models which predict the unsteady loading due to translation and torsional motions as well as a convected vortical gust. This model is then utilized to consider the fundamental differences between radial and axial cascade unsteady aerodynamics. Radial cascade unsteady aerodynamics were found to be similar in behavior to that of axial flow cascade for translation and torsional motions of the airfoils. However, behavior due to convected vortical gusts was markedly different, with the radial wake behavior a significant influence on the unsteady aerodynamic loading. Finally, the aerodynamically forced response of radial flow airfoil cascade is demonstrated through a parametric study of the effects of structural and aerodynamic parameters.

Author

A90-42137# United Technologies Research Center, East Hartford, CT.

### LINEARIZED UNSTEADY AERODYNAMICS FOR TURBOMACHINERY AEROELASTIC APPLICATIONS

JOSEPH M. VERDON (United Technologies Research Center, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 20 p. Research supported by the United Technologies Corp., NASA, U.S. Navy, and USAF. refs

(AIAA PAPER 90-2355) Copyright

The unsteady aerodynamic analyses developed for turbomachinery aeroelastic predictions must be applicable to the moderate high-frequency unsteady flows that are excited by structural motions and aerodynamic interactions between adjacent blade rows and occur over a wide range of operating conditions. In addition, there is a stringent requirement on computational efficiency. During the past decade, researchers have developed general inviscid unsteady aerodynamic linearizations that account for the effects of the nonuniform steady-flow phenomena associated with real blade geometry and mean blade loading on the unsteady aerodynamic response of two-dimensional cascades. In this paper, several recent advances to this theory are reviewed. Sample results are also presented to illustrate the current status of the theoretical model and the associated numerical prediction capabilities.

### A90-42161# INVESTIGATION OF UNSTEADY FLOW THROUGH TRANSONIC TURBINE STAGE. I - ANALYSIS

K. V. RAO and R. A. DELANEY (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs

(Contract F33615-83-C-2339)

(AIAA PAPER 90-2408) Copyright

This paper presents a numerical method for predicting the unsteady flow through a transonic turbine stage on a blade-to-blade stream surface. The method solves the quasi-three-dimensional Euler/Navier-Stokes equations using the explicit hopscotch scheme. Computations are presented for a transonic turbine stage which was tested in a short duration wind tunnel. Predicted airfoil surface time-averaged and phase-resolved pressure distributions are compared with test data in Part II of the paper.

Author

#### A90-42162#

# INVESTIGATION OF UNSTEADY FLOW THROUGH A TRANSONIC TURBINE STAGE. II - DATA/PREDICTION COMPARISON FOR TIME-AVERAGED AND PHASE-RESOLVED PRESSURE DATA

M. G. DUNN (Calspan Corp., Buffalo, NY), W. A. BENNETT, R. A. DELANEY, and K. V. RAO (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. Research supported by General Motors Corp. refs (Contract F33615-83-C-2339)

(AIAA PAPER 90-2409) Copyright

This paper presents time-averaged and phase-resolved measurements of the surface pressure data for the vane and blade of a transonic single-stage research turbine. The data are compared and contrasted with predictions from an unsteady Euler/Navier-Stokes code. The data were taken in a shock-tunnel facility in which the flow was generated with a short-duration source of heated and pressurized air. A matrix of data was obtained at two vane exit conditions and two vane/rotor axial spacings.

Author

### A90-42218#

## NAVIER-STOKES ANALYSIS OF AN EJECTOR AND MIXER-EJECTOR OPERATING AT PRESSURE RATIOS IN THE RANGE 2-4

R. E. MALECKI, S. J. MITYAS, and W. K. LORD (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 19 p. refs (AIAA PAPER 90-2730) Copyright

Navier-Stokes analyses were conducted for a long, two-dimensional, underexpanded primary stream ejector, using the k-epsilon and Baldwin-Lomax turbulence models in order to evaluate the applicability of the models in such applications. It is found that, when a fine grid is used, the shock structure in the ejector-mixing section can be adequately resolved. A comparison was also conducted between a Navier-Stokes analysis and the experimental data obtained for a three-dimensional mixer-ejector configuration originally devised for NASA's High-Speed Civil

Transport program. Good qualitative agreement was obtained.

A90-42225#

#### COMPUTATION OF VECTORING NOZZLE PERFORMANCE

P. L. CHEATHAM, S. H. WALKER, and M. C. GRIDLEY (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 15 p. refs (AIAA PAPER 90-2752)

The internal performance of three advanced thrust vectoring (TV) nozzles developed for aircraft control was calculated using Euler codes: the F-15 S/MTD TV/thrust reversing nozzle, the 3-hinge TV nozzle, and the balanced beam axisymmetric TV nozzle. Calculated nozzle performance parameters (which included the pitch and yaw vector angle, sidewall length, sidewall deflection, and thrust reverser position) and pressure distrubution were compared to experimental data, with excellent agreement found for vectoring geometries. The agreement for reversing geometries was only marginal.

### A90-42351#

# A TRANSONIC AIRFOIL DESIGN METHOD AND EXAMPLES JUN HUA, ZHONGYIN ZHANG, ZHIDE QIAO, and PEISHEN WANG (Northwestern Polytechnical University, Xian, People's Republic of China). Acta Aerodynamica Sinica (ISSN 0258-1825).

Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 117-123. In Chinese, with abstract in English. refs

Derivation of closed form integral formulations to remove the numerical integrations used in the iterative 'residual-correction' concept of Takanashi is presented. A design procedure with the condition analysis of the matrix is offered in order to develop a more accurate and efficient inverse design method. Numerical design examples for supercritical, shockless, natural laminar flow pressure distributions and low speed airfoils are discussed. It is concluded that analytic computations of the supercritical natural laminar flow airfoil design shows satisfactory results when compared with a NACA laminar flow airfoil.

### A90-42353#

### CALCULATION OF THE COMPLETE TRANSONIC UNSTEADY SMALL DISTURBANCE EQUATION BY ADI METHOD

JICHAO SU (Beijing University of Aeronautics, and Astronautics, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 129-135. In Chinese, with abstract in English. refs

Whitlow's algorithm has been modified to resolve a new nontime-linearized small disturbance equation of transonic unsteady flows derived from the complete transonic small-disturbance. The evaluation of this new algorithm of unsteady transonic flows is presented for a NACA 64A006 airfoil with oscillating trailing edge flap hinged at its 3/4 chord and a NACA 0012 airfoil oscillating in pitch about its 1/4 chord. As the steady solution by any numerical method may be used in this algorithm, it is concluded to be more convenient for engineering applications.

R.E.P.

### A90-42357#

# THE APPLICATION OF CONCENTRIC VORTEX SIMULATION TO CALCULATING THE AERODYNAMIC CHARACTERISTICS OF BODIES OF REVOLUTION AT HIGH ANGLES OF ATTACK

XIANLIN BAN and XING TU (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 161-167. In Chinese, with abstract in English. refs-

The aerodynamic characteristics of sharp-nosed bodies of revolution are calculated by using a concentric vortex simulation. Based on the experimental results, an appropriate set of free integration parameters is selected, and an empirical relation between the initial separation angle and the Reynolds number is established. The effect of the Mach number is corrected by using Goethert's rule. The differential equations of vortex motion are solved by using the fourth order Runge-Kutta method with a varying

step size. Two models are calculated. The comparison of calculation results with experimental results has shown satisfactory agreement.

Author

A90-42361#

# AN IMPROVEMENT ON UPWINDING TECHNIQUE USED IN THE GALERKIN FINITE ELEMENT METHOD FOR THE COMPUTATION OF INVISCID TRANSONIC FLOW WITH SHOCK WAVES

SHOUQIN YU, QINGBING ZHANG, and LIXIN WEI (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 188-194. In Chinese, with abstract in English. refs

The Galerkin finite element method using the upwinding technique is an effective method for the computation of inviscid transonic flow with shock waves, but the continuity equation is not satisfied in this procedure. In this paper, finite element equations are modified via penalty function to assure the conservation of mass. It improves the results considerably and leads to stronger and more stable shocks.

### A90-42363#

### NUMERICAL ANALYSIS OF VISCOUS-INVISCID INTERACTION IN TRANSONIC FLOW

BAOGUO WANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 202-206. In Chinese, with abstract in English. refs

The inviscid solution is obtained by the stream function method, with the attached and separated turbulent boundary layer calculations performed by the improved Green and East's lag entrainment method. The two calculations are coupled by an algorithm which converges rapidly for attached flows and performs well for separated flows. The classical iteration, inverse iteration, and semiinverse iteration methods are discussed. Numerical stability of these coupling algorithms is described, and the amplification factor is given, respectively, for each iteration. The numerical results obtained have been compared with test data on four different transonic cascades and are in reasonably good agreement.

### A90-42364#

### CALCULATION OF VISCOUS-INVISCID STRONG INTERACTION FOR TRANSONIC FLOWS OVER AEROFOILS

RUXIAN CHEN (China Aerodynamic Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 207-213. In Chinese, with abstract in English. refs

A method for calculating viscous-inviscid strong interaction for transonic flows over aerofoils is presented. The boundary layer inverse algorithm is employed for the calculation of the turbulent boundary layer, with velocity profile expressions applicable to both attached and separated flows. The inviscid flow is obtained by the numerical solution of fully potential equation. Viscous effects are represented by the transpiration velocity at the solid boundary in the inviscid calculation. The final viscous flow solution is obtained through viscous-inviscid iterations. The comparison of the present results with those of other methods and experimental data demonstrates that the present method can be used for engineering purposes.

### A90-42394#

### FLOW SEPARATION ON A SUPERCRITICAL AIRFOIL

B. H. K. LEE (National Research Council of Canada, High Speed Aerodynamics Laboratory, Ottawa) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 36, June 1990, p. 81-89. refs

Flow separation on the upper surface of the Bauer-Garabedian-Korn No. 1 supercritical airfoil was investigated in the National Aeronautical Establishment High Reynolds Number Two-Dimensional Test Facility. Detailed skin friction and pressures were measured to study the characteristics of separated flows. Fluctuating normal forces were determined for different types of

transonic shock/boundary-layer interaction, and the behavior of the unsteady loads experienced by the airfoil was examined. For flow conditions where discrete frequency shock wave motions were detected, ensemble-averaging of the unsteady pressures was carried out to give the amplitudes and phases of the pressure waves generated by the shock. A model of the self-sustained periodic shock motion as a result of shock/boundary-layer interaction was proposed. Broad-band cross-correlations of the pressure field were carried out to determine the convection velocities of the turbulent eddies for attached and separated flows.

#### A90-42395#

### APPLICATION OF 3-D FLOW ANALYSIS TO THE DESIGN OF A HIGH WORK TRANSONIC TURBINE

M. EL-FOULY and H. MOUSTAPHA (Pratt and Whitney Canada, Longueuil) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 36, June 1990, p. 90-96. Research sponsored by Industry, Science, and Technology Canada and Pratt and Whitney Canada. refs

This paper describes the application of three-dimensional (3-D) flow analysis techniques to the optimization of the vanes and blades for a high work, single stage, compressor turbine. The turbine has a pressure ratio of 4.4, a stage loading of 2.2, and inlet temperature sufficiently high to require stator and rotor cooling. The selection of number of airfoils, radial work distribution, and sections stacking are discussed. The use of three-dimensional flow analysis technique to handle the resulting supersonic flow and reduce the airfoil profile and shock losses is shown to be essential for achieving the target efficiency. Detailed section design, endwall contouring, reaction, and loading distribution are used to give controlled flow acceleration and minimize shock and diffusion losses. The estimated overall turbine cooled efficiency is 0.815.

Author

#### A90-42402#

### HIGHER-ORDER BOUNDARY-LAYER APPROXIMATIONS IN INTERACTIVE AIRFOIL CALCULATIONS

D. W. ZINGG and G. W. JOHNSTON (Toronto, University, Downsview, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4. 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 1-1 to 1-18. refs

A comparison of three procedures for the computation of attached incompressible flow about airfoils is presented. The first procedure solves the boundary-layer equations in the boundary layers and wake and uses a first-order approximation to the viscid-inviscid matching conditions. The second procedure solves the second-order boundary-layer equations and uses a second-order approximation to the displacement-effect matching condition. The third procedure solves the Navier-Stokes equations together with an exact matching condition. The computed flowfields are compared with experimental data for symmetric and aft-loaded airfoils. The comparisons show that the higher-order terms do not significantly affect the lift and moment predictions but lead to higher predictions of drag.

### A90-42403#

#### WIND TUNNEL RESULTS AND NUMERICAL COMPUTATIONS FOR THE NAE DEHAVILLAND SERIES OF NATURAL LAMINAR FLOW AIRFOILS

M. KHALID, D. J. JONES (National Aeronautical Establishment, Ottawa, Canada), and B. EGGLESTON (Boeing Canada, de Havilland Div., Downsview) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 2-1 to 2-17, refs.

The paper deals with numerical design and wind-tunnel tests on several airfoils with the capability of sustaining laminar flow on both upper and lower surfaces. The experimental findings on four airfoils of thickness 10, 13, 16, and 21 percent are presented, with a comparison of the results with the predictions of a computer code for subsonic and transonic flows about airfoils. It is shown

that the minimum drag levels for the four airfoils range from a low of about 0.0045 to a high of about 0.0051. It is also noted that a complete comparison of the experimental results with calculations was not possible due to nonconvergence of the code in a large number of transition-free cases. The cases with fixed transition are shown to be less likely to fail.

V.T.

**A90-42404\***# National Aeronautical Establishment, Ottawa (Ontario).

### WIND TUNNEL WALL INTERFERENCE INVESTIGATIONS IN NAE/NRC HIGH REYNOLDS NUMBER 2D FACILITY AND NASA LANGLEY 0.3M TRANSONIC CRYOGENIC TUNNEL

Y. Y. CHAN, Y. NISHIMURA (National Aeronautical Establishment, Ottawa, Canada), and R. E. MINECK (NASA, Langley Research Center, Hampton, VA) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 3-1 to 3-29. refs

Results are reported from a NAE/NRC and NASA cooperative program on two-dimensional wind-tunnel wall-interference research, aimed at developing the technology for correcting or eliminating wall interference effects in two-dimensional transonic wind-tunnel investigations. Both NASA Langley and NAE facilities are described, along with a NASA-designed and fabricated airfoil model. It is shown that data from the NAE facility, corrected for wall interference, agree with those obtained from the NASA tunnel, which has adaptive walls; the comparison of surface pressure data shows that the flowfield conditions in which the model is investigated appear to be nearly identical under most conditions. It is concluded that both approaches, posttest correction and an adaptive wall, adequately eliminate the tunnel-wall interference effects.

#### A90-42405#

### APPLICATION OF THE MOVING SURFACE BOUNDARY LAYER CONTROL TO A TWO DIMENSIONAL AIRFOIL

V. J. MODI, M. S. U. K. FERNANDO, S. SAITO, T. YOKOMIZO, and F. MOKHTARIAN (British Columbia, University, Vancouver, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 5-1 to 5-11. refs

The concept of moving surface boundary-layer control, as applied to a Joukowsky airfoil, is investigated through a planned experimental program complemented by a flow visualization study. The moving surface was provided by rotating solid and scooped cylinders located at the leading edge or the upper leading edge of the airfoil. Results suggest that the concept is quite promising leading to a substantial increase in lift and a delay in stall. Depending on the performance desired, appropriate combinations of cylinder geometry, location and speed can be selected to obtain favorable results over a wide range of the angle of attack. A flow visualization study qualitatively confirms complex character of the flow as predicted by the experimental data.

### A90-42406#

### NONLINEAR UNSTEADY AIRFOIL RESPONSE STUDIES

G. W. JOHNSTON and D. W. ZINGG (Toronto, University, Downsview, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 6-1 to 6-14. refs

A computational procedure has been developed to study the finite-amplitude, finite-thickness, unsteady response of airfoils having arbitrary time-dependent motion. The associated wake is modeled as a sequence of variable strength point vortices convecting with the computed flowfield. The wake strength and position are determined simultaneously by means of an iterative predictor/corrector algorithm. This procedure has been used to study the modifications to the linear Theodorsen and Sears transfer functions associated with finite thickness and finite amplitude effects over a range of reduced frequencies. Significant modifications to the linear phase and amplitude values are noted.

These are attributed to the near-wake influences of the shed vorticity.

#### A90-42412#

## MODELLING OF BOUNDARY LAYER AND TRAILING EDGE THICKNESS EFFECTS FOR THE EULER EQUATIONS USING SURFACE TRANSPIRATION

JOHN T. CONWAY (Canadair, Aerospace Group, Montreal, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 14-1 to 14-11. Research supported by DIR. refs

#### A90-42413#

### FINITE VOLUME SOLUTIONS OF TWO-DIMENSIONAL EULER EQUATIONS ON ADAPTED STRUCTURED MESHES

MIROSLAV MOKRY (National Aeronautical Establishment, Ottawa, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 15-1 to 15-13. refs

The paper deals with the computation of two-dimensional transonic flows around airfoils. Modifications of a structured O-mesh and its effects on the finite-volume solutions of the two-dimensional Euler equations are discussed. The initial experience with the finite-volume code is summarized and compared with experimental data from a high-speed wind tunnel. Selected examples include (1) the mesh adaptation for the outer constraints imposed by wind-tunnel boundaries and (2) successive mesh displacements to accommodate the airfoil boundary layer and wake.

#### A90-42415#

### THE FLOW OVER A WING/NACELLE COMBINATION IN THE PRESENCE OF A PROPELLER SLIPSTREAM

BRUCE A. W. SMITH (Boeing Canada, de Havilland Div., Downsview) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 17-1 to 17-17.

The desire to achieve significantly higher speeds with future commuter aircraft has increased interest in the propeller/wing interaction. The higher speed and greater disk loading has the potential to cause local regions of supercritical flow over the wing. In an effort to better predict these flows, the problem has been examined using VSAERO, a three-dimensional panel code, and an inviscid multiblock Euler code. A powered nacelle/wing model was tested in the NAE/NRC 2m x 3m low speed wind tunnel to provide experimental data for verifying the computational results. Although flow separation on the experimental model complicated the comparison, with an incidence adjustment the VSAERO model was able to predict the observed pressures and lifts quite well. Without the propeller, the Euler lift and pressure results were in agreement with the inviscid VSAERO predictions.

### A90-42416#

# APPLICATION OF THE KTRAN TRANSONIC SMALL DISTURBANCE CODE TO THE COMPLETE CF-18 AIRCRAFT WITH STORES

P. PIPERNI and F. KAFYEKE (Canadair, Aerospace Group, Montreal, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 18-1 to 18-28. Research supported by DND. refs

A computer code called KTRAN was developed at Canadair to provide accurate and cost effective predictions of inviscid transonic flows around complete military aircraft configurations with stores. The program uses a Transonic Small Disturbance Equation discretized in simple rectangular or cylindrical coordinates, and a grid embedding technique. Results of calculations on the CF-18 aircraft with two pylons and stores under each wing are presented. The program models the aircraft's complex fuselage, straked wing and tailplane. Engine mass flow effects are also modeled. The results demonstrate the ability of the method to model

multicomponent aircraft efficiently, without user intervention in the specification of grids. The fast turn-around times and the low CPU requirements for these calculations are emphasized.

Author

#### A90-42418#

### **AERODYNAMICS OF STORE SEPARATION**

F. A. KOHIYAR and B. UGOLINI (Canadair, Montreal, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 20-1 to 20-31. Research supported by DND. refs

This paper presents a description of the aerodynamic forces and moments which act on a store during separation/jettison. The significance of aerodynamic effects on store separation is demonstrated by means of an example. A brief description of some analytical methods for the derivation of aerodynamic forces and moments on stores is also provided.

### A90-42419#

# MEASUREMENTS OF AERODYNAMIC FORCES ON AIRCRAFT EXTERNAL STORES IN THE NAE TRISONIC BLOWDOWN WIND-TUNNEL

D. BROWN, F. A. ELLIS, and J. L. BUREAU (National Aeronautical Establishment, Ottawa, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 21-1 to 21-23. refs

#### A90-42422#

# AUTOMATED GENERATION OF TWO-DIMENSIONAL NON-OVERLAPPING STRUCTURED GRIDS FOR MULTIPLE ELEMENT AIRFOILS WITH EULER SOLUTIONS

MARK E. M. STEWART (Princton University, NJ) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 24-1 to 24-10. refs

Multiblock grids are shown to be an effective approach to generating grids in complex two-dimensional geometries. A novel algorithm for substantially automating the decomposition of arbitrary two-dimensional domains into nonoverlapping, topologically rectangular blocks is described. To demonstrate the technique, solutions to the Euler equations for several multielement airfoil configurations are presented, including a four-element landing configuration for the A310 Airbus. Further, accuracy estimates for the grids are developed analytically, and approximated numerically to demonstrate the accuracy characteristics of the singularities in the grids.

#### A90-42423#

### FINITE ELEMENT SIMULATION OF UNSTEADY TWO-DIMENSIONAL INCOMPRESSIBLE VISCOUS FLOWS

I. PARASCHIVOIU (Ecole Polytechnique, Montreal, Canada) and K. F. TCHON IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 26-1 to 26-23. Research supported by the Department of Energy, Mines and Resources of Canada. refs

A computer code is developed for unsteady two-dimensional incompressible visocus laminar flows around accelerated bodies. A stream function-vorticity formulation of the Navier-Stokes equations and a noninertial frame of reference are used. The chosen finite element spatial discretization circumvents the vorticity underdetermination on solid boundaries by forcing the simultaneous solution of the vorticity transport equation and the stream function Poisson equation. The single valued pressure condition is used to determine the stream function value on interior boundaries. Temporal discretization is achieved by a stable second order accurate implicit finite difference scheme. Each time step, a nonlinear algebraic system is solved using the Newton-Raphson iterative technique. To accelerate computations, a preconditioned conjugate residual method is used to solve iteratively the linearized algebraic system of equations. The numerical code is first tested on both steady and unsteady flows about a circular cylinder and an NACA 0012 airfoil, and then used to simulate dynamic stall on an NACA 0018 airfoil oscillating in pitch about its zero incidence angle with a reduced frequency of 0.5 and a Reynolds number of 10,000.

**A90-42425\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### EULER AND NAVIER-STOKES COMPUTATIONS FOR AIRFOIL GEOMETRIES USING UNSTRUCTURED MESHES

D. J. MAVRIPLIS (NASA, Langley Research Center, Hampton, VA) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 28-1 to 28-18. Previously announced in STAR as N90-15893. refs

A general purpose unstructured mesh solver for steady-state two-dimensional inviscid and viscous flows is described. The efficiency and accuracy of the method are enhanced by the simultaneous use of adaptive meshing and an unstructured multigrid technique. A method for generating highly stretched triangulations in regions of viscous flow is outlined, and a procedure for implementing an algebraic turbulence model on unstructured meshes is described. Results are shown for external and internal inviscid flows and for turbulent viscous flow over a multi-element airfoil configuration.

### A90-42431#

### NEW TRANSONIC TEST SECTIONS FOR THE NAE 5FTX5FT TRISONIC WIND TUNNEL

L. H. OHMAN, D. BROWN, Y. Y. CHAN, R. D. GALWAY, S. M. HASHIM (National Aeronautical Establishment, Ottawa, Canada) et al. IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 34-1 to 34-60. refs

The NAE 5ftx5ft blowdown wind tunnel has undergone a major upgrade of its transonic testing capabilities. Two entirely new test sections, one for testing two-dimensional models (2D) and one for testing three-dimensional models and reflection plane models (3D), have been constructed. The two test sections are parts of the so-called Roll-in Roll-out Test Section System, so designed that an interchange between the two sections can be carried out within two days, a process that previously required about three weeks. The new test sections have, as before, perforated walls, but with different hole geometry, viz. slanted holes with splitter plates as opposed to normal holes in the original test sections. The two test sections have been calibrated with regard to pressure distributions, flow quality (turbulence and pressure fluctuations), side wall boundary layer characteristics (2D), flow angularity, and wall interference characteristics.

### A90-42435#

# A STUDY OF THE INFLUENCE OF A HELICOPTER ROTOR BLADE ON THE FOLLOWING BLADES USING EULER EQUATIONS

EWALD KRAEMER, JOHANN HERTEL, and SIEGFRIED WAGNER (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p. Research supported by BMFT. refs

An Euler procedure for the calculation of subsonic and transonic flow around multibladed helicopter rotors is presented. The procedure shows that the Euler equations themselves are very well suited to describe the vortex transport correctly, if certain requirements were met. Results are presented which agree well with measurements from the model rotor of Caradonna and Tung (1985) and which reproduce the effects that grid topology and the distance of the far-field boundaries show on vortex convection.

#### A90-42436#

COMPARISON WITH EXPERIMENT OF VARIOUS COMPUTATIONAL METHODS OF AIRFLOW ON THREE HELICOPTER FUSELAGES

S. R. AHMED, J. AMTSBERG (DLR, Brunswick, Federal Republic of Germany), A. C. DE BRUIN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands), A. CLER (Aerospatiale, Marignane, France), G. FALEMPIN (ONERA, Chatillon, France) et al. Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 24 D. refs

Validation results are described of computer codes developed or in use at four different European aerospace organizations to calculate the flow around three fuselage configurations typical of current generation helicopters. The computational methods validated are: (1) a three-dimensional inviscid incompressible steady flow code incorporating a rigid prescribed geometry wake, (2) two low-order panel methods describing steady inviscid incompressible flow about arbitrary three-dimensional bodies, and (3) a three-dimensional boundary layer code which evaluates boundary layer growth on the streamline fuselage configuration. The computational methods are applied to predict the surface pressure, rotor-plane velocity distribution, and boundary layer development on the three configurations. Rotor flow is not simulated. The validation is based on wind tunnel tests performed in the open test section of a DFVLR low-speed wind tunnel. The model investigated is a 1:7-scale helicopter fuselage with interchangeable rear ends.

A90-42437\*# National Aeronautics and Space Administration.

Ames Research Center, Moffett Field, CA.

### A REVIEW OF TILT ROTOR DOWNLOAD RESEARCH

FORT F. FELKER (NASA, Ames Research Center, Moffett Field, CA) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 33 p. refs

Experimental and theoretical research on the forces on a wing immersed in the wake of a hovering rotor is reviewed, with emphasis on the tilt rotor download problem. The basic features of the rotor/wing flow field on a tilt rotor aircraft are described. The effect of important geometric and operational parameters on the wing download is assessed. The magnitude of the download for typical tilt rotor configurations is reviewed, and advanced concepts for download reduction are described. Recommendations are presented for the direction of future research efforts.

#### A90-42438#

## EXPERIMENTAL STUDY OF THE FLOW AROUND AN HELICOPTER FUSELAGE - COMPARISON WITH THREE-DIMENSIONAL BOUNDARY LAYER CALCULATIONS

C. GLEYZES, X. DE SAINT-VICTOR (ONERA, Centre d'Etudes et de Recherches de Toulouse, France), and A. CLER (Aerospatiale, Marignane, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 13 p. refs

An effort has been made to provide detailed experimental results on a simplified model in order to achieve better helicopter fuselage aerodynamics predictions. The geometry of this wind-tunnel model's surfaces is such that an analogous computational grid's generation will present no complications. There will in addition be several prominent flat surfaces in order to render LDV measurements straightforward over a substantial portion of the model's surface. A rapid contraction occurs at the junction of this helicopter model's fuselage with the tail boom, in order to minimize separations. The results obtained are compared with three-dimensional boundary-layer calculation results.

### A90-42439#

### ROTORCRAFT COMPUTATIONAL FLUID DYNAMICS - RECENT DEVELOPMENTS AT MCDONNELL DOUGLAS

R. D. JANAKIRAM, A. A. HASSAN (McDonnell Douglas Helicopter Co., Mesa, AZ), and R. AGARWAL (McDonnell Douglas Research Laboratories, Saint Louis, MO) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European

Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 31 p. refs

Recent developments in the application, validation and development of CFD techniques to solve specific rotor aerodynamics problems are presented. A rotor full-potential flow solver, RFS2, has been validated against a comprehensive set of flight test data. RFS2 was modified to model the rotor blade-vortex-interaction aerodynamics, and the predictions compare favorably with test data for subcritical interactions. A rotor Euler flow solver, MDROTH, was shown to provide good results for strong supercritical flows at the expense of significantly increased computer CPU time. A two-dimensional, full Reynolds-averaged Navier-Stokes solver DSS2 was able to predict reasonably well the transonic static and dynamic rotor airfoils characteristics, especially the lift characteristics. Navier-Stokes solvers are being used to model the effects of novel tip configurations on retreating blade stall, and in the simulation of the flow environment of a circulation control tailboom of the NOTAR helicopter configuration.

### A90-42440#

# COMPUTATION OF VISCOUS AERODYNAMIC CHARACTERISTICS OF 2-D AIRFOILS FOR HELICOPTER APPLICATIONS

R. HOUWINK, J. A. VAN EGMOND, and P. A. VAN GELDER (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 15 p. Research supported by Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs

An outline is presented of a computer code, used for the prediction of quasi-steady and unsteady aerodynamic characteristics of rotor blade sections in oscillatory and linear pitching motions. The code, named ULTRAN-V, is based on unsteady transonic small perturbation theory, coupled in strong interaction with an unsteady version of Green's lag-entrainment method for a turbulent boundary layer. Results are compared with experimental data for the NACA0012 airfoil and for actual rotor blade sections. Provided that the stall behavior is not dominated by leading edge separation, a reasonably accurate prediction of quasi-steady and unsteady airfoil characteristics up to stall conditions is obtained.

#### A90-42443#

### IMPROVING HELICOPTER AERODYNAMICS - A STEP AHEAD

M. TORRES and A. CLER (Aerospatiale, Division Helicopteres, Marignane, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 10 p.

An account is given of the helicopter main rotor and fuselage streamlining efforts of a major European manufacturer. While the effects of rotor and fuselage streamlining on weights and costs are negligible, they help reduce fuel consumption in cruising flight. Rotor design improvements are illustrated by studies conducted on the hovering and high-forward-speed flight efficiency of such novel bladetip planforms as the tapered, sweptback, anhedral, etc. Fuselage aerodynamics developments are illustrated by the engine cowl streamlining and 'fenestron' tail rotor streamlining of the Puma and Dauphin helicopters.

#### A90-42506

### A NEW LAGRANGIAN METHOD FOR STEADY SUPERSONIC FLOW COMPUTATION. I - GODUNOV SCHEME

C. Y. LOH and W. H. HUI (Waterloo, University, Canada) Journal of Computational Physics (ISSN 0021-9991), vol. 89, July 1990, p. 207-240. Research supported by NSERC. refs Copyright

The novel Lagrangian formulation of Hui and Van Roessel (1985), in which the Lagrangian time and the stream function are used as independent variables, is presently applied to the problem of steady two-dimensional inviscid and compressible fluid's

two-dimensional flow. Application of the first-order Godunov scheme to this formulation's conservation-form equations yields a shock-capturing method. Comparisons with both exact solutions and a second-order Godunov scheme based on the Eulerian formulation show that the first-order Lagrangian method reaches comparable levels of accuracy while yielding superior resolution of slip-line discontinuities.

O.C.

N90-23348\*# Scientific Research Associates, Inc., Glastonbury,

### EXTENSION OF A THREE-DIMENSIONAL VISCOUS WING FLOW ANALYSIS

BERNARD C. WEINBERG, SHYI-YAUNG CHEN, STEPHEN J. THOREN, and STEPHEN J. SHAMROTH May 1990 55 p (Contract NAS1-18140)

(NASA-CR-182023; NAS 1.26:182023; SRA-900049F) Avail: NTIS HC A04/MF A01 CSCL 01A

Three-dimensional unsteady viscous effects can significantly influence the performance of fixed and rotary wing aircraft. These effects are important in both flows about helicopter rotors in forward flight and flows about 3-D (swept and tapered) supercritical wings. A computational procedure for calculating such flow field is developed, and therefore would be of great value in the design process as well as in understanding the corresponding flow phenomena. The procedure is based upon an alternating direction technique employing the Linearized Block Implicit method for solving 3-D viscous flow problems. In order to demonstrate the viability of this method, 2-D and 3-D problems are computed. These include the flow over a 2-D NACA 0012 airfoil under steady and oscillating conditions, and the steady, skewed, 3-D flow on a flat plate. Although actual 3-D flows over wings were not obtained. the ground work was laid for considering such flows. The description of the computational procedure and results are given.

N90-23349# Nielsen Engineering and Research, Inc., Mountain View, CA.

### A STUDY OF SUPERMANUEVER AERODYNAMICS Final Report, 1 Dec. 1988 - 1 Dec. 1989

DAVID NIXON and LAURA C. RODMAN 31 Jan. 1990 76 p (Contract F49620-88-C-0006; AF PROJ. 3005)

(AD-A218378; AFOSR-90-0269TR) Avail: NTIS HC A05/MF A01 CSCL 01/1

The objective is to develop a technique for studying transient separated flows, such as those typical for maneuvering aircraft. The ultimate goal of this research is to develop flow control techniques using the boundary conditions in a Navier Stokes calculation. Once numerical boundary conditions are established, then their physical counterparts may be found. A subdomain technique was developed which allows the study of the effects of various boundary conditions on a local portion of the flowfield. A search technique, using artificial intelligence methods, was developed and was used to find the combination of boundary conditions that achieved the desired flow control. In addition, a two-dimensional boundary conditions theory for the steady Euler and Navier Stokes equations was derived. A wide range of boundary conditions for the subdomains were tried without significant success. However, a boundary condition, based on Duhamel's equation, was found to be very promising in leading to a reduction of computer time.

**N90-23353**# Naval Postgraduate School, Monterey, CA. Dept. of Aeronautics and Astronautics.

# AN EXPERIMENTAL INVESTIGATION OF SUPPORT STRUT INTERFERENCE ON A THREE-PERCENT FIGHTER MODEL AT HIGH ANGLES OF ATTACK M.S. Thesis

JOHN D. SOMMERS Sep. 1989 147 p

(AD-A219793) Avail: NTIS HC A07/MF A01 CSCL 01/3

A low-speed wind-tunnel investigation was conducted to examine the aerodynamic interference caused by support struts on a three-percent scale model of the YF-17 lightweight fighter prototype. The study was undertaken at the request of the NASA-Ames Research Center to obtain background data in support of an upcoming investigation in which a full-scale F/A-18 will be

mounted in the 80 x 120 foot wind tunnel. Force and moment measurements were made for various strut configurations using a precision six-component strain gage balance. Flow visualization studies were also conducted using smoke injected upstream of the model and illuminated by a laser sheet to highlight flow phenomenon around the model. Results of the investigation indicate that only minor aerodynamic interference was caused by the strut configuration tested. Of the configurations tested, it was determined by a subjective analysis that a slight reduction in interference could be realized by attaching the forward struts to the wing tips and the aft strut to the tail hook pivot point.

N90-23359# Centro Italiano Ricerche Aerospaziali, Naples.
A COMPUTER CODE FOR THE PREDICTION OF
AERODYNAMIC CHARACTERISTICS OF LIFTING AIRFOILS
AT TRANSONIC SPEED

DOMENICO P. COIRO, P. P. DEMATTEIS, and M. AMATO 10 May 1989 10 p Presented at GAMNI/SMAI-IMA, Antibes, France, 17-19 May 1989

(DLC-EST-TN-030; ETN-90-96560) Avail: NTIS HC A02/MF A01

The capability of computing aerodynamic performances of airfoils in subcritical and supercritical conditions is presented. Inviscid solution was obtained using a finite volume 4th order Runge-Kutta explicit time-stepping scheme. Turbulent boundary layer was solved using Green or Whitfield integral methods in inverse form. Results are shown graphically. The influence of gridspacing, boundary layer method, artificial viscosity, and interaction procedure is under investigation.

N90-23360# Centro Italiano Ricerche Aerospaziali, Naples. PREDICTION OF AERODYNAMIC PERFORMANCE OF AIRFOILS IN LOW REYNOLDS NUMBER FLOWS

DOMENICO P. COIRO and CARLO DENICOLA 28 May 1989 12 p Presented at Low Reynolds Number Flows Congress, Notre Dame, IN, Jun. 1989

(DLC-EST-TN-031; ETN-90-96561) Avail: NTIS HC A03/MF A01

A viscous/inviscid interaction procedure for the solution of incompressible flowfields with large laminar separated regions is presented, based on the approach previously followed for the prediction of the performances of airfoils up to stall conditions. The extension of the interaction procedure to take into account the existence of laminar separation bubbles is described, with an eye toward the question of the numerical determination of the transition. The application of the computational procedure for two airfoils widely investigated experimentally at low Reynolds number is discussed; numerical results show the reliability of the method in these conditions. A critical analysis of the solutions indicates the guidelines for the future improvements of the method.

N90-23363# Aeronautical Research Inst. of Sweden, Stockholm. Dept. of Aerodynamics.

LOW SPEED TESTING OF A LAMINAR FLOW AIRFOIL IN AN ADAPTIVE WALL WIND TUNNEL

F. KHADJAVI Nov. 1989 97 p Sponsored by Swedish Board for Technical Development

(FFA-TN-1989-08; ETN-90-96599) Avail: NTIS HC A05/MF A01

A natural laminar flow (NLF) airfoil was tested in a low speed wind tunnel for cruise flight condition at Reynolds numbers up to 10 million. To achieve such high numbers a large scale model was used, causing large wall interference effects during testing. A two dimensional flexible wall test section was used to reduce interference effects. The NLF0414 model was tested with both straight and adapted walls, and results compared with those of the NASA Langley Research Center. Computations show that by increasing the length of the laminar run on the pressure side and reducing the length of the laminar run on the suction side, the profile drag would decrease and the width of the low drag bucket would increase.

N90-23364# Aeronautical Research Inst. of Sweden, Stockholm. Dept. of Aerodynamics.

EULER CODE PREDICTED SEPARATION AT THE AIRFOIL TRAILING EDGE

ANDERS HOLMBERG 20 Nov. 1989 26 p (Contract FMV-82260-88-061-73-001)

(FFA-TN-1989-30; ETN-90-96601) Avail: NTIS HC A03/MF A01

The transition from trailing edge separation to upper side separation flow is investigated. A modified NACA0012 standard airfoil, with a rounded trailing edge is used. The influence from the artificial damping coefficient (artificial viscosity) and mesh density is investigated. A potential flow solver is developed in order to be used as a tool to examine the uniqueness of the solution of the discretized Euler equations. The Euler code at small coefficient values and/or a dense mesh at the trailing edge is shown to make the flow leave the symmetric airfoil (with a round trailing edge) at the symmetric plane.

N90-24237\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AERODYNAMIC PERFORMANCE OF A 0.27-SCALE MODEL OF AN AH-64 HELICOPTER WITH BASELINE AND ALTERNATE ROTOR BLADE SETS

HENRY L. KELLEY Washington Jul. 1990 24 p (Contract DA PROJ. 1L1-62211-AH-7-AA) (NASA-TM-4201; L-16725; NAS 1.15:4201; AVSCOM-TM-90-B-015) Avail: NTIS HC A03/MF A01 CSCL

Performance of a 27 percent scale model rotor designed for the AH-64 helicopter (alternate rotor) was measured in hover and forward flight and compared against and AH-64 baseline rotor model. Thrust, rotor tip Mach number, advance ratio, and ground proximity were varied. In hover, at a nominal thrust coefficient of 0.0064, the power savings was about 6.4 percent for the alternate rotor compared to the baseline. The corresponding thrust increase at this condition was approx. 4.5 percent which represents an equivalent full scale increase in lift capability of about 660 lbs. Comparable results were noted in forward flight except for the high thrust, high speed cases investigated where the baseline rotor was slightly superior. Reduced performance at the higher thrusts and speeds was likely due to Reynolds number effects and blade elasticity differences.

**N90-24238\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

STATIC WIND-TUNNEL AND RADIO-CONTROLLED FLIGHT TEST INVESTIGATION OF A REMOTELY PILOTED VEHICLE HAVING A DELTA WING PLANFORM

LONG P. YIP, DAVID J. FRATELLO, DAVID B. ROBELEN, and GEORGE M. MAKOWIEC (Vigyan Research Associates, Inc., Hampton, VA.) Washington 1990 35 p (NASA-TM-4200; L-16742; NAS 1.15:4200) Avail: NTIS HC

A03/MF A01 CSCL 01/1

At the request of the United States Marine Corps, an exploratory wind-tunnel and flight test investigation was conducted by the Flight Dynamics Branch at the NASA Langley Research Center to improve the stability, controllability, and general flight characteristics of the Marine Corps Exdrone RPV (Remotely Piloted Vehicle) configuration. Static wind tunnel tests were conducted in the Langley 12 foot Low Speed Wind Tunnel to identify and improve the stability and control characteristics of the vehicle. The wind tunnel test resulted in several configuration modifications which included increased elevator size, increased vertical tail size and tail moment arm, increased rudder size and aileron size, the addition of vertical wing tip fins, and the addition of leading-edge droops on the outboard wing panel to improve stall departure resistance. Flight tests of the modified configuration were conducted at the NASA Plum Tree Test Site to provide a qualitative evaluation of the flight characteristics of the modified configuration. Author N90-24239\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**AERODYNAMIC CHARACTERISTICS OF TWO ROTORCRAFT** AIRFOILS DESIGNED FOR APPLICATION TO THE INBOARD **REGION OF A MAIN ROTOR BLADE** 

KEVIN W. NOONAN (Army Aerostructures Directorate, Hampton, VA.) Washington Jul. 1990 89 p (Contract DA PROJ. 1L1-62211-A-47-AA)

(NASA-TP-3009; L-16737; NAS 1.60:3009;

AVSCOM-TR-90-B-005) Avail: NTIS HC A05/MF A01 CSCL 01/1

A wind tunnel investigation was conducted to determine the 2-D aerodynamic characteristics of two new rotorcraft airfoils designed especially for application to the inboard region of a helicopter main rotor blade. The two new airfoils, the RC(4)-10 and RC(5)-10, and a baseline airfoil, the VR-7, were all studied in the Langley Transonic Tunnel at Mach nos. from about 0.34 to 0.84 and at Reynolds nos. from about 4.7 to 9.3 x 10 (exp 6). The VR-7 airfoil had a trailing edge tab which is deflected upwards 4.6 degs. In addition, the RC(4)-10 airfoil was studied in the Langley Low Turbulence Pressure Tunnel at Mach nos. from 0.10 to 0.44 and at Reynolds nos. from 1.4 to 5.4 x 10 (exp 6) respectively. Some comparisons were made of the experimental data for the new airfoils and the predictions of two different theories. The results of this study indicates that both of the new airfoils offer advantages over the baseline airfoil. These advantages are discussed.

Author

N90-24240 Manchester Univ. (England). THE COMPUTATION OF TURBULENT THIN SHEAR FLOWS ASSOCIATED WITH FLOW AROUND MULTIELEMENT

**AEROFOILS Ph.D. Thesis** 

ZOUBIR NEMOUCHI 1988 328 p Avail: Univ. Microfilms Order No. BRD-87219

A computational procedure for the computation of two-dimensional incompressible thin shear associated with the flow around multi-element aerofoils was developed and assessed. The performance of three two-equation turbulence models was examined: the K-epsilon eddy-viscosity model (EVM) and two versions of the algebraic stress transport model (ASM). These were employed in conjunction with an existing parabolic solving procedure and a semi-elliptic version. The discretization of the partial differential equations in the numerical procedure is based on the fully-conservative finite-volume approach. The test cases considered include both straight and curved, free and wall-bounded, developing and self-similar, isolated and merging shear layers in zero and non-zero pressure gradients. The ASMs provided satisfactory predictions for a wider range of flows than the K-epsilon model. For example, the ASMs gave a more realistic prediction of the sensitivity of the turbulence structure to streamline curvature than the K-epsilon EVM. The last phase of the research was directed towards the refinement of, first the ASM but subsequently and more successfully, a differential stress model (DSM). The modified versions of both the ASM and DSM were applied to the computation of two free shear flows. A DSM employing a new model for the pressure-strain process and a new formulation for the turbulent kinetic energy dissipation rate gave significantly improved predictions of the weak-shear plane asymptotic wake. At the same time, the satisfactory prediction of the self-preserving plane jet in stagnant surroundings, using the new version, is Dissert, Abstr. preserved.

N90-24241 Pennsylvania State Univ., University Park. THE INTERACTION OF A SUPERSONIC STREAMWISE **VORTEX AND A NORMAL SHOCK WAVE Ph.D. Thesis** OMAR M. METWALLY 1989 268 p Avail: Univ. Microfilms Order No. DA9007895

A detailed experimental investigation on the generation of a turbulent, supersonic streamwise vortex subsequent interactions with a normal shock wave are presented. The vortex is generated in the supersonic wind tunnel inviscid freestream of Mach 3 using a streamlined, axisymmetric strut-mounted swirl injector. Flow-angularity probe measurements show that the supersonic

vortex core, having a streamwise Mach number of 3.0 and transonic tangential Mach numbers up to 0.9, resembles the incompressible vortex in its three-layered structure: an innermost viscous layer with solid body rotation, a logarithmic middle layer and an outer inviscid layer. Total temperature probe surveys show an isoenergetic vortical flow condition. The vortex is then passed through a normal shock created by mismatching static pressure of the vortical flow with that of the Mach 2 freestream. The resulting interaction, primarily observed by way of non-intrusive optical flow diagnostics, is shown to be sensitive to the initial swirl rate of the vortex. Passing a low-swirl vortex through the shock results in a weak interaction which resembles the inviscid, non-swirling flow case. For otherwise similar flow conditions, increasing the initial swirl rate of the vortex resulting in a strong, highly unsteady interaction as the shock distends upstream in a cone-like behavior and recompression shock forms downstream. Flow-angularity probe surveys show that the flow well downstream of both interactions is vortical again with a streamwise Mach number of 1.7. Two other vortex Mach numbers of 2.2 and 3.5 are covered for different initial swirl rates up to 0.4. On the basis of the current observations, a physical model that postulates the effect of the vortex breakdown phenomenon on the interaction flow pattern is presented. Navier-Stokes computations utilizing the present initial flow conditions partially support the physical model is predicting several key features of the observed strong interaction flow pattern.

Dissert. Abstr.

Old Dominion Univ., Norfolk, VA. Dept. of N90-24242\*# Mechanical Engineering and Mechanics.

SUBSONIC STING INTERFERENCE ON THE AERODYNAMIC CHARACTERISTICS OF A FAMILY OF SLANTED-BASE **OGIVE-CYLINDERS** 

COLIN P. BRITCHER, CHARLES W. ALCORN, and W. ALLEN KILGORE Washington Jun. 1990 75 p (Contract NAG1-716)

(NASA-CR-4299; NAS 1.26:4299) Avail: NTIS HC A04/MF A01 **CSCL 01/1** 

Support interference free drag, lift, and pitching moment measurements on a range of slanted base ogive cylinders were made using the NASA Langley 13 inch magnetic suspension and balance system. Typical test Mach numbers were in the range 0.04 to 0.2. Drag results are shown to be in broad agreement with previous tests with this configuration. Measurements were repeated with a dummy sting support installed in the wind tunnel. Significant support interferences were found at all test conditions and are quantified. Further comparison is made between interference free base pressures, obtained using remote telemetry, and sting cavity pressures. Author

### N90-24243 George Washington Univ., Washington, DC. ROTARY-JET THRUST AUGMENTOR WITH JET-FLAPPED **BLADES Ph.D. Thesis**

STEPHANE JEAN CORDIER 1989 190 p Avail: Univ. Microfilms Order No. DA9010239

The concepts and the mechanisms of thrust augmentation are analyzed. The theoretical performance of different types of thrust augmentors is discussed with an emphasis on the Rotary-Jet ejector. The application of thrust augmentors to STOVL aircrafts and the merits of the ejector in this application are discussed where the theoretical performance of the Rotary-Jet is shown to be particularly attractive. Recent experimental work on the Rotary-Jet is analyzed and several factors adversely affecting performance are identified and discussed. To address these problems a new configuration is proposed where the rotor is fitted with blades, allowing better control of the primary/secondary interaction. The jet sheet exiting at the trailing edge of the foil forms a jet flap. A two-dimensional analysis of the aerodynamics around a jet-flapped airfoil is performed for the first time using a fluid finite element code. In previous models the presence of the pressure gradient across the jet sheet is an assumption, its presence is predicted by the present method. This method is applied to the geometry of blade model 10. An original three-dimensional model of the self-driven, jet-flapped bladed rotor

is presented which, given set geometrical parameters and operating conditions, solves at each section for the jet and blade angle and calculates the rotor thrust augmentation. The results of parametric runs identify favorable design trends which are applied to the design of prototype test models. An experimental test program was performed. Flow visualization and local flow velocity and pressure measurements were used to identify favorable jet sheet characteristics. Seven blade models were tested in a parametric study. Rotor thrust augmentation without shroud is on the order of 1.0 with a maximum of 1.14. Within the range of parameters tested, optimum spin and flap angles were identified and a maximum thrust augmentation of 2.18 was reached. Tests with increasing exit to primary area ratio shows a monotonic increase in performance as opposed to the non-bladed rotary-jet, which reached a peak performance at a certain area ratio.

Dissert, Abstr.

N90-24246\*# Lockheed Engineering and Sciences Co., Hampton,

UNSTEADY POTENTIAL FLOW PAST A PROPELLER BLADE SECTION Final Report

M. A. TAKALLU Washington NASA Jul. 1990 28 p (Contract NAS1-19000)

(NASA-CR-4307; NAS 1.26:4307) Avail: NTIS HC A03/MF A01 CSCL 01/1

An analytical study was conducted to predict the effect of an oscillating stream on the time dependent sectional pressure and lift coefficients of a model propeller blade. The assumption is that as the blade sections encounter a wake, the actual angles of attack vary in a sinusoidal manner through the wake, thus each blade is exposed to an unsteady stream oscillating about a mean value at a certain reduced frequency. On the other hand, an isolated propeller at some angle of attack can experience periodic changes in the value of the flow angle causing unsteady loads on the blades. Such a flow condition requires the inclusion of new expressions in the formulation of the unsteady potential flow around the blade sections. These expressions account for time variation of angle of attack and total shed vortices in the wake of each airfoil section. It was found that the final expressions for the unsteady pressure distribution on each blade section are periodic and that the unsteady circulation and lift coefficients exhibit a hysteresis loop.

N90-24249# Scientific Research and Technology, Inc., Hampton, VA

LOW-DENSITY FLOW EFFECTS FOR HYPERVELOCITY VEHICLES, PHASE 2 Final Report, Jan: 1988 - Dec. 1989 ROOP M. GUPTA and SUDHEER N. NAYANI (Vigyan Research Associates, Inc., Hampton, VA.) 2 Mar. 1990 96 p (Contract F33615-87-C-3020; AF PROJ. 3005) (AD-A221034; WRDC-TR-90-3007) Avail: NTIS HC A05/MF A01 CSCL 20/4

Detailed flowfield results were obtained for sphere-cone shaped bodies at various angles of attack with a 3D nonequilibrium viscous-shock-layer (VSL) code. Recently obtained surface and shock-slip boundary conditions are implemented to account for the low-density effects. These boundary conditions may also be employed with the Navier-Stokes equations with or without a shock-fitting solution technique. A method is suggested for obtaining the input shock shape for the 3D nonequilibrium viscous flow. This approach gives a superior convergence of results, especially under the low-density flow conditions and makes the VSL method self-starting. The analytic algebraic grid implemented with the equations does not add any numerical dissipation. Obtained results show the effect of low density on the surrounding flowfield and surface quantities for a hypervelocity vehicle. Good agreement is obtained with the available numerical results (including the Direct Simulation Monte-Carlo predictions) and experimental data for the low-density flight conditions.

N90-24250# Douglas Aircraft Co., Inc., Long Beach, CA.
AN INTERACTIVE BOUNDARY-LAYER METHOD FOR
UNSTEADY AIRFOIL FLOWS. PART 1: QUASI-STEADY-STATE
MODEL Final Technical Report, 1 Jan. 1988 - 31 Dec. 1989
TUNCER CEBECI and HONG-MING JANG (California State Univ.,
Long Beach.) Feb. 1990 29 p

(Contract F49620-88-C-0020; AF PROJ. 2307)

(AD-A221220; MDC-K4856; AFOSR-90-0404TR) Avail: NTIS HC A03/MF A01 CSCL 01/1

An interactive boundary-layer method previously developed and tested for steady flows is used here in a quasi-steady manner to examine the evolution of the flow behavior of airfoils subject to harmonic oscillation and ramp-type motions. The calculations encompass the airfoil and wake flows at angles of attack which lead to separation. The results quantify the effects of the viscous boundary layer and wake on the variation of lift coefficient with angle of attack and reduced frequency. These effects are shown to be large at angles of attack which involve boundary-layer separation.

N90-24251# Naval Surface Warfare Center, Silver Spring, MD. WIND TUNNEL TESTS OF A 20-GORE DISK-GAP-BAND PARACHUTE Final Report, FY 1989 - FY 1990

WILLIAM P. LUDTKE 28 May 1989 64 p (AD-A221326; NSWC/TR-89-180) Avail: NTIS HC A04/MF A01 CSCL 01/3

This report documents wind tunnel tests of a series of 20 gore Disk-Gap-Band parachutes to determine the effects of gap length, band billow, and cloth air permeability on the parachute aerodynamic characteristics. Measurements for the steady-state drag-force, opening shock force, oscillation stability, and inflation stability were made of the various configurations and are presented in tabular and graphical format.

N90-24253# Technische Univ., Brunswick (Germany, F.R.). Fakultaet fuer Maschinenbau und Elektrotechnik.
TESTS FOR INTEGRATING MEASUREMENT OF GAS PRESSURES IN FLIGHT PROPELLERS Ph.D. Thesis [VERSUCHE ZUR INTEGRIERENDEN MESSUNG VON GASDRUECKEN IN FLUGTRIEBWERKEN]
GERARDO WALLE 1989 217 p In GERMAN (ETN-90-96498) Avail: NTIS HC A10/MF A02

The possibility of carrying out integrated pressure measurements with light wave conductors is discussed. An intensity modulated process is chosen in which the measured value changes the weakening of the light in the conduction by curvature of the fiber. The physical measurement principle was experimentally and theoretically analyzed at a fiber deformation unity in which a firmly fixed fiber section is mechanically weakened. The integral signal depiction of a measurement is examined for the mean value along the fiber, by means of the alignment of fiber deformation unities, which do not influence one another mechanically. The principle of the integrating measurement by means of amplitude modulation of the light in a mechanically distorted fiber is examined and the simulation of a practical utilization is evaluated.

N90-24254# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Abt. Instationaere Aerodynamik.

A TIME-MARCHING METHOD TO CALCULATE UNSTEADY AIRLOADS ON THREE-DIMENSIONAL WINGS. PART 1: LINEARIZED FORMULATION

LUIS PABLO RUIZ-CALAVERA Aug. 1989 54 p (DLR-FB-89-58; ISSN-0171-1342; ETN-90-97008) Avail: NTIS HC A04/MF A01; DLR, VB-PL-DO, Postfach 40 60 58, 5000 Cologne, Fed. Republic of Germany, 23.50 deutsche marks

A linearized time-marching method to calculate unsteady airloads on three-dimensional wings arbitrarily moving in an incompressible potential flow is presented. A panel method with constant doublet panels on the wing and linearly varying doublet panels on the wake is used. The method is described in detail and some comparisons with analytical solutions and other numerical methods are presented.

N90-24255# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Abt. fuer Instationaere Aerodynamik.

A TIME-MARCHING METHOD FOR CALCULATING UNSTEADY AIRLOADS ON THREE-DIMENTIONAL WINGS. PART 2: FULL-POTENTIAL FORMULATION

LUIS PABLO RUIZ-CALAVERA Aug. 1989 68 p (DLR-FB-89-59; ISSN-0171-1342; ETN-90-97009) Avail: NTIS HC A04/MF A01; DLR, VB-PL-DO, Postfach 40 60 58, 5000 Cologne, Fed. Republic of Germany, 28.50 deutsche marks

A time-marching method to calculate unsteady airloads on the three-dimensional wings arbitrarily moving in an incompressible potential flow is presented. A panel method with constant source and doublet panels on the wing and linearly varying doublet panels on the wake is used. The method allows nonlinear influences, such as those due to thickness, static angle of attack, amplitude of oscillation and position of the wake to be taken into account.

ESA

N90-25035\*# Norfolk State Univ., VA.
GROUND EVALUATION OF SEEDING AN IN-FLIGHT WINGTIP
VORTEX USING INFRARED IMAGING FLOW VISUALIZATION
TECHNIQUE

TED AKINYANJU *In Old Dominion Univ.*, NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 38-40 Sep. 1989

Avail: NTIS HC A09/MF A02 CSCL 01/1

An experimental simulation of an in-flight wingtip vortical flow visualization technique uses infrared imaging to observe strong and concentrated vortices. This experiment is phase 1 of a two-phase infrared evaluation program. The system includes a vortex generator (model 320 Vortec Vortex Tube) which generates the required vortex. The mouth of the unit is mounted close to the free end of a half-inch diameter, sixteen and a half foot long stainless steel tubing (sized after tubing currently installed in the wings of an experimental Beechcraft Sundowner 180 aircraft). Dichloro difluoromethane (Freon-12) is entrained into the generated vortex. A breakdown of the vortices is indicated by the rapid diffusion and the resulting pattern is tracked using the infrared imager and video systems. Flow rates (volume and mass) are estimated at the laboratory and proposed flight conditions. The nominal flight altitude is expected to be 2500 feet.

03

### AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A90-40687#

ANALYSES OF ARROW AIR DC-8-63 ACCIDENT OF DECEMBER 12, 1985 - GANDER, NEWFOUNDLAND

JAMES K. LUERS and MARK A. DIETENBERGER (Dayton, University, OH) Journál of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 543-550. Previously cited in issue 10, p. 1433, Accession no. A89-28448. refs
Copyright

A90-41728

A NEW NOISE CERTIFICATION METHOD FOR 'LIGHT PROPELLER AIRCRAFT' IN TESTING [EIN NEUES LAERMZERTIFIKATIONSVERFAHREN FUER 'LEICHTE PROPELLERFLUGZEUGE' IN DER ERPROBUNG]

HANNO HELLER, HELMUT DAHLEN, and WERNER DOBRZYNSKI (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), May 1990, p. 7-11. In German. refs

The evolution of German and international laws against aircraft

noise is summarized, and the development of a new noise certification test for light propeller aircraft is discussed. The previous noise certification test is reviewed, and criticisms of it are examined. The results of wind tunnel tests which influenced the development of the new certification test are described, and the new test is briefly discussed. The differences between the new test and the old one are outlined.

C.D.

### A90-42456#

#### THE SAFETY ANALYSIS APPROACH FOR THE EH101

ALAN J. WILSON (Westland Helicopters, Ltd, Yeovil, England) and FRANCESCO CORTELLINI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Cascina Costa di Samarate, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 14 p.

The background of Safety Analysis as a discipline is examined, and the logic behind the formulation of rotorcraft Safety Analysis requirements is presented. Based on these requirements, an idealized procedure is described for performing Safety Analysis using a top-down analysis technique. It is shown that the major advantage of the Safety Analysis approach described here is that it is the only design safety evaluation technique that assesses in a systematic manner combinations of failures from different systems in order to assure that there are no catastrophic combinations.

V.L

### A90-42481#

### EIGHT YEARS OF FLIGHT OPERATIONS WITH COMPOSITE ROTORBLADES

KARL HIERGEIST (Luftwaffe, Cologne, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p.

The results of eight years of flight operations with fiber glass composite rotor blades, involving a total of more than 1200 rotor blades and 1 million hours of operation, are summarized. Based on this experience, it is shown that composite rotor blades offer the following advantages over conventional metal blades: considerable life cycle cost savings, greater safety in the case of contact with obstacles, improved attack resistance, greater residual strength after repairs, easy repairability with simple means, and extreme fatigue strength. Some typical repair procedures are described.

N90-23367# General Accounting Office, Washington, DC:
AVIATION SECURITY: CORRECTIVE ACTIONS UNDERWAY,
BUT BETTER INSPECTION GUIDANCE STILL NEEDED.
REPORT TO THE CHAIRWOMAN, GOVERNMENT ACTIVITIES
AND TRANSPORTATION SUBCOMMITTEE, COMMITTEE ON
GOVERNMENT OPERATIONS, HOUSE OF REPRESENTATIVES
Aug. 1988 30 p

(GAO/RCED-88-160) Avail: NTIS HC A03/MF A01

This report presents the Federal Aviation Administration's (FAA) findings, conclusions, and recommendations regarding the effectiveness of FAA's inspections in identifying and rectifying security deficiencies. It was prepared for the Subcommittee on Government Activities and Transportation of the House of Representatives Committee on Government Operations. Author

N90-23368# Systems Control Technology, Inc., Arlington, VA.
AERONAUTICAL DECISIONMAKING FOR AIR AMBULANCE
PROGRAM ADMINISTRATORS Final Report

R. J. ADAMS and E. D. MCCONKEY Washington, DC FAA Feb. 1990 20 p

(Contract DTFA01-87-C-00014)

(DOT/FAA/DS-88/8) Avail: NTIS HC A03/MF A01

This manual discusses five of the most critical administrative aeronautical decision areas. The treatment is brief to ensure that the important, basic aeronautical limits will be read and understood by the largest possible audience. The concerns are: accident characteristics, pilot characteristics, weather restrictions, training needs, and risk management. Each of these concerns is discussed

in a summary format. The summaries begin with a concise statement of the problem. The statement is followed by a discussion of the governing regulations, an explanation of the underlying reasons for the limitation, and recommended solutions an administrator could implement to reduce the impact of, or eliminate, the risk. This summary material is supplemented by appropriate references for use by the reader who would like to explore on or more of these areas in greater detail. This administrator's manual is one of an integrated set of five Aeronautical Decisionmaking (ADM) manuals developed by the Federal Aviation Administration in a concerted effort to reduce the number of human factor related helicopter accidents. It can be used as one element of a comprehensive program for improving safety, reducing risk, and, hopefully, the high cost of helicopter hull and liability insurance.

Author

N90-23369# Federal Aviation Administration, Atlantic City, NJ. FIRE HAZARDS OF AEROSOL CANS IN AIRCRAFT CARGO COMPARTMENTS Final Report

DAVID R. BLAKE Dec. 1989 24 p Original contains color illustrations

(DOT/FAA/CT-89/32) Avail: NTIS HC A03/MF A01; 4 functional color pages

Some hazards associated with aerosol cans involved in cargo fires were determined. Over the last several years the chlorofluorocarbon propellant used in aerosol cans has been replaced with hydrocarbons such as butane, propane, and isobutane. These flammable gases would normally be prohibited on passenger carrying airplanes but there is an exception for up to 75 ounces per person for medicinal and toilet articles when carried in checked baggage only. Seven fire tests involving aerosol cans were conducted in an 800-cubic-foot cargo compartment. The main conclusions of the study were that hydrocarbon propellants in aerosol cans increase the damage potential of luggage fires; the fires in a simulated Class D compartment where aerosol cans ruptured and ignited were not contained; a Class C compartment provides significantly more protection against aerosol can fire threat than does a Class D compartment; an aerosol can rupturing and igniting in a Class D or Class C cargo compartment would eliminate the compartment's ability to control ventilations and drafts; and aerosol cans would be exposed to elevated temperatures for a longer period of time in a luggage fire in a Class D compartment than in a Class C compartment.

N90-23371# Civil Aeromedical Inst., Oklahoma City, OK.
THE INFLUENCE OF ADJACENT SEATING CONFIGURATIONS
ON EGRESS THROUGH A TYPE 3 EMERGENCY EXIT Final
Report

PAUL G. RASMUSSEN and CHARLES B. CHITTUM Dec. 1989 22 p Sponsored by FAA, Washington, DC (AD-A218393; DOT/FAA/AM-89/14) Avail: NTIS HC A03/MF A01 CSCL 01/3

When the United Kingdom Civil Aviation Authority (CAA) established a mandatory action intended to improve access to, and opening of, Type 3 emergency exits, the Northwest Mountain Region identified a need for a study to evaluate the proposed changes against existing minimum requirements of the Federal Aviation Regulations (FAR). The results indicate that the proposed CAA configuration and the alternative configuration were both more effective than the minimum configuration required by the FARs as measured by evacuation flow rate. There were no significant differences in the exit preparation time among the four seating arrangements.

N90-23372# Army Aviation Systems Command, Saint Louis, MO.

PEACETIME REPLACEMENT AND CRASH DAMAGE FACTORS FOR ARMY AIRCRAFT Final Report, 1975 - 1988

ROBERT L. BENSON May 1989 90 p (AD-A218544; USAAVACOM-TR-89-F-2) Avail: NTIS HC A05/MF A01 CSCL 01/2

Army aircraft mishaps are among the highest concerns of Army management. The Army invests significant amounts of money into

training aviators. The Worldwide Aviation Logistics Conference (WALC) meets annually at the U.S. Army Aviation Systems Command (USAAVSCOM) in St. Louis, Missouri. One of the issues that the WALC addresses is safety. The WALC uses factors to assess probable accident rates for proposed flying levels. The Peacetime Replacement Factor (PTRF) relates flying hours to the expected number of aircraft losses. The Crash Damage (CD) Factor relates flying hours to the expected number of crash damaged aircraft. Flying hours are expressed in a per 100,000 basis. Annual updates are made to these factors by the Operational Systems Analysis Division of the Directorate for Systems and Cost Analysis at AVSCOM.

N90-23373\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

ANALYSIS OF SEQUENCING AND SCHEDULING METHODS FOR ARRIVAL TRAFFIC

FRANK NEUMAN and HEINZ ERZBERGER Apr. 1990 47 p (NASA-TM-102795; A-90086; NAS 1.15:102795) Avail: NTIS HC A03/MF A01 CSCL 01/3

The air traffic control subsystem that performs scheduling is discussed. The function of the scheduling algorithms is to plan automatically the most efficient landing order and to assign optimally spaced landing times to all arrivals. Several important scheduling algorithms are described and the statistical performance of the scheduling algorithms is examined. Scheduling brings order to an arrival sequence for aircraft. First-come-first-served scheduling (FCFS) establishes a fair order, based on estimated times of arrival, and determines proper separations. Because of the randomness of the traffic, gaps will remain in the scheduled sequence of aircraft. These gaps are filled, or partially filled, by time-advancing the leading aircraft after a gap while still preserving the FCFS order. Tightly scheduled groups of aircraft remain with a mix of heavy and large aircraft. Separation requirements differ for different types of aircraft trailing each other. Advantage is taken of this fact through mild reordering of the traffic, thus shortening the groups and reducing average delays. Actual delays for different samples with the same statistical parameters vary widely, especially for heavy traffic.

N90-23374\*# National Aeronautics and Space Administration.
Ames Research Center, Moffett Field, CA.

SIMULATOR EVALUATION OF THE FINAL APPROACH SPACING TOOL

THOMAS J. DAVIS, HEINZ ERZBERGER, and STEVEN M. GREEN May 1990 18 p

(NASA-TM-102807; A-90122; NAS 1.15:102807) Avail: NTIS HC A03/MF A01 CSCL 01/3

The design and simulator evaluation of an automation tool for assisting terminal radar approach controllers in sequencing and spacing traffic onto the final approach course is described. The automation tool, referred to as the Final Approach Spacing Tool (FAST), displays speed and heading advisories for arrivals as well as sequencing information on the controller's radar display. The main functional elements of FAST are a scheduler that schedules and sequences the traffic, a 4-D trajectory synthesizer that generates the advisories, and a graphical interface that displays the information to the controller. FAST was implemented on a high performance workstation. It can be operated as a stand-alone in the Terminal Radar Approach Control (TRACON) Facility or as an element of a system integrated with automation tools in the Air Route Traffic Control Center (ARTCC). FAST was evaluated by experienced TRACON controllers in a real-time air traffic control simulation. Simulation results show that FAST significantly reduced controller workload and demonstrated a potential for an increase in landing rate. Author

N90-23375# Technische Univ., Brunswick (Germany, F.R.).
RESULTS OF TCAS-2 SIMULATIONS IN RECONSTRUCTED
DANGEROUS ENCOUNTERS (JUL. 1986 TO JUN. 1989)
[ERGEBNISSE DER TCAS-2 SIMULATIONEN IN
REKONSTRUIERTEN GEFAEHRLICHEN BEGEGNUNGEN (7/86

BIS 6/89)]

ANDREAS HERBER Jul. 1989 97 p In GERMAN (ETN-90-96474) Avail: NTIS HC A05/MF A01

Experiments of traffic departures in controlled air lanes considered dangerous by the federal administration are carried out to test the efficiency of a collision protection system. Validation or modification of the system design is addressed. The high contribution of adverse vertical operations is difficult for a system with linear extrapolation after the conflict recognition by TCAS. In about a quarter of the examined cases a variation of the vertical velocity of 500 fpm or more arises. Combination of TCAS2 -traffic aeroplane - Rode C - flight aeroplane seems to be a good solution for sure and operational encounters.

N90-24257.\*# Environmental Research Inst. of Michigan, Ann Arbor.

SYNTHETIC APERTURE RADAR IMAGERY OF AIRPORTS AND SURROUNDING AREAS: DENVER STAPLETON INTERNATIONAL AIRPORT Final Report, 31 Aug. 1987 - 30 Nov. 1989

ROBERT G. ONSTOTT and DENISE J. GINERIS Washington Jul. 1990  $\,$  385 p

(Contract NAS1-18465)

(NASA-CR-4305; NAS 1.26:4305; DOT/FAA/DS-89/16) Avail: NTIS HC A17/MF A02 CSCL 01/3

This is the third in a series of three reports which address the statistical description of ground clutter at an airport and in the surrounding area. These data are being utilized in a program to detect microbursts. Synthetic aperture radar (SAR) data were collected at the Denver Stapleton Airport using a set of parameters which closely match those which are anticipated to be utilized by an aircraft on approach to an airport. These data and the results of the clutter study are described. Scenes of 13 x 10 km were imaged at 9.38 GHz and HH-, VV-, and HV-polarizations, and contain airport grounds and facilities (up to 14 percent), cultural areas (more than 50 percent), and rural areas (up to 6 percent). Incidence angles range from 40 to 84 deg. At the largest depression angles the distributed targets, such as forest, fields, water, and residential, rarely had mean scattering coefficients greater than -10 dB. From 30 to 80 percent of an image had scattering coefficients less than -20 dB. About 1 to 10 percent of the scattering coefficients exceeded 0 dB, and from 0 to 1 percent above 10 dB. In examining the average backscatter coefficients at large angles, the clutter types cluster according to the following groups: (1) terminals (-3 dB), (2) city and industrial (-7 dB), (3) warehouse (-10 dB), (4) urban and residential (-14 dB), and (5) grass (-24

N90-24258# PPG Industries, Inc., Huntsville, AL. Aircraft Products

# FORWARD CANOPY FEASIBILITY AND THRU-THE-CANOPY (TTC) EJECTION SYSTEM STUDY Final Report, Dec. 1981 - Sep. 1989

JAMES W. MYERS Jan. 1990 160 p (Contract F33615-81-C-3403; AF PROJ. 1926) (AD-A220360; PPG-CDRL-6; WRDC-TR-89-3118) Avail: NTIS HC A08/MF A01 CSCL 01/3

This study presents the development and production of a half scale forward canopy to integrate bird strike protection for the T-38 aircraft. Actual half scale T-38 forward canopy fabrication process and production procedures are included. Forward canopy cross sections that should provide the desired bird strike protection level as recommended by the Univ. of Dayton Research Institute and PPG Industries, Inc. are included. A detailed final report on the T-38 Clear Path Egress (CPE) System which includes technology assessment and concept review of six systems is also included. Integration of the forward canopy, the T-38 airframe, and thru-the-canopy (TTC) escape capability systems have been mechanically and economically considered.

N90-24259# Simula, Inc., Phoenix, AZ.
OPERATIONAL EFFECTS ON CRASHWORTHY SEAT
ATTENUATORS Final Report, Sep. 1987 - Nov. 1989

MARVIN KENT RICHARDS Mar. 1990 141 p (Contract DAAJ02-87-C-0022) (AD-A221148; USAAVSCOM-TR-89-D-21) Avail: NTIS HC A07/MF A01 CSCL 01/3

Energy absorbers were removed from crashworthy crew and troop seats aboard UH-60A Black Hawk helicopters which had been in service for up to nine years. The fielded energy absorbers were tested both statistically and dynamically and the load-deflection characteristics were compared to new energy absorbers to determine the operational effects. There were three energy absorber types tested: inversion tube, rolling torus, and wire bender. Seat systems with energy types absorbers not meeting the manufacturer's specified load-deflection characteristics were modeled by computer simulation to determine the change in injury potential in a vertical crash scenario. In general, the inversion tube and rolling torus energy absorbers' performance did not change as compared to new attenuators. The wire benders, however, had a failure rate of 48 percent which appeared to be fatigue related.

N90-24260# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge.
AERODYNAMIC DEVELOPMENT PERSPECTIVE FOR TRAFFIC ,

AERODYNAMIC DEVELOPMENT PERSPECTIVE FOR TRAFFIC AEROPLANES [AERODYNAMISCHE ENTWICKLUNGSPERSPEKTIVEN FUER VERKEHRSFLUGZEUGE]

R. HILBIG and J. SZODRUCH 1989 26 p In GERMAN (DGLR-89-141; ETN-90-96781) Avail: NTIS HC A03/MF A01

The market possibilities for Airbus Industry are reviewed and the problems of increasing flight needs and atmospheric pollution are dicussed. Several tables and graphs are presented which show the evolution in the aerodynamic research in subsonics and hypersonics: the friction resistance could be reduced by influence of the turbulence structure or by a variable wing curve.

N90-24261# Deutsche Lufthansa A.G., Hamburg (Germany, F.R.).

### THÉ 30TH AIRLINES INTERNATIONAL ELECTRONICS MEETING PROCEEDINGS

1989 305 p Meeting held in Berlin, Fed. Republic of Germany, 15-17 Nov. 1989

(ETN-90-96973) Avail: NTIS HC A14/MF A02

The subjects of computer controlled systems, radio communication and navigation and sensors and instruments are discussed. Test equipment and facilities are considered. Autoflight guidance, stability augmentation and autothrottle are discussed. Electronic engine control, electronic displays and ground proximity and windshear warnings are considered. Flight data recording, aircraft condition monitoring, engine instrumentation and a wide range of other areas of concern to commercial airlines are discussed.

04

### AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

### A90-39002

### A DAYLIGHT STELLAR SENSOR USING A CHARGE-COUPLED DEVICE

T. M. DUNCAN (Ball Corp., Electro-Optics/Cryogenics Div., Boulder, CO) IN: Acquisition, tracking, and pointing III; Proceedings of the Meeting, Orlando, FL, Mar. 27-29, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 2-13. Research supported by Litton Industries and USAF. refs Copyright

Aircraft-mounted inertial navigation systems use stellar observations to improve accuracy of position and attitude. One

target star appears at a time on the 6 x 6 arcmin field of view (FOV), with speeds up to 11 arcmin/sec. Previous implementations used optomechanical techniques to separate a star from a sky of up to 3000 fL luminance, allowing estimation to 5 arcsec accuracy in the daytime and on the ground.; This paper describes a more reliable implementation using a CCD and high-speed microprocessor. Out of 385 x 288 pixels in the image section, only 30 x 30 are digitized each frame time of 10 ms. To reduce background shot noise, the charge accumulation duty cycle is varied so that pixel wells fill each frame regardless of sky brightness. During each frame time the microprocessor corrects each pixel for responsivity and background charge, averages over several frames, and forms a multipixel window. It then either searches an empty field for a star or tracks and interpolates to estimate the centroid of one already found.

### A90-39581 AIR TRAFFIC CONTROL (UPRAVLENIE VOZDUSHNYM **DVIZHENIEM**]

IURII P. DARYMOV, GEORGII A. KRYZHANOVSKII, VIKTOR M. ZATONSKII, IU. F. TSEPLIAEV, A. V. SIDOROV et al. Moscow, Izdatel'stvo Transport, 1989, 328 p. In Russian.

A textbook on the characteristic features of the Soviet ATC system is presented. The basic features of the ATC system are outlined, including system structure, the role of the dispatcher, and the general characteristics of aircraft and air transportation. Consideration is given to ATC organization, civil aviation services, the organization of dispatcher shifts, safety and security in ATC, ATC at air transportation centers, local airlines, and flight scheduling. The rules of ATC, ATC technology, and the automation of ATC processes are examined. The operation of the Start and Terkas automatic ATC systems is described.

### A90-39855

### SIMULATION OF THE REDUCTION CHARACTERISTICS OF SCATTERING FROM AN AIRCRAFT COATED WITH A THIN-TYPE ABSORBER BY THE SPATIAL NETWORK **METHOD**

T. KASHIWA, N. YOSHIDA, and I. FUKAI (Hokkaido University, Sapporo, Japan) Electronics Letters (ISSN 0013-5194), vol. 26, March 1, 1990, p. 289, 290. Copyright

The significant reduction characteristics of the scattering far-field from an aircraft coated with a thin-type absorber are obtained. A simulation employing a recently proposed three-dimensional time-domain analysis method is used. The resultant characteristics are also compared to the base where no absorber is used. C.D.

### A90-39959

### **NEURAL NETWORKS FOR ADAPTIVE SHAPE TRACKING**

ALASTAIR MCAULAY (Wright State University, Dayton, OH) and IVAN KADAR (Grumman Corp., Bethpage, NY) IN: Advances in image compression and automatic target recognition; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 74-82. refs

Copyright

A practical approach to tracking aircraft with similar looking silhouettes while maintaining identification is proposed and simulated. Preprocessing is performed using moment invariants that are shown to be almost constant for images in which the object is translated in position, rotated, or changed in scale. These moment invariants are used to train a neural network to identify the aircraft for different aspect angles. Consequently, tracking of a specific aircraft is achieved no matter what the aspect angle, the position, rotation, or scale.

### A90-40979

**DUAL CROSS-POLARIZATION PLANAR ARRAYS IN THE C** AND X BANDS [RESEAUX PLATS A DOUBLE POLARISATION ORTHOGONALE DANS LES BANDES C ET X1

GERARD DUBOST, ROGER FRIN, SAIED TOUIMER (Rennes I,

Universite, France), DANIEL BEGUIN, and LEON DUPONT (Centre Thomson des Applications Radar, Velizy-Villacoublay, France) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 1. Boulogne-Billancourt, France, RADAR 89, 1989, p. 201-206. In French. Copyright

The arrays described are used with two scatterometers mounted on small helicopters or aircraft. The first array operates in C band (5.25 to 5.45 GHz) and the second in X band (9.5 to 9.8 GHz). Each array is composed of 96 dual polarized multilayer microstrip antennas. Two interlaced stripline feeding networks are used to excite the totality of the radiating sources equivalent to a dual polarized array. The linear isotropic gain measured at the central frequency is equal to 20 dB. The coupling between the two polarizations is lower than -10 dB.

### A90-41004

### DIFFERENTIAL-GEOMETRICAL TECHNIQUE OF SIGNAL TRANSFORMATION AND ESTIMATION OF POSITION, RATE AND ACCELERATION PARAMETERS USING SUPPLEMENTARY DATA SOURCES

GENNADII N. GROMOV (All-Union Scientific Research Institute of Radio Equipment, Leningrad, USSR) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 26-30. Copyright

Direct and inverse equations are given for position, velocity, and acceleration transformation vectors in the case of aircraft mass center motion along an arbitrary trajectory. Using this approach, navigation parameters can be determined and the filtering problem can be solved using linear nonstationary Kalman-Bucy estimation. Aircraft range and azimuth estimation is considered as an example.

### A90-41034

### THE TVD 900 - A MODERN SIGNAL PROCESSING APPLIED TO PRIMARY CIVILIAN ATC RADAR

JACQUES KUNEGEL (Thomson-CSF, Meudon-la-Foret, France) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 236-241. Copyright

In order to associate possibilities offered by modern technology with past experience in PSR signal processing and extraction, THOMSON CSF SDC has developed and industrialized a new equipment, called TVD900, which responds to present and future needs in civilian en route or terminal approach trafic control. This paper focuses on the major originalities of the equipment architecture (4 filter MTD filter bank, efficient constant false alarm rate thresholding system, extraction), explaining as well the design approach, considering the required performance. Moreover, its built in test equipment is described, which greatly simplifies the equipment operation and maintenance.

### A90-41035

### DESIGN OF NEW POLISH PRIMARY RADARS AVIA DM/CM

WIESLAW KLEMBOWSKI and JERZY PIKIELNY (Przemyslowy Instytut Telekomunikacji, Warsaw, Poland) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 242-247. refs

Basic design ideas of the new Polish L-band radars AVIA DM (for TMA) and AVIA CM (for en route control) are presented. The main goal of the design is an unattended system giving high quality aircraft reports and auxiliary weather information. Both radars operate in frequency diversity system and polarization diversity in each channel. After short description of radars architecture their main performances are given. The photos of PPI with display of various echo and control signals are presented.

#### A90-41036

#### PERFORMANCES AND NEW SURVEILLANCE POSSIBILITIES IN SSR - MODE S

MICHEL WYBIERALA (Thomson-CSF, Meudon-la-Foret, France) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 248-253. Copyright

The features and capabilities of Mode S surveillance are examined. The performance of Mode S and monopulse surveillance are compared using real data obtained at Orly airport in France. The advantages of Mode S surveillance are discussed. It is shown that a system operating on a one selective transaction per scan per aircraft basis achieves the same performance as a multiple scan per beam system and Mode S surveillance is compatible with the Air Traffic Control Radar Beacon System.

#### A90-41056

APPLICATIONS OF MODE S SECONDARY SURVEILLANCE RADAR TO CIVIL AIR TRAFFIC CONTROL - STUDIES, EXPERIMENTS, AND POLICY OF THE FRENCH DIRECTION DE LA NAVIGATION AERIENNE [LES APPLICATIONS DU RADAR SECONDAIRE DE SURVEILLANCE MODE S AU **CONTROLE DU TRAFIC AERIEN CIVIL - ETUDES,** EXPERIMENTATIONS ET PLAN D'ACTION DE LA DIRECTION **DE LA NAVIGATION AERIENNE FRANCAISE**]

F. BRANGIER, F. MONTEIL, and JEAN LOUIS PIRAT (Centre d'Etudes de la Navigation Aerienne, Orly, France) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 404-409. In French. refs Copyright

#### A90-41057

**EXPERIMENTS ON MODE S SECONDARY SURVEILLANCE RADAR - THE PARTICIPATION OF THE FRENCH DIRECTION** DE LA NAVIGATION AERIENNE IN THE EUROPEAN EFFORT **[EXPERIMENTATION DU RADAR SECONDAIRE DE** SURVEILLANCE MODE S - LA PARTICIPATION DE LA **DIRECTION DE LA NAVIGATION AERIENNE FRANCAISE A** L'EFFORT EUROPEENI

MICHEL GUETTIER (Direction Generale de l'Aviation Civile, Service Technique de la Navigation Aerienne, Paris, France) International Conference on Radar 89, Paris, France, Apr. 24-28, 1989. Proceedings. Volume 2. Boulogne-Billancourt, France. RADAR 89, 1989, p. 410-414. In French. Copyright

### THE DEVELOPMENT RESULT OF SPEKTR AUTOMATED AIR TRAFFIC CONTROL (ATC) SYSTEM WITH EXTENDED GRADE OF AUTOMATION FOR TÉRMINAL AND HUB AREAS

P. M. ANISHCHENKO and B. A. LAPIN (All-Union Scientific Research Institute of Radio Equipment, Leningrad, USSR) International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 421-426.

Copyright

The development and design of the Spektr system are examined. The operation of Start, the first automatic ATC system in the USSR, is analyzed. The improved features in the 'Spektr' ATC system, designed for terminal and hub areas, are described. Spektr is a base modular system with a higher automation level. The system provides acquisition, storage, processing, distribution, and display of flight plan data; the system also records and reproduces information for air situation and control process. The components of the Spektr system and their functions are discussed. The performance of the Spektr system is evaluated and it is concluded that there is an improvement in safety and traffic capacity in aerodrome and hub areas using the Spektr system.

### A90-41062

THE GE SOLID STATE AIR DEFENCE/ATC RADAR

ANTHONY E. ZEBROWSKI (General Electric Co., Syracuse, NY) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989. Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 448-453.

Copyright

This paper describes a radar that has the capability to fulfill a stressing air defense and air traffic mission. A general picture of the radar's architecture is presented, from the electronically scanned array to the digital data processing and software functions that control the overall radar operation. Performance proof is given in the form of typical detection and accuracy.

#### A90-41705

### FLIGHT SAFETY PERFORMANCE OF THE MICROWAVE LANDING SYSTEM

DANIEL J. BERNINGER (Galaxy Scientific Corp., Mays Landing, IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 3-8. Research supported by Galaxy Scientific Corp. refs Copyright

The microwave landing system (MLS), which is scheduled to be implemented progressively over the next 10 years, is intended to supplant the instrument landing system (ILS) as the international standard landing aid. MLS has been demonstrated to be superior to ILS from both performance and reliability standpoints, yet considerable debate persists on its relative merits. Although tolerance criteria for flight safety are embedded in these comparisons, flight safety has not been a major component of these discussions. The reasons why flight safety has not been an issue are addressed, and observations on the flight safety of MLS are related from a systems point of view. The effect of MLS on airport capacity is identified as a central issue. Observations are derived from a review of available documentation and operational results to date as well as discussions with the participants.

### A90-41706#

### **ILS - PAST AND PRESENT**

FRANK ROEPCKE (FAA, Washington, DC) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 9-11.

Insight is provided into the evolution of VHF/UHF instrument landing system (ILS) equipment and the role of the US Civil Aeronautics and Federal Aviation Administrations in its development. The discussion covers the ILS localizer, glide slope (image arrays and nonimage arrays), marker beacon, reliability, and avionics.

### A90-41707

### ILS - A SAFE BET FOR YOUR FUTURE LANDINGS

RICHARD H. MCFARLAND (Ohio University, Athens) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 12-15. refs Copyright

An argument is presented in favor of the ILS (instrument landing system), the principal components of which are the localizer, which provides lateral guidance to the pilot, and the glide slope, which gives the vertical guidance. A pilot flying these signals precisely will end up over the hard surface runway with the ILS receiving antenna, wherever it is mounted on the aircraft, being about 20 ft above the touchdown point. The safety record and evolution of the ILS are examined, and a pilot's view of ILS (that of the author, an engineer who has worked with ILS since 1957 and a pilot who has used ILS safely for over 30 years) is given. System availability is discussed, and comments concerning future use are offered.

I.E.

### A90-41708

### APPLICATIONS OF SLOTTED CABLE ANTENNAS IN THE **INSTRUMENT LANDING SYSTEM**

C. B. WATTS, JR. (Watts Antenna Co., Annandale, VA) Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 16-20. refs Copyright

The use of slotted waveguides in the instrument landing system (ILS) is discussed, and applications of slotted cable antennas to the ILS localizer and glide slope are described. Examples are given of both existing and prospective designs intended to provide solutions for specific siting problems. Important applications are to the end-fire glide slope and category-III localizers.

### A90-41709#

### MLS - KEEPING PACE WITH THE FUTURE

RICHARD ARNOLD (FAA, Washington, DC) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 23-26.

It is argued that the instrument landing system (ILS) is now at its operational limit in terms of radio frequency availability, approach flexibility, and technology. The operational requirements for a microwave landing system (MLS), which will overcome key limitations of the ILS and provide growth to meet future requirements of precision landing systems, are discussed. John F. Kennedy (JFK) International Airport and LaGuardia Airport in New York City are discussed as examples to demonstrate the capabilities of MLS.

#### A90-41710

#### MLS - A TOTAL SYSTEM APPROACH

R. J. KELLY and E. F. C. LABERGE (Allied-Signal Aerospace Co., Bendix Communications Div., Baltimore, MD) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 27-40. refs Copyright

A typical approach and landing operation is described. The microwave landing system (MLS) is then examined, its design characteristics and how it works are shown, and how the MLS design fulfills the user's operational requirements by protecting the guidance signal from reflected signal interference is highlighted MLS angle system accuracy is discussed in great detail, and its reliability, integrity, and coverage volume are briefly considered. MLS availability at any runway to all aircraft types and their landing scenarios, which is accomplished using narrow scanning beam antennas, is examined.

### A90-41711

### DEMONSTRATION OF MLS ADVANCED APPROACH TECHNIQUES

ROBERT W. LILLEY (Ohio University, Athens) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 41-46. refs

Copyright -

Instrument approach designs and flight-test results using the microwave landing system (MLS) are presented. A general-aviation aircraft was flown on linear computed centerline and curved approach paths with MLS guidance displayed on basic course-deviation indicator and horizontal situation indicator instruments. Approach performance was documented using a ground tracker system, recording three-dimensional position information. These tests demonstrated the flyability of such advanced paths with basic cockpit instrumentation.

#### A90-41712

MICROWAVE LANDING SYSTEM - A PILOT'S POINT OF VIEW RALPH W. RISSMILLER, JR. (FAA, Aircraft Certification Office, Wichita, KS) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 5, May 1990, p. 47-49.

The author describes the MLS installation on runway 19L at Mid-Continent Airport, Wichita, Kansas, which has been operational since mid-1987. He describes the MLS equipment installation in his aircraft, which is one of a number of aircraft in the Wichita area that have been equipped with MLS equipment and routinely utilize the system. He summarizes his operational experience with the system. He reports complete satisfaction and increased versatility as a result of the guidance information provided. I.E.

#### A90-42452#

### SYSTEM CONCEPT AND PERFORMANCE CRITERIA OF MODERN HELICOPTER NAVIGATION

WOLFGANG HASSENPFLUG (LITEF GmbH, Freiburg im Breisgau, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p.

Guided by the requirements for the new generation of combat and military transport helicopters, a concept for the hybrid navigation subsystem is developed. This system matches the requirements concerning navigation accuracy during enroute and tactical flights, precise TAS determination within the entire flight envelope, and FO/FS availability for flight safety critical signals to feed the AFCS. The subsystem presented comprises two strapdown inertial measurement units augmented by means of a magnetometer and a Doppler velocity sensor. A radar altimeter provides height above ground information. Using a new LITEF proprietary calibration procedure, the magnetometer can be calibrated very accurately and completely in flight, including the local magnetic variation. With the new method a tremendous reduction of survey workload can be achieved.

# N90-23377# Federal Aviation Administration, Atlantic City, NJ. AN EVALUATION OF THE ACCURACY OF A MICROWAVE LANDING SYSTEM AREA NAVIGATION SYSTEM AT MIAMI/TAMIAMI FLORIDA AIRPORT Technical Report, Nov. 1989

CLIFFORD W. MACKIN Mar. 1990 22 p (Contract T0604L)

(DOT/FAA/CT-TN89/40) Avail: NTIS HC A03/MF A01

A series of flight tests were performed by the Federal Aviation Administration (FAA) Technical Center at the Miami/Tamiami Florida Airport to demonstrate the operation and capabilities of a prototype Microwave Landing System (MLS) Area Navigation System (RNAV). The Technical Center's test bed MLS was transported to and collocated with the commissioned Category 1 Instrument Landing System (ILS) on runway 9R at Tamiami. The flight data collected indicate that the errors in aircraft position, as computed by the MLS RNAV algorithm, consistently met Category 1 performance criteria, and that computed centerline and glide slope operations can be conducted with Category 1 accuracies to runways with lateral offsets of up to 3500 feet.

# N90-23378# Federal Aviation Administration, Atlantic City, NJ. MLS MATHEMATICAL MODEL VALIDATION STUDY USING AIRBORNE MLS DATA FROM MIDWAY AIRPORT ENGINEERING FLIGHT TESTS, AUGUST 1988 Technical Report, Mar. 1989

LINDA PASQUALE and JESSE D. JONES Apr. 1990 42 p (Contract T06-038)

(DOT/FAA/CT-TN90/2) Avail: NTIS HC A03/MF A01

The Microwave Landing System (MLS) mathematical model validation study evaluated the performance of the MLS math model by comparing the results of the model's simulation of flight test profiles flown at Midway Airport in Chicago with actual airborne data collected during the test flights. The study specifically addressed the problems of scattering and shadowing of MLS signals by buildings in the airport environment. Comparisons of model output with real world data showed good agreement. Discrepancies between the two were explainable as either the model's sensitivity to input parameters or the model's worst case scenario strategy. The conclusion is supported that the MLS math model is a valuable tool for use in the evaluation of potential sources of signal interference for an MLS system configuration in a particular airport environment.

N90-23379# Federal Aviation Administration, Atlantic City, NJ. POSITION COMPUTATION WITHOUT ELEVATION INFORMATION FOR COMPUTED CENTERLINE OPERATIONS Technical Report, Aug. 1989

BARRY R. BILLMAN and CHRISTOPHER J. WOLF Apr. 1990

23 p (Contract T0707A)

(DOT/FAA/CT-TN89/42) Avail: NTIS HC A03/MF A01

Computed centerline approaches can be divided into two subclasses: approaches to an instrument runway with an offset azimuth configuration, and approaches to a runway parallel to the primary instrumented runway. The use of lateral position computation algorithms that do not require an input elevation parameter were proposed for situations where a full three-dimensional algorithm would be difficult in terms of memory requirements or computational power. The impact of siting configurations on the accuracy of this type of algorithm was investigated to determine its acceptability for different categories of operation. The results of this investigation are presented.

Author

N90-24263# Federal Aviation Administration, Washington, DC. Office of Aviation Policy and Plans.

### IFR AIRCRAFT HANDLED FORECAST BY AIR ROUTE TRAFFIC CONTROL CENTER: FISCAL YEARS 1990 TO 2005 Final Report

Feb. 1990 70 p (Contract DTFA01-88-C-00059) (AD-A220312; FAA-APO-90-3) Avail: NTIS HC A04/MF A01 CSCL 17/7

This report provides forecasts of Instrument Flight Rule (IFR) aircraft handled by Federal Aviation Administration Air Route Traffic Control Centers. The current study is an update to FAA-AVP 80-4, IFR AIRCRAFT HANDLED Forecast by Air Route Traffic Control Center, Fiscal Years 1980 to 1991. The forecasts serve as a base for the FAA planning and budget process in determining future requirements for facilities, equipment, and manpower. The forecasts show that total aircraft handled will increase from 37.0 million in FY 1989 to 50.6 million in FY 2005. These national total numbers along with the intervening years are broken down by FAA region and for each air route traffic control center in this report. This appendix contains a technical description of the data sources, methodology, and regression models used in the Instrument Flight Rule (IFR), aircraft activity forecasts for each Air Route Traffic Control Center. Section 2 presents an overview of the forecasting model for IFR aircraft activity. Section 3 provides a detailed description of the various data bases used in the forecasts. Section 4 allocating county data to the various ARTCCs, and estimating models to forecast IFR aviation activity. The final section presents the forecasting models for IFR departures and overs at each ARTCC.

N90-24264# Aeronautical Research Labs., Melbourne (Australia).

## APPLICATION OF OPTIMAL TRACKING METHODS TO AIRCRAFT TERRAIN FOLLOWING Aircraft Systems Technical Memorandum

M. E. HALPERN Dec. 1989 29 p (AD-A221099; ARL-SYS-TM-133; DODA-AR-005-644) Avail: NTIS HC A03/MF A01 CSCL 17/7

Some approaches using least squares optimization for improving tracking control system performance are developed and applied to a simplified aircraft terrain following problem. A basic tracking control system is described. The design of an optimal moving-average precompensator which gives improved tracking performance over the basic system is then given. This filter design is modified to use future values of the reference input to give further improved performance. An approach involving the design of an optimal signal to drive the control system is also given. These approaches are applied to an aircraft terrain following system simulation. The performance obtained is examined and discussed. It appears that as worthwhile performance improvements can be obtained by using the algorithms which make use of knowledge of future terrain as could be obtained from a terrain data-base. These improvements allow the aircraft to fly at lower altitudes.

**GRA** 

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### AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A90-39286#

### THE MECHANISMS AND BENEFITS OF AEROELASTIC TAILORING

CHONGQING ZOU (Beijing University of Aeronautics and Astronautics, People's Republic of China) Acta Materiae Compositae Sinica (ISSN 1000-3851), vol. 6, Dec. 1989, p. 1-9. In Chinese, with abstract in English. refs

This paper comprehensively introduces the theoretical foundation of aeroelastic tailoring in composite aircraft. The mechanisms of aeroelastic tailoring are explained including the basic principles on which the realization of aeroelastic tailoring depends. The effects on the aircraft performance due to tailoring are illustrated by the use of a series of curves.

Author

A90-39976

# FATIGUE METHODOLOGY III; PROCEEDINGS OF THE AHS NATIONAL TECHNICAL SPECIALISTS' MEETING ON ADVANCED ROTORCRAFT STRUCTURES, SCOTTSDALE, AZ, OCT. 3-5, 1989

Meeting sponsored by AHS. Alexandria, VA, American Helicopter Society, 1989, 201 p. For individual items see A90-39977 to A90-39993

Papers on rotorcraft and fatigue methodology are presented, covering topics such as reliability design for rotorcraft, a comparison between theory and fatigue test data on stress concentration factors, the retirement lives of rolling element bearings, hydrogen embrittlement risk analysis for high hardness steel parts, and rotating system load monitoring with minimum fixed system instrumentation. Additional topics include usage data collection to improve structural integrity of operational helicopters, usage monitory of military helicopters, improvements to the fatigue substantiation of the H-60 composite tail rotor blade, helicopter surviellance programs, and potential application of automotive fatigue technology in rotorcraft design. Also, consideration is given to fatique evaluation of C/MH-53 E main rotor damper threaded joints, SH-2F airframe fatigue test program, a ply termination concept for improving fracture and fatigue strength of composite laminates, the analysis and testing of composite panels subject to muzzle blast effects, the certification plan for an all-composite main rotor flexbeam, and the effects of stacking sequence on the flexural strength of composite beams.

### A90-39978#

### DESIGNING ROTORCRAFT DYNAMIC COMPONENTS TO RELIABILITY REQUIREMENTS

BOGDAN R. KRASNOWSKI (Bell Helicopter Textron, Inc., Fort Worth, TX) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 17 p. refs

The paper discusses the impact of reliability requirements on the design and fatigue analysis of metallic rotorcraft dynamic components. It is shown that the required level of reliability affects allowable stresses and the causes of service failures, and is therefore an important factor in the selection of an appropriate method for life prediction. Three basic approaches to fatigue life prediction are considered: safe-life method, damage tolerance method, and integrated method. Methodologies for determining the reliability of complex structures under spectrum loading for these approaches are given. In reliability calculations, random variations in the load spectrum, fatigue strength, fracture toughness, crack growth data, crack growth threshold, and initial crack size are taken into account. To support general considerations, a pitch horn, designed first as a single-load-path structure and then as a

multiple-load-path structure, is analyzed. The results of the analysis are supported and verified by component fatigue test data and by coupon and component crack growth data.

#### A90-39985#

### IMPROVEMENTS TO THE FATIGUE SUBSTANTIATION OF THE H-60 COMPOSITE TAIL ROTOR BLADE

JAMES P. RENNA (Sikorsky Aircraft, Stratford, CT) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 11 p. refs

Consideration is given to the empirically-derived parameter, based on shear load resulting from an analytical flatwise moment distribution and torsion due to pushrod load offset, used in the fatique substantiation of the critical fracture mode of the H-60 composite tail rotor blade. A reevaluation of this parameter is presented, resulting in the development of a new bond line shear stress derived parameter based on more detailed moment distributions. The development of this parameter is described and the flight test data correlation is discussed. Changes to the manufacturing process for the bond line are reviewed, noting their effect on bond quality.

### A90-39986#

### HELICOPTER SURVEILLANCE - A LOOK AT CURRENT AND PROPOSED FUTURE PROGRAMS

JIM KIERAS (Sikorsky Aircraft, Stratford, CT) methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 8 p.

The U.S. Army Surviellance Program for checking the performance and strength of critical helicopter components is examined. The various phases and results from the surviellance program for the Black Hawk helicopter are presented. Results are presented for the main rotor shaft, the tail rotor horn, and the swashplate guide. It is suggested that format of the Black Hawk program is a practical, comprehensive surveillance method that can be applied to new and already existing aircraft.

### A90-39988#

### FATIGUE EVALUATION OF C/MH-53E MAIN ROTOR DAMPER THREADED JOINTS

CRAIG J. WERLEY (Sikorsky Aircraft, Stratford, CT) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society,

After three isolated in-service fatigue cracks occurred in the C/MH-53E main rotor damper threaded joints, a fatigue evaluation of the joints was conducted. An engineering investigation showed that the main factor affecting the fatigue strength of the joint was loss of torque. Also, it is found that the data processing technique used in the flight test program did not measure the rotor shutdown compressive load peak. The irregular and unforeseen field service considerations and manufacturing anomaly that caused reduced preload in the joint and the fatigue strength of the joint in the degraded torque condition are determined. A design solution is obtained, consisting of a thread configuration change that applied dry-film lubricant to the thread surface. R.B.

### A90-39989#

### SH-2F AIRFRAME FATIGUE TEST PROGRAM

MICHAEL A. BOWES, EDWARD G. NAGY, CHARLES P. HARDERSEN, and LORI E. HURST (Kaman Aerospace Corp., Bloomfield, CT) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 18 p. Research supported by the U.S. Navy.

Low cycle fatigue loading is applied to test a full scale SH-2F helicopter airface simulating flight maneuver and landing loads.

Maneuvering loads derived from measurements of the airframe strain distributions during flight and landing loads obtained from analyses were correlated with test loads calculated directly from the required strain distributions using the matrix inversion technique of generalized force determination. Test loading of more than 40,000 flight hours was applied with no life limiting structural failure and no need for structural repair.

#### A90-39992#

### CERTIFICATION PLAN FOR AN ALL-COMPOSITE MAIN **ROTOR FLEXBEAM**

LYNDON C. LAMBORN (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 7 p. refs

Analysis and testing methodology for certification of an advanced rotor flexbeam are discussed. Detailed analysis and testing plans are outlined, together with necessary correlation between analysis and test. Logical step-by-step methods of determining and accounting for environmental effects, manufacturing flaws, inspection intervals, and flaw growth are set environmental forth. A fatigue methodology and failure criteria for the flexbeam are discussed. Author

### A90-40128

### CERTIFICATION TESTING METHODOLOGY FOR FIGHTER HYBRID STRUCTURE

K. B. SANGER, H. D. DILL (McDonnell Aircraft Co., Saint Louis, MO), and E. F. KAUTZ (U.S. Navy, Naval Air Development Center, Warminster, PA) IN: Composite materials: Testing and design. Volume 9; Proceedings of the Ninth Symposium, Sparks, NV, Apr. 27-29, 1988. Philadelphia, PA, American Society for Testing and Materials, 1990, p. 34-47. refs Copyright

A methodology for certification testing of bolted hybrid aircraft structures was developed that accounts for inherent differences between composite and metal behavior. The effects of scatter and environment on static strength and fatigue life certification were characterized based on analytic correlation with test results of over 8000 carbon/epoxy specimens.

### A90-40130\* Douglas Aircraft Co., Inc., Long Beach, CA. IMPACT DAMAGE AND RESIDUAL STRENGTH ANALYSIS OF **COMPOSITE PANELS WITH BONDED STIFFENERS**

RAM C. MADAN (Douglas Aircraft Co., Long Beach, CA) and MARK J. SHUART (NASA, Langley Research Center, Hampton, VA) IN: Composite materials: Testing and design. Volume 9; Proceedings of the Ninth Symposium, Sparks, NV, Apr. 27-29, 1988. Philadelphia, PA, American Society for Testing and Materials, 1990, p. 64-85. refs (Contract NAS1-17970)

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Blade-stiffened, compression-loaded cover panels designed, manufactured, analyzed, and tested. All panels were fabricated from IM6/1808I interleafed graphite-epoxy. orthotropic blade stiffener and an orthotropic skin were selected to satisfy the design requirements for an advanced aircraft configuration. All specimens were impact damaged prior to testing. Experimental results were obtained for three- and five-stiffener panels. Analytical results described interlaminar forces caused by impact and predicted specimen residual strength. The analytical results compared reasonably with the experimental results for residual strength of the specimens.

A90-40166\*# Advanced Rotorcraft Technology, Inc., Mountain View, CA.

### PARAMETER IDENTIFICATION OF AEROELASTIC MODES OF **ROTARY WINGS FROM TRANSIENT TIME HISTORIES**

AHMED OMAR AMRANI and RONALD DU VAL (Advanced Rotorcraft Technology, Inc., Mountain View, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 669-674. refs (Contract NAS2-12518) Copyright

A novel moving-block technique is presented for parameter-identification tasks concerning the aeroelastic modes of rotary wings, using a least-squares solver in the time domain to estimate dampings and eigenvector components. The least-squares moving-block (LSMB) technique is shown to yield superior estimates to those of the previous moving-block technique for four different analytical test cases. An additional advantage of the LSMB approach is its ability to estimate eigenvector components with good accuracy; this feature is useful in assessing the coupling of the different modes. The method can also be used to perform periodic modal identification, and is applicable to experimental data for the extraction of modal information. O.C.

## A90-40172# EXPERIMENTAL STUDY OF THE EFFECTS OF NONLINEARITIES ON GROUND RESONANCE

GEORGE T. FLOWERS (Auburn University, AL) and BENSON H. TONGUE (California, University, Berkeley) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 725-731. Research supported by the U.S. Army. refs Copyright

An experimental investigation into the effects of nonlinearities on the ground resonance behavior of rotorcraft is conducted and the results correlated with analytical predictions. The experimental techniques and results are described in detail and representative graphs of the observed behavior are shown and discussed. It is found that responses of destructively high amplitude may occur in systems for which a linear analysis predicts stable behavior.

Author

### A90-40344 YF-23A PREVIEWS DESIGN FEATURES OF FUTURE

WILLIAM B. SCOTT Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, July 2, 1990, p. 16-21. Copyright

The YF-23A demonstrator is a distinct departure from earlier fighters, blending low-observable and aerodynamic features into a complex, yet balanced design. The Advanced Tactical Fighter must have longer range capabilities and be more difficult to detect in flight, yet be faster, more maneuverable, more reliable, and easier to maintain than current inventory fighters. They will have to cruise supersonically, without using afterburner, and carry a respectable payload of air-to-air weapons. The Northrop/McDonnell YF-23A is longer than an F-15. It has widespread, sharply canted tail surfaces; a bubble canopy; and twin engines buried internally, well aft of the cockpit. Large-area, widely separated butterfly tails mounted on the extreme aft fuselage at 45 deg. angles provide pitch, yaw, and probably some roll control. Along with the competing YF-22A prototype, the demonstration/validation tests are expected to begin in August.

### A90-40685#

### **ACOUSTICS OF ULTRALIGHT AIRPLANES**

HANNO HELLER, HELMUT DAHLEN, and WERNER DOBRZYNSKI (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 2, p. 1342-1355) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 529-535. Research supported by the Umweltbundesamt. Previously cited in issue 03, p. 266, Accession no. A89-13636. Copyright

### A90-41339

### THE EFFECT ON FATIGUE CRACK GROWTH UNDER SPECTRUM LOADING OF AN IMPOSED PLACARD 'G' LIMIT

K. WALKER (Royal Australian Air Force, Aircraft Engineering Div., Melbourne, Australia) and A. F. GRANDT, JR. (Purdue University, West Lafayette, IN)
 IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture

(ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 1029-1036. refs Convright

The effect of modifying peak load in the applied load spectrum on fatigue crack growth was investigated analytically and experimentally with particular reference to fatigue cracking problems in the main spar of the Mirage 111 aircraft. The limits were in the form of a g limit, also referred to as a placard limit. It is found that an imposition of a placarded g limit on a fighter aircraft, such as the Mirage, may lead to an increase in the crack growth rate for a mode I crack subjected to tensile loads associated with positive g maneuvers. The amount of the crack growth rate increase depends on the amount of retardation present from the initial spectrum and the level of the imposed limit.

#### A90-41727

### ATTHES - A HELICOPTER IN-FLIGHT SIMULATOR FOR ACT TESTING [ATTHES - EIN HUBSCHRAUBER-IN-FLIGHT-SIMULATOR FUER ACT-ERPROBUNG]

HEINZ-JUERGEN PAUSDER, GERHARD BOUWER, and WOLFGANG VON GRUENHAGEN (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), May 1990, p. 2-6. In German, refs

An Advanced Technology Testing Helicopter System (ATTHeS) helicopter in-flight simulator is discussed which can be used in the research and development of helicopter Advanced Control Technology (ACT). The model control system for the in-flight simulation is examined, including its design, on-board system, and real-time realization. Preliminary results with ATTHeS are summarized.

#### A90-41737#

# THE INFLUENCE OF CONTROL-SURFACE COMPENSATION PARAMETERS ON THE HINGE MOMENT CHARACTERISTICS [WPLYW PARAMETROW KOMPENSACJI STERU NA CHARAKTERYSTYKI MOMENTU ZAWIASOWEGO]

ROBERT JOZWIAK Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 116, 1989, p. 3-13. In Polish. refs

The evaluation of hinge moments in a wind tunnel is considered. The dependence of the hinge moment on the compensation parameters of the control surface is discussed. The empirical relations obtained are a result of many tests of various control configurations and may be useful for design purposes and optimization studies.

Author

#### A90-41738#

# APPLICATION OF MATHEMATICAL MODELING TO THE STUDY OF RIGID HELICOPTER ROTORS [WYKORZYSTANIE MODELOWANIA MATEMATYCZNEGO DO BADANIA WIRNIKOW BEZPRZEGUBOWYCH]

ANDRZEJ PROKOPIUK (Instytut Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 116, 1989, p. 14-29. In Polish. refs

A simplified model of a single blade of a rigid helicopter rotor is considered in the hovering case. The equations of motion of a rigid blade elastically fixed in equivalent hinges are established using the linear stationary flow model and are numerically integrated. The results are analyzed by the Fourier Transformation method. The model presented may be used to analyze the behavior of a rigid rotor within the region of lowest natural frequencies.

Author

### A90-41739#

INFLUENCE OF SOME GEOMETRICAL AND DESIGN PARAMETERS ON THE HINGE MOMENT CHARACTERISTICS OF RUDDERS [WPŁYW NIEKTORYCH PARAMETROW GEOMETRYCZNYCH I KONSTRUKCYJNYCH NA CHARAKTERYSTYKI MOMENTOW ZAWIASOWYCH STEROW] ROBERT JOZWIAK Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 117, 1989, p. 3-11. In Polish. refs

The results of aerodynamic investigations showing the influence of some geometrical and design solutions of a control surface on the hinge moment coefficient are presented. Some unconventional solutions are also presented which were used during optimization tests. They removed the overbalancing of a control surface.

Author

#### A90-41899

### **EXPANDING THE B-1B FLIGHT ENVELOPE**

Aerospace Engineering (ISSN 0736-2536), vol. 10, July 1990, p. 13-16.

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Enhanced flying qualities and safety as well as improved operational capabilities in the B-1B have resulted from the incorporation of a stall inhibitor system (SIS). The design of this system focused on a flight control system modification which would allow the aircraft to fly to higher angles of attack. The SIS was developed in three phases: (1) a minimum aircraft modification requirement and interim capability for early operational use, (2) introduction of the first part of a stability enhancement function (SEF) using the same basic aerodynamic stability limits as in the first phase of this SIS and serving as a failure mode, (3) the SEF mode becomes triple-redundant and fail-operational. The test points were checked in a simulator to familiarize pilots and engineers, as well as to provide predictions of aircraft responses. Finally, it is expected that the B-1B fleet will soon be operating in a greatly enhanced flight envelope provided by this flight control system development test program.

#### A90-41991#

### REQUIREMENTS FOR BUSINESS JET AIRCRAFT

E. C. KILLINGSWORTH, JR. and R. R. WOLZ (Gulfstream Aerospace Corp., Savannah, GA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs

(AIAA PAPER 90-2038) Copyright

The issues related to future business jet design requirements are examined. Various features of a business jet aircraft are discussed, including the requirements for speed, range, payload capabilities, reliability, comfort, operational flexibility, security, and safety. The trends that will effect future design requirements are considered, including increased range requirements due to the emergence of new commerce centers and the need for more efficient materials and design features. Also, the process of developing new configurations through an evolutionary approach is reviewed.

### A90-42047#

### AIRFRAME/PROPULSION INTEGRATION OF SUPERSONIC CRUISE VEHICLES

J. THOMAS ANDERSON (Lockheed Aeronautical Systems Co., Burbank, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. Research supported by USAF.

(AIAA PAPER 90-2151) Copyright

The process of supersonic propulsion system cross-sectional shape definition involves consideration of engine airflow, cruise angle-of-attack, vehicle integration, vehicle weight and balance, thrust distribution vs Mach number, and internal duct pressures. Attention is presently given to the cases of such an inlet/engine/airframe integration problem for turbojet powerplants matched to either two-dimensional or axisymmetric inlets for a Mach 4.2-cruise, JP-fueled aircraft. The axisymmetric propulsion system is found to yield significant reductions in vehicle gross weight and increases in mission range, relative to the two-dimensional inlet configurations.

### A90-42103#

### DIRECT LIFT STOVL ENGINE INTEGRATION

ROBERT F. TAPE (Rolls-Royce, Inc., Atlanta, GA) and MICHAEL E. MCINTYRE (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint

Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. Research supported by USAF and Rolls-Royce, Inc. (AIAA PAPER 90-2274) Copyright

Direct lift engines were studied and developed in the fifties and sixties and used in several V/STOL aircraft prototypes and demonstrator rigs. The recent revival of interest in STOVL has caused these high thrust/weight, short life engines to be re-evaluated in light of current and projected developments in gas turbine technology and materials. Rolls-Royce, under WRDC sponsorship, has defined a 15,000 lbf. lift engine and studied its design, performance and integration into an STOVL fighter. The integration and operational issues associated with the design and use of a direct lift in an STOVL tactical fighter are discussed in this paper.

### A90-42104#

### EXPLORATION OF CONCEPTS FOR MULTI-ROLE FIGHTERS

SQUIRE L. BROWN and STEVEN P. SNYDER (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. (AIAA PAPER 90-2276)

The study deals with three issues involved in the exploration of concepts for a multirole fighter: time required to develop technology, the uncertainty of future requirements, and the affordability of future systems in a budget-constrained environment. It is shown that the possibilities for transitioning technologies during next 15 years range from upgrades and derivatives to far-term options that fully exploit technology capabilities. It is noted that the need to assess affordability can hinder progress until adequate methodology becomes generally available. Six different design vectors are suggested for assessing candidate exploration concepts. It is recommended that work on a design database be initiated and that methodology for affordability be developed in order that decisions on cost and capabilities can be made. V.T.

### A90-42105#

### INTEGRATED AIR VEHICLE/PROPULSION TECHNOLOGY FOR A MULTIROLE FIGHTER - A MCAIR PERSPECTIVE

JAMES MACE and PAUL DOANE (McDonnell Aircraft Co., Saint Louis, MO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p.

(AIAA PAPER 90-2278) Copyright

The study deals with the integration of the propulsion and airframe systems for a new multirole fighter (MRF) making it possible for new technologies to reduce life-cycle cost while providing enhanced supportability ability, flexibility, and survivability. Emphasis is placed on those technologies considered important to MRF propulsion system/airframe integration. First, the inlet system is addressed. This is followed by engine/airframe integration issues. Technologies influencing the integration of the exhaust nozzle into the airframe are highlighted, and airframe/propulsion control system interfaces are discussed.

A90-42106\*# National Aeronautics and Space Administration. Flight Research Center, Edwards, CA.

### PROPULSION SYSTEM-FLIGHT CONTROL

### INTEGRATION-FLIGHT EVALUATION AND TECHNOLOGY TRANSITION

FRANK W. BURCHAM, JR., GLENN B. GILYARD, and LAWRENCE P. MYERS (NASA, Flight Research Facility, Edwards, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 23 p. refs (AIAA PAPER 90-2280) Copyright

Integration of propulsion and flight control systems and their optimization offering significant performance improvement are assessed. In particular, research programs conducted by NASA on flight control systems and propulsion system-flight control interactions on the YF-12 and F-15 aircraft are addressed; these programs have demonstrated increased thrust, reduced fuel consumption, increased engine life, and improved aircraft performance. Focus is placed on altitude control, speed-Mach control, integrated controller design, as well as flight control

systems and digital electronic engine control. A highly integrated digital electronic control program is analyzed and compared with a performance seeking control program. It is shown that the flight evaluation and demonstration of these technologies have been a key part in the transition of the concepts to production and operational use on a timely basis.

V.T.

#### A90-42278

### INFLUENCE OF GROUND EFFECT ON HELICOPTER TAKEOFF AND LANDING PERFORMANCE

T. CERBE, G. REICHERT (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany), and H. C. CURTISS, JR. (Princeton University, NJ) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 14, June 1990, p. 155-167. refs

(Contract DFG-SFB-212)

Copyright

The steady state ground effect for hover and forward flight is discussed using experimental flight test results with a BO 105 helicopter. The results are compared with theoretical results from performance calculations, and a modified source model is used to describe the ground effect. The dynamic ground effect for low forward velocities and the influence of acceleration and deceleration are discussed using experimental results from model rotor tests. Takeoff without power excess is investigated theoretically, taking the stationary and dynamic ground effect into account, with a quasi-stationary data field simulation model. The simulation results are verified by flight test results, and a vertical landing with constant power setting is simulated.

#### A90-42355#

### A NOVEL SYNTHETIC METHOD FOR STUDYING NONLINEAR FLIGHT STABILITY

ZHIDAI HE and WEN GUO (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 143-151. In Chinese, with abstract in English. refs

A new synthetic method is presented that results in generalized nonlinear stability criteria. Examples for two typical aircraft are given from which the process of solving the stability problem is derived, and the data on flight stability obtained from this method are shown. The data derived include the equilibrium surface of the state vectors, the time histories of the state parameters and the time variation of the dynamic stability. Also indicated are the sensitivity of the nonlinear system stability to aerodynamic, structural and combination parameters, and the linear and nonlinear analytical terms that have a strong effect on stability. It is concluded that these data have proved useful in aircraft design.

#### A90-42407#

#### PRELIMINARY DESIGN AND ANALYSIS OF PROPELLERS

P. VYRIOTES and D. J. BARBER (Boeing Canada, de Havilland Div., Downsview) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 7-1 to 7-13. refs

Two analytical methods for propeller performance estimation are evaluated at low to moderate ratios of advance with a range of loading from slightly negative to stalling. Prediction of induced velocities by both methods gives good performance estimation with some differences at conditions where the induced velocities represent a significant fraction of the forward speed, while neither method is capable of rigorously accounting for sweep. The second method is extended to provide off-axis forces and moments for radially and azimuthally arbitrary flow. Some simplifying assumptions concerning the coupling between various velocity components are discussed.

#### A90-42417#

### AN EXPERIMENTAL AND ANALYTICAL INVESTIGATION OF THE BUFFET EXCITATION PARAMETER

S. J. ZAN (National Aeronautical Establishment, Ottawa, Canada) and D. J. MAULL (Cambridge, University, England) IN: Canadian

Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 19-1 to 19-21. Research supported by the Department of Trade and Industry of England. refs

The nature of the buffet excitation parameter in subsonic flow at low values of Reynolds number for a wing section with sharp leading and trailing edges is addressed. First, various methods used to characterize the data from wind-tunnel and flight-test buffet investigations are reviewed, and their strengths and weaknesses, similarities and differences are discussed. Then the experimental setup is described, and test results are presented. It is shown that since a buffeting wing can be described as a linear system at and beyond the stall condition, the buffet excitation parameter is a reasonable parameter to use when presenting buffeting results. It is noted that the buffet excitation parameter is influenced by angle of incidence and wing sweep, and that the constancy of the buffet excitation parameter seems to be related to the slowly decreasing power spectral density of aerodynamic force. V.T.

#### A90-42420#

## DEVELOPMENT OF THE STALL WARNING/STICK PUSHER SYSTEM FOR THE BOEING/DE HAVILLAND DASH 8 SERIES 300

ALLAN B. PAIGE (Boeing Canada, de Havilland Div., Downsview) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 22-1 to 22-19. refs

During development of the Boeing/de Havilland Dash 8 Series 300, it was necessary to incorporate a stick pusher system to meet airworthiness requirements for stall characteristics. A digital computer was developed to process data for stall warning and stick pusher functions. Flight testing provided experimental results for defining and evaluating the computer algorithms, and for determining optimum stick pusher actuator characteristics. The stick pusher provides stall identification and enhances the level of safety for the aircraft, but does not impact on performance stall speeds.

Author

#### A90-42434#

#### **ACTIVE CONTROL OF HELICOPTER CABIN NOISE**

G. P. EATWELL and I. J. HUGHES (Topexpress, Ltd., Cambridge, England) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 8 p. refs

The principal methods of reducing the cabin noise of helicopters are briefly reviewed, and one of the methods, active control, is discussed in terms of feasibility and costs. The main factors determining the cost of an active noise control system are examined with particular reference to the size and complexity of the system, power requirements, weight, performance, and maintenance. With a balance of cost and weight penalties taken into account, it is suggested that a mixture of active and passive techniques might provide the best solution.

#### A90-42441#

### EUROFAR - STATUS OF THE EUROPEAN TILT-ROTOR PROJECT

J. ANDRES (Aerospatiale, Division Helicopteres, Marignane, France) and G. MONTI (Agusta S.p.A., Milan, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 22 p.

The European Future Advanced Rotorcraft (Eurofar) project is a cooperative, five-nation, six-company undertaking currently in its initial three-year phase. The reference aircraft configuration on which current technical studies are based will transport 30 passengers over 1000 km at a cruise speed of 300 kts; attention is being given to a tilt-rotor twin-engine vehicle for high-density and regional route use, whose potential military applications encompass tactical transport, rapid supply, ship-based operations, airborne assault, and search-and-rescue. It is intended that this tilt-rotor aircraft should make extensive use of composites, fly-by-wire/light controls, and advanced rotor blades.

#### A90-42442#

#### **EH101 DEVELOPMENT PROGRESS**

P. G. DUNFORD (Westland Helicopters, Ltd., Yeovil, England) and F. MUSSI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Cascina Costa di Samarate, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 16 p.

The current status of the ground and flight test program for the EH101 helicopter is briefly reviewed. In particular, flight results for the preproduction aircraft are discussed with reference to the handling qualities, noise, vibration, performance, and general functioning. The discussion also covers the results of the rig and bench test program, with particular attention given to the airframe strength and vibration tests, and test results for dynamic components, aircraft systems, and avionic and electrical equipment.

#### A90-42445#

### IMPROVING TILT ROTOR AIRCRAFT PERFORMANCE WITH VARIABLE-DIAMETER ROTORS

EVAN A. FRADENBURGH (Sikorsky Aircraft, Stratford, CT) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p. refs

The hovering-condition optimized rotor of a tilt-rotor aircraft is grossly oversized for high-speed forward flight. An account is presently given of the design features, performance characteristics, and complexity and weight penalties of a variable-diameter rotor system for tilt-rotor aircraft capable of both efficient hover and cruise speeds approaching 500 kts. Attention is given to the two-component telescoping rotor blade's jackscrew-based extention/retraction mechanism, which doubles as a primary tension load-bearing structural member of the blade. The heart of the blade jackscrew mechanism is a differential gear set contained within the rotor head.

#### A90-42457#

#### HELICOPTER GROUND AND AIR RESONANCE DYNAMICS

G. REICHERT and J. EWALD (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p. refs (Contract BMFT-LFF-84318)

The paper reviews the state-of-the-art in understanding of helicopter rotor/fuselage dynamics phenomena and discusses the methods to study and predict the behavior. Main objectives are the techniques to avoid or overcome instabilities and to eliminate design penalties. For ground and air resonance problems a good understanding and useful analytical and experimental methods have been developed, but the influencing design parameters - e.g. coupling effects of the rotor dynamics need more systematic studies. The influence on stability of dynamic inflow, aeroelastic and structural coupling of flap and lead-lag motion as well as pitch-lag coupling is investigated. Theoretical results are compared with test data of a model rotor.

#### A90-42458#

#### KANE'S METHODS IN ROTORBLADE DYNAMICS

S. HANAGUD and S. SARKAR (Georgia Institute of Technology, Atlanta) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 17 p. refs

In this paper, Kane's method of formulation of dynamical equations has been applied to derive rotor blade equations. Equations have been derived for articulated blade and hingeless rotor-systems. The simplicity of the formulated equations vary with the choice of selected dynamic variables.

Author

#### A90-42460#

A COMPREHENSIVE APPROACH TO COUPLED ROTOR-FUSELAGE DYNAMICS

P. T. W. JUGGINS (Westland Helicopters, Ltd., Yeovil, England) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p. refs

As part of a program to develop methods for the comprehensive analysis of the coupled behavior of rotor and fuselage systems, an analysis for Coupled Rotor-Fuselage Dynamics (CRFD) has been written, and progress has been made in the development of a corresponding aeroelastic model for the calculation of responses and loads. Some examples of problems to be addressed by the coupled rotor-fuselage approach are given, including blade lead-lag dynamics, blade torsion dynamics, fuselage dynamics and hub motion, and tail rotor stability. The development and initial validation of the CRFD analysis are discussed.

#### A90-42464#

## AEROELASTIC RESPONSE CHARACTERISTICS OF A ROTOR EXECUTING ARBITRARY HARMONIC BLADE PITCH VARIATIONS

TOMOARI NAGASHIMA, GIZO HASEGAWA, TOSHIFUMI NEKOHASHI, and TAKEICHIRYO HIROSE (Defense Academy, Yokosuka, Japan) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p. refs

Analytical and experimental studies of the aeroelastic characteristics of the collective control responses of a rotor due to the harmonic blade pitch variations, with the hub fixed in space, are carried out. The steady state responses of dynamic hub vertical load are analyzed by modal integral methods. To verify the computed results, force tests to measure the hub vertical loads over a wide frequency range up to fifth harmonics of the rotor speed are conducted with a one-bladed model rotor. Flow visualization studies are also made for a rotor in hover to disclose diversity of the wake geometries piled beneath the rotor under various pitch change frequency ratios. Both numerical and experimental results reveal their unique dependencies on the pitch change frequency as well as the modal parameters. For a rotor in forward flight, there may be optimum blade pitch variations by which the hub dynamic vertical load could be minimized. Author

#### A90-42465#

### AGUSTA METHODOLOGY FOR PITCH LINK LOADS PREDICTION IN PRELIMINARY DESIGN PHASE

FABIO NANNONI and ALESSANDRO STABELLINI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Cascina Costa di Samarate, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 28 p. refs

The Agusta methodology for estimating static and torsional loads at the root of helicopter blades in the preliminary design phase is described. An algorithm is presented which can evaluate the forces, moments, and flapping and lagging motion of a rotor arbitrarily placed in space, if the control angle at 75 percent of the radius and the component of the flight speed with respect to the shaft axis are known. The identification of the aerodynamic loads, inertial loads, loads due to blade weight, and loads due to the lead-lag damper is shown, as is the way that unsteady aerodynamic effects are taken into account.

#### A90-42468#

### INFLUENCE OF GROUND EFFECT ON HELICOPTER TAKEOFF AND LANDING PERFORMANCE

T. CERBE, G. REICHERT (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany), and H. C. CURTISS, JR. (Princeton University, NJ) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 17 p. refs

(Contract DFG-SFB-212)

The influence of the ground effect on the power required for helicopter hover and forward flight is shown by experimental results from flight tests with a BO 105 helicopter as well as from track tests with a model rotor. Theoretical performance calculations are compared with experimental results and discussed. In the performance calculation a semiempirical model for the ground effect is used. The performance calculation and the simulation model for simulation of takeoff and landing procedures are described.

Author

## A90-42473\* Maryland Univ., College Park. AEROELASTIC EFFECTS ON STABILITY AND CONTROL OF HINGELESS ROTOR HELICOPTERS

ROBERTO CELI (Maryland, University, College Park) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 22 p. Research supported by the U.S. Army. refs

(Contract NCA2-310)

The combined effect of torsional flexibility and offset of the aerodynamic center relative to the elastic axis on the stability and control of a hingeless rotor helicopter in forward flight is studied in this paper. The aeroelastic model of the blade is based on fully coupled flap-lag-torsion equations of motion, which include kinematic nonlinearities due to moderate deflections. The equations are discretized using a finite element Galerkin method in space, and a classical Galerkin method in time. The vehicle trim calculations are coupled to the blade aeroelastic response calculations. Quasilinearization is used to compute aeroelastic stability. Reducing torsional stiffness and moving the elastic axis ahead of the aerodynamic center strongly stabilizes the phugoid mode without reducing control sensitivity. Aeroelastic stability calculations must accompany flight dynamics calculations to prevent aeroelastic instabilities that might easily go undetected.

Author

#### A90-42494#

## PRELIMINARY FLIGHT EVALUATION OF THE SA 365 PANTHER HELICOPTER IN AIR-TO-AIR COMBAT MANOEUVRES

B. FOUQUES (Aerospatiale, Division Helicopteres, Marignane, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 15 p.

Results of preliminary aerobatics tests conducted on the SA 365 Panther helicopter are summarized. The first aerobatic maneuvers included some LH wing overs (1/4 loop, 1/4 turn, 1/4 loop) and LH clover leaves (1/4 loop, 1/4 roll, 3/4 loop) followed by loops and LH barrel rolls. These maneuvers were initiated from 2000 to 2500 ft. The discussion covers negative load factor testo with the helicopter center of gravity, helicopter motion around its center of gravity, stresses, and engine and circuits operation.

V.L

#### A90-42495#

### HELICOPTER STORE SEPARATION - PREDICTIVE TECHNIQUES AND FLIGHT TESTING

M. TREMBLAY (DND, Ottawa, Canada) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 22 p. refs

The analyses and test methods that are currently used to certify the safe separation of a store (e.g., fuel tanks, photographic and survival equipment, and weapons) from a helicopter are briefly reviewed. In particular, attention is given to helicopter/store aerodynamics, helicopter flowfield environment, and methods for predicting the store separation trajectory, including theoretical, analogy, and empirical predictive methods. The discussion also covers wind tunnel and flight testing, test instrumentation, and instrumentation tolerances.

#### A90-42496#

#### **EH101 VIBRATION CONTROL**

D. I. BATTARBEE, G. J. VENN (Westland Helicopters, Ltd., Yeovil, England), and G. VIGNATI (Agusta S.p.A., Milan, Italy)

Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 10 p.

Current efforts to control the vibration of the EH101 helicopter are discussed with particular reference to the control of vibration at the main rotor blade passing frequency of 17.5 Hz. Attention is given to mathematical modeling of the vehicle, required for the prediction of forces generated within the rotor and the resultant vibration levels within the airframe structure. The discussion also covers in-flight vibration measurements and their correlation with both theoretical predictions and shake test results. Some elements of the vibration control program planned for the future are also briefly discussed.

#### A90-42497

## ESTIMATION OF ROTOR BLADE INCIDENCE AND BLADE DEFORMATION FROM THE MEASUREMENT OF PRESSURES AND STRAINS IN FLIGHT

JOHN RILEY, GARETH PADFIELD, and JANE SMITH (Royal Aerospace Establishment, Bedford, England) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 20 p. refs
Copyright

A technique for deriving local blade incidence from a single pressure measurement is discussed with reference to preliminary flight test results. Values of lift and incidence determined from the leading edge pressure are considered generally satisfactory and are in reasonable agreement with predicted values, although the unsteady incidence corrections available are not included in the results presented. Blade deformations obtained from strain measurements using the strain pattern analysis approach are characterized by certain anomalies resulting from uncertainties in the strain calibration pattern currently used.

#### A90-42498#

### FLIGHT TESTS TO EXPLORE TAIL ROTOR LIMITATIONS IN THE LOW SPEED ENVELOPE

S. F. BALDWIN and C. S. HANDLEY (Royal Aerospace Establishment, Bedford, England) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 28 p. refs

A flight research program utilizing a Puma helicopter was conducted in order to examine the tail rotor performance within the aircraft's low speed flight envelope. Two series of tests were flown, the first to highlight areas of interest, such as poor or restricted tail rotor performance, and the second to investigate these areas with an instrumented tail rotor blade fitted to the aircraft. The discussion covers the background, approach, and flight test techniques adopted for these trials and also results from the first series of flight tests and some preliminary data from the instrumented blade. The design and development of the instrumented blade is also discussed.

#### A90-42499#

### ANALYTICAL EVALUATION OF HELICOPTER TRUE AIR SPEED AND ASSOCIATED FLIGHT TESTS

MANFRED BAEUMKER and WOLFGANG HASSENPFLUG (LITEF GmbH, Freiburg im Breisgau, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 20 p.

A new accurate analytical method for determining the true air speed of helicopters over the entire range of speed, dynamic, and altitude regimes is described. The new method is primarily based on control lever positions; outside temperature, static pressure, and aircraft mass are required only to correct the model used to enhance the accuracy of speed determinations. The algorithms and calibration functions of the method, called the Analytical Air Data System for Helicopters, can be handled by standard microprocessors. Results of simulations and flight tests are discussed.

N90-23386\*# Kansas Univ. Center for Research, Inc., Lawrence. Flight Research Lab.

FIGHTER AGILITY METRICS, RESEARCH, AND TEST

RANDALL K. LIEFER, JOHN VALASEK, and DAVID P. EGGOLD 19 Jun. 1990 200 p

(Contract NCC2-588)

(NASA-CR-186118; NAS 1.26:186118; KU-FRL-831-2) Avail: NTIS HC A09/MF A02 CSCL 01/3

Proposed new metrics to assess fighter aircraft agility are collected and analyzed. A framework for classification of these new agility metrics is developed and applied. A completed set of transient agility metrics is evaluated with a high fidelity, nonlinear F-18 simulation provided by the NASA Dryden Flight Research Center. Test techniques and data reduction methods are proposed. A method of providing cuing information to the pilot during flight test is discussed. The sensitivity of longitudinal and lateral agility metrics to deviations from the pilot cues is studied in detail. The metrics are shown to be largely insensitive to reasonable deviations from the nominal test pilot commands. Instrumentation required to quantify agility via flight test is also considered. With one exception, each of the proposed new metrics may be measured with instrumentation currently available. Simulation documentation and user instructions are provided in an appendix.

N90-23387# Army Aviation Engineering Flight Activity, Edwards AFB, CA.

### PRELIMINARY AIRWORTHINESS EVALUATION OF THE

RC-12K Final Report, 12 Jun. - 22 Jun. 1989 JOSEPH C. MIESS, GEORGE M. YAMAKAWA, ROBERT D. ROBBINS, and WARREN P. GOULD Aug. 1989 102 p (AD-A219545; USAAEFA-88-03) Avail: NTIS HC A06/MF A01 **CSCL 01/3** 

During this test program, ten flights were conducted for a total of 22.8 hours, of which 14.6 hours were productive. Tests were performed in the Guardrail/Common Sensor System mission configuration ballasted to an average gross weight of 16,000 lb and centers of gravity at fuselage station 188.1 (forward) and 195.1 (aft). Test results were evaluated against military specification MIL-F-8785C for handling qualities. Performance data presented in the operator's manual were confirmed, as was the Beech Aircraft Corp. provided drag polar. The RC-12K test aircraft had good takeoff, accelerate-stop, landing, and climb performance. At 16,000 Ib maximum gross weight, the standard day service ceiling is above the certified ceiling of 35,000 ft. The handling qualities of the RC-12K were satisfactory. Minimum control speeds dictated that the flaps down approach speed was 106 knots indicated airspeed regardless of weight. The heavy-duty main gear wheel and brake system contributed to good accelerate-stop and performance. Lack of adequate stall warning and the poor engine cowl securing device were identified as deficiences. One shortcoming was identified.

N90-23388# Naval Postgraduate School, Monterey, CA. Dept. of Aeronautics and Astronautics.

#### INITIAL FLIGHT TEST OF HALF-SCALE UNMANNED AIR **VEHICLE M.S. Thesis**

YEHO KEE Sep. 1989 67 p

(AD-A219584) Avail: NTIS HC A04/MF A01 CSCL 01/3

Pioneer, a short range Unmanned Air Vehicle, was recently introduced into fleet operations. Due to the manner of test and evaluation of UAV's, problems with the air vehicle have been identified during, rather than prior to, operational use and contractor testing. A flight research program has begun at the Naval Postgraduate School to use a half-scale Pioneer UAV in an attempt to study the flight behavior of Pioneer. Limitation of flight endurance below original estimations has prompted a drag analysis of the vehicle to be performed. Previously, wind tunnel work was carried out for propeller studies. The current investigation uses the results of that work to complete flights for determination of a drag polar for the vehicle. A drag clean-up of the original wing configuration was performed, and though the data are scattered due to the measurement techniques trends indicate a significant reduction in drag for the new wing. Comparison of the drag data with numerical predictions shows a reasonable correlation.

N90-23389# Air Force Inst. of Tech., Wright-Patterson AFB. OH. School of Engineering.

#### DEVELOPMENT OF A LEAST SQUARES TIME RESPONSE LOWER-ORDER EQUIVALENT SYSTEMS TECHNIQUE M.S. Thesis

CLARKE O. MANNING Mar. 1990 266 p (AD-A220527; AFIT/GAE/ENY/90M-02) Avail: NTIS HC A12/MF A02 CSCL 01/1

The most widely accepted method for specifying flying qualities of highly-augmented aircraft is the low-order equivalent systems technique. This technique matches the frequency response of a high-order system (HOS) with a lower-order equivalent system (LOES). The LOES is generally in the form of a classical (unaugmented) aircraft so that comparisons with the classical data base can be made. Most LOES research has been accomplished using frequency response matching. However there are also methods available for matching the time responses of the HOS and LOES. Time response matching is an attractive option for flight test applications since all that is required is output versus input data. This thesis develops and tests a Least Squares LOES time response matching program. The program was tested analytically at the Air Force Institute of Technology, Wright-Patterson AFB, OH. During the analytical testing, a HOS was modeled using an A-4D aircraft with servo-actuator and feel system dynamics. Lower order equivalent parameters were calculated using the Least Squares program and the results were compared to those obtained using a frequency response matching program (LONFIT). Various flight conditions and feel system dynamics were used to change the HOS dynamics and the effects of these changes on the two matching techniques were investigated. GRA

N90-23390\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### **ACTUATED FOREBODY STRAKES Patent**

DANIEL G. MURRI, inventor (to NASA) 17 Apr. 1990 11 p Filed 11 May 1988 Supersedes N88-24628 (26 - 18, p 2464) (NASA-CASE-LAR-13983-1; US-PATENT-4,917,333; US-PATENT-APPL-SN-192563; US-PATENT-CLASS-244-75R; US-PATENT-CLASS-244-45A; US-PATENT-CLASS-244-46; US-PATENT-CLASS-244-90R; INT-PATENT-CLASS-B64C-9/02; INT-PATENT-CLASS-B64C-9/08) Avail: US Patent and Trademark Office CSCL 01/3

Actuated forebody strakes provide yaw control at high angles of attack. In one embodiment, the strakes are axially slidable in the forebody to be deployed out of slots provided for the strakes in the forebody. In another embodiment, the strakes are pivotally connected at the tip of the strakes to pivot radially outwardly out of the slots provided in the forebody. In another embodiment, the forebody is provided with either a single strake or two strakes and the forebody is rotatable to vary the radial location of the strake or strakes. All embodiments achieve significant yaw control capability over a wide angle of attack and sideslip ranges.

Official Gazette of the U.S. Patent and Trademark Office

N90-23392\*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA. ESTIMATING SHORT-PERIOD DYNAMICS USING AN **EXTENDED KALMAN FILTER** 

JEFFREY E. BAUER and DOMINICK ANDRISANI (Purdue Univ., West Lafayette, IN.) 1990 38 p Presented at the 5th Biannual Flight Test Conference, Ontario, CA, 21-24 May 1990 Previously announced in IAA as A90-33901

(NASA-TM-101722; H-1625; NAS 1.15:101722) Avail: NTIS HC À03/MF A01 CSCL 01/3

An extended Kalman filter (EKF) is used to estimate the parameters of a low-order model from aircraft transient response data. The low-order model is a state space model derived from the short-period approximation of the longitudinal aircraft dynamics. The model corresponds to the pitch rate to stick force transfer

function currently used in flying qualities analysis. Because of the model chosen, handling qualities information is also obtained. The parameters are estimated from flight data as well as from a six-degree-of-freedom, nonlinear simulation of the aircraft. These two estimates are then compared and the discrepancies noted. The low-order model is able to satisfactorily match both flight data and simulation data from a high-order computer simulation. The parameters obtained from the EKF analysis of flight data are compared to those obtained using frequency response analysis of the flight data. Time delays and damping ratios are compared and are in agreement. This technique demonstrates the potential to determine, in near real time, the extent of differences between computer models and the actual aircraft. Precise knowledge of these differences can help to determine the flying qualities of a test aircraft and lead to more efficient envelope expansion.

N90-23393\*# General Electric Co., Cincinnati, OH. Advanced Technology Operations.

EXPERIMENTAL PERFORMANCE AND ACOUSTIC INVESTIGATION OF MODERN, COUNTERROTATING BLADE **CONCEPTS Final Report** 

G. E. HOFF Jan. 1990 659 p (Contract NAS3-24080)

(NASA-CR-185158; NAS 1.26:185158) Avail: NTIS HC A99/MF CSCL 01/3

The aerodynamic, acoustic, and aeromechanical performance of counterrotating blade concepts were evaluated both theoretically and experimentally. Analytical methods development and design are addressed. Utilizing the analytical methods which evolved during the conduct of this work, aerodynamic and aeroacoustic predictions were developed, which were compared to NASA and GE wind tunnel test results. The detailed mechanical design and fabrication of five different composite shell/titanium spar counterrotating blade set configurations are presented. Design philosophy, analyses methods, and material geometry are addressed, as well as the influence of aerodynamics, aeromechanics, and aeroacoustics on the design procedures. Blade fabrication and quality control procedures are detailed; bench testing procedures and results of blade integrity verification are presented; and instrumentation associated with the bench testing also is identified. Additional hardware to support specialized testing is described, as are operating blade instrumentation and the associated stress limits. The five counterrotating blade concepts were scaled to a tip diameter of 2 feet, so they could be incorporated into MPS (model propulsion simulators). Aerodynamic and aeroacoustic performance testing was conducted in the NASA Lewis 8 x 6 supersonic and 9 x 15 V/STOL (vertical or short takeoff and landing) wind tunnels and in the GE freejet anechoic test chamber (Cell 41) to generate an experimental data base for these counterrotating blade designs. Test facility and MPS vehicle matrices are provided, and test procedures are presented. Effects on performance of rotor-torotor spacing, angle-of-attack, pylon proximity, blade number, reduced-diameter aft blades, and mismatched rotor speeds are addressed. Counterrotating blade and specialized aeromechanical hub stability test results are also furnished.

N90-23394\*# Kansas Univ., Lawrence.

PRELIMINARY DESIGN OF A SUPERSONIC SHORT TAKEOFF AND VERTICAL LANDING (STOVL) FIGHTER AIRCRAFT

LARRY BELLMARD, PAUL BORCHERS, CHARLIE GOMER, DEAN TODD LAWSON, ERIC HENDERSON, TAVIS JACOBS, PETERSON, and TWEED ROSS, III 1990 422 p (Contract NASW-4435)

(NASA-CR-186670; NAS 1.26:186670) Avail: NTIS HC A18/MF **CSCL 01/3** 

The preliminary design study of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter is presented. A brief historical survey of powered lift vehicles was presented, followed by a technology assessment of the latest supersonic STOVL engine cycles under consideration by industry and government in the U.S. and UK. A survey of operational fighter/attack aircraft and the modern battlefield scenario were completed to develop,

respectively, the performance requirements and mission profiles for the study. Three configurations were initially investigated with the following engine cycles: a hybrid fan vectored thrust cycle, a lift+lift/cruise cycle, and a mixed flow vectored thrust cycle. The lift+lift/cruise aircraft configuration was selected for detailed design work which consisted of: (1) a material selection and structural layout, including engine removal considerations, (2) an aircraft systems layout, (3) a weapons integration model showing the internal weapons bay mechanism, (4) inlet and nozzle integration, (5) an aircraft suckdown prediction, (6) an aircraft stability and control analysis, including a takeoff, hover, and transition control analysis, (7) a performance and mission capability study, and (8) a life cycle cost analysis. A supersonic fighter aircraft with STOVL capability with the lift+lift/cruise engine cycle seems a viable option for the next generation fighter.

N90-23395\*# Auburn Univ., AL.

AVION: A DETAILED REPORT ON THE PRELIMINARY DESIGN OF A 79-PASSENGER, HIGH-EFFICIENCY, COMMERCIAL TRANSPORT AIRCRAFT

WILLIAM MAYFIELD, BRETT PERKINS, WILLIAM ROGAN, RANDALL SCHUESSLER, and JOE STOCKERT

(Contract NASW-4435)

(NASA-CR-186663; NAS 1.26:186663) Avail: NTIS HC A05/MF A01 CSCL 01/3

The Avion is the result of an investigation into the preliminary design for a high-efficiency commercial transport aircraft. The Avion is designed to carry 79 passengers and a crew of five through a range of 1,500 nm at 455 kts (M=0.78 at 32,000 ft). It has a gross take-off weight of 77,000 lb and an empty weight of 42,400 lb. Currently there are no American-built aircraft designed to fit the 60 to 90 passenger, short/medium range marketplace. The Avion gathers the premier engineering achievements of flight technology and integrates them into an aircraft which will challenge the current standards of flight efficiency, reliability, and performance. The Avion will increase flight efficiency through reduction of structural weight and the improvement of aerodynamic characteristics and propulsion systems. Its design departs from conventional aircraft design tradition with the incorporation of a three-lifting-surface (or tri-wing) configuration. Further aerodynamic improvements are obtained through modest main wing forward sweeping, variable incidence canards, aerodynamic coupling between the canard and main wing, leading edge extensions, winglets, an aerodynamic tailcone, and a T-tail empennage. The Avion is propelled by propfans, which are one of the most promising developments for raising propulsive efficiencies at high subsonic Mach numbers. Special attention is placed on overall configuration, fuselage layout, performance estimations, component weight estimations, and planform design. Leading U.S. technology promises highly efficient flight for the 21st century; the Avion will fulfill this promise to passenger transport aviation. Author

N90-23396\*# Auburn Univ., AL. Dept. of Aerospace Engineering.

HIGH SPEED CIVIL TRANSPORT

SCOTT BOGARDUS, BRENT LOPER, CHRIS NAUMAN, JEFF PAGE, RUSTY PARRIS, and GREG STEINBACH

(Contract NASW-4435)

(NASA-CR-186661; NAS 1.26:186661) Avail: NTIS HC A05/MF A01 CSCL 01/3

The design process of the High Speed Civil Transport (HSCT) combines existing technology with the expectation of future technology to create a Mach 3.0 transport. The HSCT was designed to have a range in excess of 6000 nautical miles and carry up to 300 passengers. This range will allow the HSCT to service the economically expanding Pacific Basin region. Effort was made in the design to enable the aircraft to use conventional airports with standard 12,000 foot runways. With a takeoff thrust of 250,000 pounds, the four supersonic through-flow engines will accelerate the HSCT to a cruise speed of Mach 3.0. The 679,000 pound (at

takeoff) HSCT is designed to cruise at an altitude of 70,000 feet, flying above most atmospheric disturbances.

N90-23397\*# Worcester Polytechnic Inst., MA. FEASIBILITY STUDY FOR A MICROWAVE-POWERED OZONE SNIFFER AIRCRAFT B.S. Thesis

DAVID F. BOTROS, CHARLOTTE K. CODY, NOAH P. FORDEN, MARTIN A. HELSING, THOMAS H. JUTRAS, DOHOON KIM, CHRISTOPHER LABARRE, ETHAN M. ODIN, and SCOTT B. SANDLER 1990 340 p

(Contract NASW-4435; PROJ. MSG-89A1)

(NASA-CR-186660; NAS 1.26:186660) Avail: NTIS HC A15/MF A02 CSCL 01/3

The preliminary design of a high-altitude, remotely-piloted, atmospheric-sampling aircraft powered by microwave energy beamed from ground-based antenna was completed. The vehicle has a gross weight of 6720 pounds and is sized to carry a 1000 pound payload at an altitude of 100,000 feet. The underside of the wing serves as the surface of a rectenna designed to receive microwave energy at a power density of 700 watts per square meter and the wing has a planform area of 3634 square feet to absorb the required power at an optimum Mach number M = 0.44. The aircraft utilizes a horizontal tail and a canard for longitudinal control and to enhance the structural rigidity of the twin fuselage configuration. The wing structure is designed to withstand a gust-induced load factor n = 3 at cruise altitude but the low-wing loading of the aircraft makes it very sensitive to gusts at low altitudes, which may induce load factors in excess of 20. A structural load alleviation system is therefore proposed to limit actual loads to the designed structural limit. Losses will require transmitted power on the order of megawatts to be radiated to the aircraft from the ground station, presenting environmental problems. Since the transmitting antenna would have a diameter of several hundred feet, it would not be readily transportable, so we propose that a single antenna be constructed at a site from which the aircraft is flown. The aircraft would be towed aloft to an initial altitude at which the microwave power would be utilized. The aircraft would climb to cruise altitude in a spiral flight path and orbit the transmitter in a gentle turn.

N90-24265\*# Psycho-Linguistic Research Associates, Woodside,

**EVALUATION OF SPEECH RECOGNIZERS FOR USE IN** ADVANCED COMBAT HELICOPTER CREW STATION

RESEARCH AND DEVELOPMENT

CAROL A. SIMPSON Mar. 1990 90 p Prepared in cooperation with Army Aviation Systems Command, Moffett Field, CA (Contract NAS2-12425)

(NASA-CR-177547; A-90090; NAS 1.26:177547;

USAAVSCOM-TM-90-A-001) Avail: NTIS HC A05/MF A01 CSCL 01/3

The U.S. Army Crew Station Research and Development Facility uses vintage 1984 speech recognizers. An evaluation was performed of newer off-the-shelf speech recognition devices to determine whether newer technology performance and capabilities are substantially better than that of the Army's current speech recognizers. The Phonetic Discrimination (PD-100) Test was used to compare recognizer performance in two ambient noise conditions: quiet office and helicopter noise. Test tokens were spoken by males and females and in isolated-word and connected-work mode. Better overall recognition accuracy was obtained from the newer recognizers. Recognizer capabilities needed to support the development of human factors design requirements for speech command systems in advanced combat helicopters are listed. Author

N90-24266\*# California State Polytechnic Univ., Pomona. NASA/USRA HIGH ALTITUDE RECONNAISSANCE AIRCRAFT MICHAEL RICHARDSON, JUAN GUDINO, KENNY CHEN, TAI LUONG, DAVE WILKERSON, and ANOOSH KEYVANI 1990 106 p (Contract NASW-4435)

(NASA-CR-186685; NAS 1.26:186685) Avail: NTIS HC A06/MF A01 CSCL 01/3

At the equator, the ozone layer ranges from approximately 80,000 to 130,000+ feet which is beyond the capabilities of the ER-2, NASA's current high altitude reconnaissance aircraft. This project is geared to designing an aircraft that can study the ozone layer at the equator. This aircraft must be able to cruise at 130,000 lbs. of payload. In addition, the aircraft must have a minimum of a 6,000 mile range. The low Mach number, payload, and long cruising time are all constraints imposed by the air sampling equipment. A pilot must be able to take control in the event of unforseen difficulties. Three aircraft configurations were determined to be the most suitable for meeting the above requirements, a joined-wing, a bi-plane, and a twin-boom conventional airplane. The techniques used have been deemed reasonable within the limits of 1990 technology. The performance of each configuration is analyzed to investigate the feasibility of the project requirements. In the event that a requirement can not be obtained within the given constraints, recommendations for proposal modifications are Author given.

N90-24267# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge.

TRANSONIC WING CHARGE IMPROVEMENTS BY PASSIVE SHOCK BOUNDARY LAYER INTERFERENCE CONTROL: **DEVELOPMENT STATUS AND PROSPECTS** 

[TRANSSONISCHE FLUGLEISTUNGSVERBESSERUNGEN **DURCH PASSIVE** 

STOSS-GRENZSCHICHT-INTERFERENZKONTROLLE: **ENTWICKLUNGSSTAND UND PERSPEKTIVEN]** 

P. THIEDE In GERMAN 1989 7 p. DLGR-Jahrestagung, Hamburg, Fed. Republic of Germany, 2-4 Oct.

(ETN-90-96463) Avail: NTIS HC A02/MF A01

A digital simulation of viscous transonic profile flows with shock ventilation is presented. Development status and results of an iterative coupled local calculation process are described. The aerodynamic and structural project can be evaluated in order to optimally integrate the ventilation apparatus into the wing structure. The experimental results show that the ventilation effect weakens shocks, slows down the shock induced damping and reduces the air resistance by 3 percent.

N90-24268# Royal Air Force Coll., Cranwell (England). Dept. of Transport Technology.

A STUDY OF THE TECHNOLOGY REQUIRED FOR ADVANCED **VERTICAL TAKE-OFF AIRCRAFT M.S. Thesis - Loughborough** Univ. of Technol.

R. I. KILFORD 1989 142 p

(ETN-90-96786) Copyright Avail: NTIS HC A07/MF A01

Reasons for the desirability of VSTOL aircraft and previous projects are discussed. Main design areas are considered and related to future requirements. An attempt to choose a configuration and produce a theoretical design for such an aircraft is made. The tandem fan design is concluded to be the most suitable to produce a fighter aircraft that can be put to economical operational use in the future.

N90-24270# Army Materials Technology Lab., Watertown, MA. Polymer Research Branch.

HPLC ANALYSIS OF HELICOPTER ROTOR BLADE **MATERIALS Final Report** 

GARY L. HAGNAUER and DAVID A. DUNN Mar. 1990 42 p. (Contract DA PROJ. 1L1-62105-AH-84) (AD-A221121; MTL-TR-90-12) Avail: NTIS HC A03/MF A01

**CSCL 01/3** 

This report describes high performance liquid chromatography (HPLC) test methods developed for the quality assurance of organic materials used in the manufacture of Army helicopter rotor blades. Since the chemical compositions of most of the organic materials were unknown at the start of this project, HPLC was employed to help identify components in specimens. Test methods were developed and then applied to monitor the chemical compositions of specimens received from the manufacturer during blade fabrication. Six HPLC test methods were used to evaluate eight sets of specimens of 12 different materials received over a span of three years. The HPLC test methods included size-exclusion, normal-phase, and reverse bonded-phase chromatography techniques and employed a variety of columns, mobile phases, and detectors. Major changes in chemical composition and variations in relative concentrations of chemical components were noted in seven of the 12 materials monitored during the course of this study.

N90-25043\*# Washington Univ., Seattle. Dept. of Aeronautics and Astronautics.

### CONCEPTUAL DESIGN FOR AEROSPACE VEHICLES Abstract Only

LOÚIS B. GRATZER In Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 71-72 Sep. 1989

Avail: NTIS HC A09/MF A02 CSCL 01/3

The designers of aircraft and more recently, aerospace vehicles have always struggled with the problems of evolving their designs to produce a machine which would perform its assigned task(s) in some optimum fashion. Almost invariably this involved dealing with more variables and constraints than could be handled in any computationally feasible way. With the advent of the electronic digital computer, the possibilities for introducing more variable and constraints into the initial design process led to greater expectations for improvement in vehicle (system) efficiency. The creation of the large scale systems necessary to achieve optimum designs has, for many reason, proved to be difficult. From a technical standpoint, significant problems arise in the development of satisfactory algorithms for processing of data from the various technical disciplines in a way that would be compatible with the complex optimization function. Also, the creation of effective optimization routines for multi-variable and constraint situations which could lead to consistent results has lagged. The current capability for carrying out the conceptual design of an aircraft on an interdisciplinary bases was evaluated to determine the need for extending this capability, and if necessary, to recommend means by which this could be carried out. Based on a review of available documentation and individual consultations, it appears that there is extensive interest at Langley Research Center as well as in the aerospace community in providing a higher level of capability that meets the technical challenges. By implication, the current design capability is inadequate and it does not operate in a way that allows the various technical disciplines to participate cooperately interact in the design process. Based on this assessment, it was concluded that substantial effort should be devoted to developing a computer-based conceptual design system that would provide the capability needed for the near-term as well as framework for development of more advanced methods to serve future needs. Author

N90-25057\*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.

### EXTENSION-TORSION COUPLING BEHAVIOR OF ADVANCED COMPOSITE TILT-ROTOR BLADES

J. B. KOSMATKA *In Old Dominion Univ.*, NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 105-110 Sep. 1989

Avail: NTIS HC A09/MF A02 CSCL 01/3

An analytic model was developed to study the extension-bend-twist coupling behavior of an advanced composite helicopter or tilt-rotor blade. The outer surface of the blade is defined by rotating an arbitrary cross section about an initial twist axis. The cross section can be nonhomogeneous and composed of generally anisotropic materials. The model is developed based upon a three dimensional elasticity approach that is recast as a coupled two-dimensional boundary value problem defined in a curvilinear coordinate system. Displacement solutions are written in terms of known functions that represent extension, bending, and twisting and unknown functions for local cross section deformations. The unknown local deformation functions are

determined by applying the principle of minimum potential energy to the discretized two-dimensional cross section. This is an application of the Ritz method, where the trial function family is the displacement field associated with a finite element (8-node isoparametric quadrilaterals) representation of the section. A computer program was written where the cross section is discretized into 8-node quadrilateral subregions. Initially the program was verified using previously published results (both three-dimensional elasticity and technical beam theory) for pretwisted isotropic bars with an elliptical cross section. In addition, solid and thin-wall multi-cell NACA-0012 airfoil sections were analyzed to illustrate the pronounced effects that pretwist, initial twist axis location, and spar location has on coupled behavior. Currently, a series of advanced composite airfoils are being modeled in order to assess how the use of laminated composite materials interacts with pretwist to alter the coupling behavior of the blade. These studies will investigate the use of different ply angle orientations and the use of symmetric versus unsymmetric Author

06

#### AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

#### A90-39982#

### ROTATING SYSTEM LOAD MONITORING USING MINIMUM FIXED SYSTEM INSTRUMENTATION

C. T. GUNSALLUS (Kaman Aerospace Corp., Bloomfield, CT) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 11 p.

A general helicopter load monitoring system has been developed and demonstrated in flight test. The chief features of this system are minimum fixed system inputs, no rotating system instrumentation, and accurate real time output for any number of fixed or rotating system parameters. This paper contains examples of rotating system parameters as synthesized from fixed system recorded strains with comparison to rotating system data recorded directly via slip rings. Also, test results using recorded and in-flight data and two generations of the load monitoring system are presented.

#### A90-39983#

### THE COLLECTION OF USAGE DATA TO IMPROVE STRUCTURAL INTEGRITY OF OPERATIONAL HELICOPTERS

RANDY L. BUCKNER (U.S. Army, Aviation Applied Technology Directorate, Fort Eustis, VA) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 18 p.

The OH-58C Helicopter Usage Monitoring (HUM) program to collect data to assess rotorcraft fatigue lives. As part of the HUM program, a solid state microprocessor flight data recording system collects data on 13 quasi-static parameters from 10 aircraft at two locations for at least six months. This paper examines the design mission spectrum for the OH-58C aircraft, the selection of parameters for the HUM program, the regime recognition algorithms, and the solid state microprocessor assessment process.

#### A90-39984#

#### USAGE MONITORING OF MILITARY HELICOPTERS

A. A. TEN HAVE (Nationaal Lucht- en Ruimtevaartlaboratorium, Delft, Netherlands) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 9 p.

Detailed inventories of the usage of helicopters by the Dutch military are used to develop rotorcraft fatigue life monitoring procedures. The process of monitoring the usage of the Lynx and the Bo-105 helicopters is reviewed and the applications of the usage inventory data are described. Consideration is given to the relationship between airframe fatigue damages and operational usage patterns. The inventory data is used to check the validity of theoretical fatigue life limits for rotorcraft components such as sponsons; hinge frame lugs, engines, and airframes.

#### A90-40195

### UV SPECTRORADIOMETRIC OUTPUT OF AN F404 TURBOJET AIRCRAFT ENGINE

WILLIAM E. SCHNEIDER (Optronic Laboratories, Inc., Orlando, FL) and GORDON H. SPABERG (GE Aircraft Engines, Lynn, MA) IN: Optical radiation measurements II; Proceedings of the Meeting, Orlando, FL, Mar. 27, 28, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 169-185.

Spectroradiometric measurements of the ultraviolet output of a GE F404 aircraft engine were made over the wavelength range of 200 to 320 nm. The severe environmental conditions associated with the F404 ram test cell required a special acoustical noise-proof and mechanical shock-proof enclosure for the double monochromator and UV detectors, along with special long cabling to the externally located radiometer and automatic data reduction system. The tests successfully provided spectral irradiance measurements of the afterburner over the 225-320 nm wavelength range with a UV-enhanced silicon detector and over the 200-260 nm range with a PMT detector.

#### A90-40381

### FLIGHT TESTING AND APPLICATION OF A PERIPHERAL VISION DISPLAY

ARTHUR E. KENNEDY (Garrett Canada, Rexdale) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 13-24. refs. Copyright

The presentation traces the development and application of Garrett's Peripheral Vision Display - sometimes known as the Peripheral Vision Horizon Device, or Malcolm Horizon - from the beginning of commercial development to its initial series production and operational application in military aircraft. Problems of reducing a unique, advanced technology concept to standard military practice, and those associated with its flight testing by trained and untrained test pilots, are highlighted. Conclusions with respect to the conduct of the program are drawn and predictions are made regarding the future of such displays.

#### A90-40382

### TAKING A NEW LOOK AT COCKPIT VERTICAL SITUATION DISPLAYS

MOSES ARONSON (Aronson Industries, Orlando, FL) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 25-35. refs Copyright

Consideration is given to the specifications and requirements of cockpit vertical situation displays for future high-speed aircraft, including combat and hypersonic commercial transports. Previous research concerning the pilot control/display performance of the displays in aircraft and simulators with minimal time delay are analyzed. This analysis is used to determine the subtended angle and resolution requirements. Recommendations for cockpit designers are given. Hardware technologies that can provide the defined subtended angle of view and resolution are discussed.

#### A90-40394

HOLOGRAPHIC COMBINER DESIGN TO OBTAIN UNIFORM SYMBOL BRIGHTNESS AT HEAD-UP DISPLAY VIDEO CAMERA DAVID E. BATTEY (Kaiser Optical Systems, Ann Arbor, MI) and JAMES E. MELZER (Kaiser Electronics, San Jose, CA) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 178-186.

A typical head-up display (HUD) system incorporates a video camera for recording the HUD symbology and the scene outside the cockpit. When using a HUD video camera (HVC) with a zero-power holographic combiner, the brightness of the HUD symbology seen by the camera changes significantly as a function of vertical field angle because the holographic combiner's reflectance characteristics are angularly sensitive and optimized for the pilot's eye position. A holographic combiner design is presented that overcomes this problem while simultaneously maintaining high reflectance of the phosphor's light to the pilot and high visual transmittance. The combiner contains an additional holographic layer tuned to the blue emission of the P53 phosphor as viewed from the HVC, taking advantage of the HVC's high sensitivity in the blue. The reflectance of the additional hologram is tapered to achieve minimum brightness variation at the HVC. The response of the additional hologram is tapéred to achieve minimum brightness variations at the HVC. The response of the additional hologram as viewed by the pilot shifts toward the ultra-violet and is thus nearly invisible. Theoretical and measured performance of the combiner are presented.

#### A90-40398

#### MULTIFUNCTION DISPLAYS OPTIMIZED FOR VIEWABILITY

RICHARD HOCKENBROCK and JERRY MURCH (Tektronix, Inc., Beaverton, OR) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 216-218. Copyright

Consideration is given to the cockpit design requirements that ensure the viewability of multifunction displays. Results from illuminance profiles and flight tests on an F-16C are presented and used in the design of the CRT to optimize display luminance, contrast ratio, color differentiability, and symbol legibility. The characteristics of the F-16C cockpit design are outlined and recommendations are made for the placement of the multifunction display.

#### A90-40399

### NEW TECHNOLOGY ADVANCES FOR BRIGHTER COLOR CRT DISPLAYS

RICHARD HOCKENBROCK (Tektronix, Inc., Beaverton, OR) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 219-226. refs

An integrated taut shadow mask color CRT for head down displays in jet fighter and helicopter applications is introduced. The brightness and resolution requirements for a color CRT display are discussed. Consideration is given to the process of choosing the optimum filter for a high illumination environment and the development of the taut mask CRT ruggedized structure. The taut mask CRT display is viewable in full sunlight and can display high resolution maps and tactical information in the vibration environment of a military aircraft.

#### A90-40462

R.B.

#### THE EH101 ELECTRONIC INSTRUMENT SYSTEM

KEITH N. ATKIN (Aerospace and Defence Systems, Ltd., Cheltenham, England) and JOHN REVELL (Westland Helicopters, Ltd., Yeovil, England) Defence Science Journal (ISSN 0011-748X), vol. 40, April 1990, p. 139-159. Copyright

The electronic instrument system (EIS) for the British-Italian EH101 helicopter is described. The design requirements for the EIS are reviewed. The EH101 all-CRT cockpit and the civil and naval variants of the EIS are discussed. Consideration is given to the primary flight, navigation, and power system displays, the EIS

hardware implementation, the EIS system architecture, interfaces, and data sources. Also, the system integrity and flexibility are evaluated.

#### A90-41114#

#### **OBSTACLE WARNING SYSTEM FOR HELICOPTERS**

Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 40, 41.

Copyright

Several advantages are offered by imaging laser radars over other systems when utilized as obstacle warning devices for helicopters. These systems are suitable for day/night missions and offer high resolution in both the close and distant range. The image information is stable, and the information as to shape and distance of the obstacle is easily determined. The overall application of such a system thus meets the required criteria.

R.E.P.

#### A90-41729

### THE EVALUATION OF FLIGHT RECORDERS [DIE AUSWERTUNG VON FLUGSCHREIBERN]

K. KLEIN (DLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), May 1990, p. 12-16. In German.

Copyright

Installations for evaluating flight recorders are discussed, and their principle of functioning is examined. ARTAS, an evaluation and copying installation for flight recorders, is discussed. The way that ARTAS evaluates digital flight data recordings is described, and the ARTAS software is examined.

#### A90-41730

# MEASUREMENT OF ANGLES AND ANGLE CHARACTERISTICS WITH ACCELEROMETERS AND GYROSCOPES [VERMESSUNG VON WINKELN UND WINKELKENNLINIEN MIT BESCHLEUNIGUNGSMESSERN UND KREISELN]

BERNHARD STIELER (DLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), May 1990, p. 17-22. In German. refs

Copyright

The measurement of pitch and angle using accelerometers, pendulums, and gyroscopes is addressed. The use of these techniques for directional orientation in aircraft is considered. The improvements made using these techniques are pointed out.

C.D.

A90-41741#

### DIGITAL AUTOPILOT FOR LIGHT AIRCRAFT [CYFROWY AUTOPILOT DO SAMOLOTOW LEKKICH]

STANISLAW BOCIEK, BOGUSLAW DOLEGA, JOZEF GRZYBOWSKI, and ANDRZEJ TOMCZYK (Rzeszow, Politechnika, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 117, 1989, p. 58-69. In Polish. refs

The design of a digital autopilot for light planes is presented. The criteria and synthesis methods of control laws are described. A brief description of the autopilot prototype and its microprocessor software structure is given. Some results of laboratory tests of the prototype are presented.

Author

A90-41742#

#### ONBOARD DIGITAL RECORDING SYSTEM FOR FLIGHT TESTS [POKLADOWY CYFROWY SYSTEM REJESTRACJI DO PROB W LOCIE]

JOZEF GRZYBÓWSKI and ANDRZEJ TOMCZYK (Rzeszow, Politechnika, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 117, 1989, p. 70-80. In Polish.

#### A90-42447#

#### THE ALL GLASS HELICOPTER COCKPIT

J. L. SICRE and T. PHAM DUC (Societe Francaise d'Equipements pour la Navigation Aerienne, Velizy-Villacoublay, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 18 p.

The concept of all-raster scanning for the helicopter cockpit is discussed. The present use of this concept in the Super Puma Mark II helicopter is described, including the presentation of the display system, the symbol generator computer, the graphics generator, the video mixing, and the display unit. The role of three-dimensional processing and liquid crystal flat panels in future all-raster scanning systems is addressed.

C.D.

#### A90-42448#

#### DIGITAL MAP READER FOR HELICOPTERS

G. GUERIN (Thomson-CSF, Paris, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 11 p.

An account is given of the advantages obtainable from an airborne digital map reader (ADMR) in military rotorcraft, as well as of the substantial modifications of cockpit activities which will result. The ADMR will facilitate autonomous landing procedures under instrument meteorological conditions (IMC), especially in non-IFR airfields, and should allow for an automated choice and display of the best IMC-related tactical procedures. An airborne interactive tactical display is expected to be an especially useful component of an ADMR system.

#### A90-42450#

### MAIN CHARACTERISTICS OF AN INTEGRATED FLIGHT AND DISPLAY SYSTEM FOR AS MKII SUPER-PUMA

S. RIOCHE and B. RONTANI (Aerospatiale, Division Helicopteres, Marignane, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p.

The main characteristics of the integrated flight and display system (IFDS) of the MKII Super-Puma helicopter are described. The IFDS is an integrated dual-pilot digital system incorporating two identical semisystem which operate separately and are capable of being reconfigured in the event of a failure detected on either semisystem. The general architecture of the IFDS is described. This includes descriptions of the display subsystem, the automatic flight control system, and the primary reference subsystem. The safety aspects of the IFDS are also outlined, covering the particular precautions taken as regards to the software development, symbology definition, system architecture, and cockpit ergonomics. Finally, the possible upgrading of the system is outlined. S.A.V.

#### A90-42451#

#### MODERN STRAPDOWN SYSTEM FOR HELICOPTER

J. L. ROCH (Crouzet, S.A., Valence, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 19 p. refs

The AS 332 MK 2 helicopter's flight data system (FDS) is described. The FDS is a dual redundant system which provides all the basic necessary flight information. This includes flight attitude and heading data, airspeed, and air data. The FDS will be included as part of the integrated flight and display system. It can also be connected to a Doppler radar in order to provide filtered ground speed information. Special emphasis is placed on the quality and safety assurance of the system. The additional options of Doppler navigation, whole flight envelope air data computation, and GPS coupling are described. The essentially modular and open-ended design of the system is likely to provide navigation data for any civil or military mission of the carrier.

#### A90-42477#

### NEW SYSTEMS FOR HELICOPTER AND AIRCRAFT VIBRATION MONITORING

RICHARD C. MUNDEN (Stewart Hughes, Ltd., Southampton, England) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 11 p.

The options for the wide range of vibration monitoring equipment and technique capabilities available to the operator are presented.

They range from the lowest cost 'measure and tell' capability of vibration monitoring to the fully automated track and balance equipment. Both the analog vibration monitoring system and the digital airborne monitoring system are discussed and attention is also given to the new health and usage monitoring systems.

R.E.P.

N90-23398# Wright Research Development Center, Wright-Patterson AFB, OH. Environmental Control Branch.
CORRELATION/VALIDATION OF FINITE ELEMENT CODE
ANALYSES FOR VIBRATION ASSESSMENT OF AVIONIC
EQUIPMENT Final Report, Mar. 1985 - Sep. 1989
AMAR BHUNGALLA and GEORGE KURYLOWICH 31 Dec.
1989 35 p
(Contract AF PROJ. 2402)

(AD-A220393; WRDC-TR-89-3110) Avail: NTIS HC A03/MF A01 CSCI 12/5

Avionics Environmental Reliability is a major issue for present and future military aircrafts. The printed wiring boards are getting more and more populated with electronic components because of very complex avionics requirements with limited space available in the avionic bay. With this limited available space, we are forced to design the printed wiring board with very densely populated electronic components. It appears that this kind of condition can create structural integrity problems for avionics in military aircrafts. It has been determined that vibration and thermal environments are major problems in military avionics, and these environments cause more than half avionics failures. There is a need to evaluate a design before we approve go ahead on production of these complex avionics boxes. WRDC/FIVE has started to develop a computer capability to predict avionics reliability prior to production, so that the design can be changed if it does not meet the Air Force requirements. WRDC/FIVE has selected/developed a finite element program which will allow avionics reliability prediction. The Numerically Integrated elements for System Analysis (NISA) software was selected to accomplish this task. In May 1984, the Environmental Control Branch (WRDC/FIVE) started In-House effort to validate vibration prediction using NISA and test data acquired from laboratory test, with similar boundary conditions. This report contains the results of validation of predictions by showing comparisons with test data.

N90-23399\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### HELICOPTER AIRBORNE LASER POSITIONING SYSTEM (HALPS)

JOSEPH C. EPPEL, HOWARD CHRISTIANSEN (Northrop Services, Inc., Sunnyvale, CA.), JEFFREY CROSS, and JOSEPH TOTAH Mar. 1990 21 p Presented at the Optical Engineering and Aerospace Sensing Meeting, Orlando, FL, 16-20 Apr. 1990 (NASA-TM-102814; A-90139; NAS 1.15:102814) Avail: NTIS HC A03/MF A01 CSCL 01/4

The theory of operation, configuration, laboratory, and ground test results obtained with a helicopter airborne laser positioning system developed by Princeton University is presented. Unfortunately, due to time constraints, flight data could not be completed for presentation at this time. The system measures the relative position between two aircraft in three dimensions using two orthogonal fan-shaped laser beams sweeping across an array of four detectors. Specifically, the system calculates the relative range, elevation, and azimuth between an observation aircraft and a test helicopter with a high degree of accuracy. The detector array provides a wide field of view in the presence of solar interference due to compound parabolic concentrators and spectral filtering of the detector pulses. The detected pulses and their associated time delays are processed by the electronics and are sent as position errors to the helicopter pilot who repositions the aircraft as part of the closed loop system. Accuracies obtained in the laboratory at a range of 80 ft in the absence of sunlight were + or - 1 deg in elevation; +0.5 to -1.5 deg in azimuth; +0.5 to -1.0 ft in range; while elevation varied from 0 to +28 deg and the azimuth varied from 0 to + or - 45 deg. Accuracies in sunlight

were approximately 40 deg (+ or - 20 deg) in direct sunlight.

Author

N90-23400# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

CONTINUED DEVELOPMENT AND ANALYSIS OF A NEW EXTENDED KALMAN FILTER FOR THE COMPLETELY INTEGRATED REFERENCE INSTRUMENTATION SYSTEM (CIRIS) M.S. Thesis

FARON BRITT SNODGRASS Mar. 1990 174 p (AD-A220106; AFIT/GE/ENG/90M-5) Avail: NTIS HC A08/MF A01 CSCL 12/5

The Completely Integrated Reference Instrumentation System (CIRIS) is operated by the Central Inertial Guidance Test Facility (CIGTF), at Holloman AFB, New Mexico. CIRIS functions as a reference navigation system used for evaluating the accuracy of other types of navigations systems. As a reference standard, the root-mean-square errors in CIRIS estimates of aircraft trajectory variables must be maintained an order of magnitude smaller that the corresponding errors of the navigation system under test. The primary hardware components of CIRIS are a reference inertial navigation system (INS), a baro-altimeter, an array of ground-based transponders, a transponder interrogator, and data recording equipment. The transponder equipment provides transponderto-aircraft range and range-rate measurements during test flights. The primary software component of CIRIS is a Kalman filter program which processes the recorded measurements and estimates the true position and velocity of the aircraft throughout the test flight. The estimation accuracy of CIRIS must be increased so that CIRIS can serve as a benchmark for measuring the accuracy of Global Positioning System (GPS) aided inertial navigation systems. The continuation of research to develop completely new Kalman filter software for CIRIS is documented.

#### 07

#### AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

#### A90-40503#

#### APPLICATION OF LEANED BLADES TO AN AEROENGINE

JINGMAN GAO (Shenyang Aeroengine Research Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 113-117. In Chinese, with abstract in English.

In order to match the low-pressure compressor with a high-pressure compressor, the outlet guide vane blades of the low-pressure compressor have been designed to be leaned circumferentially and radially. The two types of the leaned blades have been tested in an aircraft engine. The results show that the leaned blades improve the compressor performance in the hub region, decrease the radial pressure ratio gradient, and control the flow at the end wall.

#### A90-40512#

### PARTIAL SIMILARITY AND A REAL-TIME MODEL OF TWIN-SPOOL GAS TURBINE

XUEYU WANG and XINGJIAN ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 159-162. In Chinese, with abstract in English.

Partial similarity of twin-spool gas turbine means that the high pressure rotor can be considered as a single-spool gas turbine operating under specific circumstances; the high and low pressure turbines and exhaust nozzle are considered a single component of a combination. In the formulation of a real-time gas turbine model, this method reduces dimensions of the dynamic parameters

of the model. Therefore, calculation speed and accuracy of the model are good enough for real-time modeling. Thus, the model is capable of microcomputer digital control of gas turbine and of real-time estimation of malfunction parameters in the gas turbine monitoring system.

#### A90-40519#

#### LINEAR DYNAMICS OF SUPERSONIC RAMJET

BOSHUN QIAN and QINGFU ZENG (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 5, April 1990, p. 179-181. In Chinese, with abstract in English.

This paper presents a mathematical model of a supersonic ramjet. The basic thermoaerodynamical equations of the ramjet components are linearized in conformity with small perturbation. Then the transfer functions of the components are deduced in the S domain. With the method of a sybsystem in series, the dynamical mathematical model of a ramjet with an inlet-normal shock position is constructed, and the parameters along duct and thrust are formulated under the perturbation of the upstream Mach number, temperature, pressure, and downstream fuel for flow rate. A numerical example of the digital simulation of a real ramjet is completed and gives reasonable results.

#### A90-40526#

### THE SEPR 844 REUSABLE LIQUID ROCKET ENGINE FOR MIRAGE COMBAT AIRCRAFT

HERVE GROSDEMANGE (SEP, Vernon, France) and GUY SCHAEFFER (AMDBA, S.A., Saint-Cloud, France) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p.

(AIAA PAPER 90-1835) Copyright

The SEPR 844 bipropellant liquid rocket engine for military and experimental aircraft auxilliary propulsion generates 15 kN thrust on the basis of nitric acid oxidizer and kerosene fuel that is derived from these aircraft's primary, turbojet propulsion system. The single, regeneratively cooled chamber is fed by two centrifugal pumps. Since 1961, 275 engines of the SEPR 84 class (encompassing the present SEPR 844 variant and its SEPR 841 predecessor) have completed over 10,000 flights with a 99 percent success rate. Individual engines are typically operated for more than 50 ignitions without removal, and can be serviced in less than 15 min. The Mirage III S fighter is the latest aircraft to be mated to the SEPR 844 engine.

#### A90-40530#

### ACOUSTIC CHARACTERISTICS OF A RESEARCH STEP COMBUSTOR

S. P. HENEGHAN, M. D. VANGSNESS, D. R. BALLAL (Dayton, University, OH), A. L. LESMERISES (USAF, Wright-Patterson AFB, OH), and G. J. STURGESS (Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (Contract F33615-87-C-2767; F33615-87-C-2822) (AIAA PAPER 90-1851) Copyright

For a gas turbine combustor, combustion stability and freedom from acoustic coupling are the two essential design requirements. Acoustic characteristics of a research step combustor are investigated by measuring acoustic fluctuations, lean blowout, and visual observations of flame behavior. This combustor was designed to serve as a test bed for evaluating lean blowout and refining combustor design modeling codes. The combustor operated satisfactorily under all the conditions of interest and its lean blowout performance resembled that of a well-stirred reactor.

R.E.P.

#### A90-40533#

## INVERSE HEAT TRANSFER STUDIES AND THE EFFECTS OF PROPELLANT ALUMINUM ON TVC JET VANE HEATING AND EROSION

ARNOLD O. DANIELSON (U.S. Navy, Naval Weapons Center, China Lake, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (AIAA PAPER 90-1860)

A recent subscale jet vane test series, accomplished largely under Air-Launched Weaponry Block Program sponsorship, was designed to determine the effect of propellant aluninum content on vane durability in terms of leading edge erosion and shaft heating. Additionally, inverse heat transfer modeling was used to deduce details on vane heating processes under various plume conditions. The tests were normalized based on the product of exit plane pressure ratio and Mach number. This constraint focused tests on finding the minimum expected differences in vane leading edge erosion and shaft heating due to viscous, stagnation temperature and particle impingement effects. To date, jet vanes have been tested in the three solid propellants: nonaluminized hydroxyl-terminated polybutadiene (NTPB) (87 percent solids); 9 percent aluminized HTPB (88 percent solids); and 18 percent aluminized HTPB (89 percent solids).

#### A90-40539#

### NUMERICAL SIMULATION OF THE BEHAVIOUR OF INTERNAL COMBUSTION SUPERCHARGED ENGINES

G. TORELLA (Accademia Aeronautica, Pozzuoli, Italy) and P. DI MARTINO (Alfa Romeo Avio S.p.A., Pomigliano d'Arco, Italy) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-1873) Copyright

The paper deals with the activities carried out for developing the methods and the numerical computer codes for the simulation of the behavior and the calculation of performance of turbocharged engine. Some techniques used for the gas turbine engine have been successfully used. The codes have been employed for calculations of different types. In the paper results of simulation, diagnostic, trend analysis and the fault simulation are shown.

Author

#### A90-40540#

### IDENTIFICATION OF MULTIVARIABLE MODELS OF JET ENGINES

A. CHRYSANTHOU, A. H. JONES, and B. PORTER (Salford, University, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p. Research supported by the Ministry of Defence Procurement Executive. refs

(AIAA PAPER 90-1874) Copyright

In this paper, the main issues involved in developing multivariable models for jet-engines are discussed and typical results from actual engine tests are presented. The results are obtained using specially written software developed at the University of Salford which processes actual engine data so as directly to produce multivariable engine models.

#### A90-40541#

### DESIGN OF DIGITAL SELF-SELECTING MULTIVARIABLE CONTROLLERS FOR JET ENGINES

A. H. JONES, B. PORTER, and A. CHRYSANTHOU (Salford, University, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. Research supported by the Ministry of Defence Procurement Executive. refs

(AIAA PAPER 90-1875) Copyright

In this paper, the tunable digital set-point tracking PI controllers for linear multivariable plants developed at Salford are extended to deal with plants with more output variables than input variables. This extension is effected by delineating the concept of asymptotic positive-real closed-loop transfer function and by using this concept in the design of self-selecting highest- or lowest-wins controllers. The effectiveness of the resulting design methodology is illustrated by designing a self-selecting lowest-wins set-point tracking PI controller for a two-input five-output turbofan jet engine. Author

#### A90-40552#

### HIGH MACH EXHAUST SYSTEM CONCEPT SCALE MODEL TEST RESULTS

T. H. FLUGSTAD, B. M. ROMINE, and R. W. WHITTAKER (GE Aircraft Engines, Cincinnati, OH) AIAA, SAE, ASME, and ASEE,

Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p.

(AIAA PAPER 90-1905) Copyright

The results of a scale model test of the Two-Dimensional Convergent-Divergent (2DCD) and Two-Dimensional Single Expansion Ramp Nozzle (SERN) configurations are presented to assess the performance, to establish geometric design criteria, and to validate advanced computational fluid dynamics codes for Mach 4 to 6 applications. The major conclusions derived are that the peak performance for all systems is comparable to the existing lower Mach nozzle designs; the ejector pumping performance is, in general, comparable to the existing ejector nozzle performance; and the predicted performance was consistently below levels of the performance measured in the scale model test. The nozzles tested are considered viable candidates for high Mach applications, and the test data provide an extensive design data base.

#### A90-40554#

#### STALL MARGIN IMPROVEMENT IN AXIAL-FLOW COMPRESSORS BY CIRCUMFERENTIAL VARIATION OF STATIONARY BLADE SETTING ANGLES

JOHN P. RUKAVINA, THEODORE H. OKIISHI (Iowa State University of Science and Technology, Ames), and ARTHUR J. WENNERSTROM (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. (Contract F33615-87-C-2739)

(AIAA PAPER 90-1912) Copyright

The useful operating range of the multistage, axial-flow compressor component of a gas turbine engine limits the extent of operation of that engine. Generally, the compressor stalls or surges at low flow rates and chokes at high flow rates. Thus, any improvement in the range between these compressor aerodynamic limits is normally of benefit to the engine also. An idea for delaying the onset of rotating stall in a multistage, axial-flow compressor by circumferentially scheduling the stationary vane setting angles in a periodic varying pattern was investigated. Tests involving two low-speed, multistage, axial-flow compressors were completed. Comparisons between baseline compressor and modified compressor performance data were made. A variety of vane setting angle variation patterns were tested. Test results suggest that rotating stall onset in these low-speed compressors could be delayed only slightly but consistently. The results indicated that a small improvement in stall recovery was also possible. Until more tests are completed and analyzed, caution in extending these results too optimistically is urged.

#### A90-40556# **CORRELATION OF RADIAL-TO-AXIAL VANELESS TURNS** FOR CENTRIFUGAL COMPRESSORS

K. ELLIOTT and T. EXLEY (Teledyne CAE, Toledo, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs

(AIAA PAPER 90-1917) Copyright

Several correlations were developed for a one-dimensional design model of the radial-to-axial turn in compact centrifugal compressor diffusion systems. A correlation with experimental data for pressure loss around the bend is examined, and the effects of inlet Mach number, inlet swirl, and increased axial height are assessed in terms of losses and quality of flow leaving the bend. A correlation is also examined for the location of the leading edge of the axial diffuser vanes aft of the right-angle turn, based on a decayed radial velocity component. Five diffuser geometries, from a smooth, gradual turn to a sharp turn radius, are analyzed. N.B.

A90-40558\*# PRC Systems Services Co., Edwards, CA. A PROPOSED KALMAN FILTER ALGORITHM FOR ESTIMATION OF UNMEASURED OUTPUT VARIABLES FOR AN F100 TURBOFAN ENGINE

GURBUX S. ALAG (PRC Systems, Edwards, CA) and GLENN B. GILYARD (NASA, Flight Research Center, Edwards, CA) AIAA,

SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 29 p. (AIAA PAPER 90-1920) Copyright

To develop advanced control systems for optimizing aircraft engine performance, unmeasurable output variables must be estimated. The estimation has to be done in an uncertain environment and be adaptable to varying degrees of modeling errors and other variations in engine behavior over its operational life cycle. This paper presents an approach to estimate unmeasured output variables by explicitly modeling the effects of off-nominal engine behavior as biases on the measurable output variables. A state variable model accommodating off-nominal behavior is developed for the engine, and Kalman filter concepts are used to estimate the required variables. Results are presented from nonlinear engine simulation studies as well as the application of the estimation algorithm on actual flight data. The formulation presented has a wide range of application since it is not restricted or tailored to the particular application described in the paper.

National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA. A PRELIMINARY EVALUATION OF AN F100 ENGINE PARAMETER ESTIMATION PROCESS USING FLIGHT DATA TRINDEL A. MAINE, GLENN B. GILYARD, and HEATHER H.

LAMBERT (NASA, Flight Research Center, Edwards, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 29 p. refs

(AIAA PAPER 90-1921) Copyright

The parameter estimation algorithm developed for the F100 engine is described. The algorithm is a two-step process. The first step consists of a Kalman filter estimation of five deterioration parameters, which model the off-nominal behavior of the engine during flight. The second step is based on a simplified steady-state model of the 'compact engine model' (CEM). In this step the control vector in the CEM is augmented by the deterioration parameters estimated in the first step. The results of an evaluation made using flight data from the F-15 aircraft are presented, indicating that the algorithm can provide reasonable estimates of engine variables for an advanced propulsion-control-law development.

A90-40562\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### ON THE USE OF EXTERNAL BURNING TO REDUCE AEROSPACE VEHICLE TRANSONIC DRAG

CHARLES J. TREFNY (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 15 p. Previously announced in STAR as N90-21762. refs

(AIAA PAPER 90-1935) Copyright

The external combustion of hydrogen to reduce the transonic drag of aerospace vehicles is currently being investigated. A preliminary analysis based on a constant pressure control volume is discussed. Results indicate that the specific impulse of the external burning process rivals that of a turbojet and depends on the severity of the initial base drag as well as on the Mach flight number and the equivalence ratio. A test program was conducted to investigate hydrogen-air flame stability at the conditions of interest and to demonstrate drag reduction on a simple expansion ramp. Initial test results are presented and compared with the control-volume analysis. The expansion ramp surface pressure coefficient showed little variation with fuel pressure and altitude, in disagreement with the analysis. Flame stability results were encouraging and indicate that stable combustion is possible over an adequate range of conditions. Facility interference and chemical kinetics phenomena that make interpretation of subscale ground test data difficult are discussed. Author

#### A90-40573#

#### **ULTRASONIC REGRESSION RATE MEASUREMENT IN SOLID FUEL RAMJETS**

F. DIJKSTRA (Delft, Technische Universiteit, Netherlands), P. A.

O. G. KORTING, and R. P. VAN DEN BERG (TNO, Prins Maurits Laboratoria, Rijswijk, Netherlands) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. Research supported by the Stichting voor de Technische Wetenschappen. refs

(AIAA PAPER 90-1963) Copyright

Experiments were performed to validate the ultrasonic pulse echo technique for regression rate measurements in solid fuel ramjets. Measurements at more than one location are found to be feasible. It is concluded that the instantaneous regression rate can be determined with 5-10 percent accuracy, with accuracy improvement at higher rates; and the technique can be applied during transient processes. It is shown that by using the ultrasonic technique the amount of experimental work can be decreased.

#### A90-40597#

#### APPLICATION OF CFD TO PITCH/YAW THRUST VECTORING SPHERICAL CONVERGENT FLAP NOZZLES

S. A. SYED, J. J. ERHART, and E. W. KING (Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 22 p. refs

(AIAA PAPER 90-2023) Copyright
The Computational Fluid Dynamics (CFD) methodology required to accurately model the complex three-dimensional flow generated by the complex three-dimensional flow generated by the vectoring nozzles is discussed and the tools currently being used at Pratt & Whitney (P&W) are described. These tools are then applied to calculate the flowfield in two Spherical Convergent Flap (SCF) nozzle configurations. The accuracy of the computations is calibrated by comparing the calculated wall pressure values to those experimentally measured. It is shown that Euler calculations are adequate for the prediction of pressure and, hence, thrust for these nozzles. More extensive data is needed for calibrating the Navier-Stokes calculations for boundary layer migration and heat transfer.

#### A90-40598# CONFINED JET THRUST VECTOR CONTROL NOZZLE

J. H. FRIDDELL and M. E. FRANKE (USAF, Institute of Technology, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p.

(AIAA PAPER 90-2027)

Axial and vectored flow behavior of an axisymmetric confined iet thrust vector control (CJTVC) nozzle is studied experimentally under steady state and dynamic conditions. Secondary pressurized air injection is used to vector the nozzle at various levels of primary (chamber) air pressure. Attention is focused on internal flow characterization, nozzle instability, and influence of secondary mass flow rate on vectored side force. The overexpanded flow separation point is located during axial test runs and compared to empirical predictions. Side force and mass flow rate measurements suggest that choked secondary mass flow occurs prior to the secondary mass flow rate that generates a maximum side force. Cavity pressure oscillations and nozzle side force response times are investigated to further characterize the dynamic behavior of the CJTVC nozzle.

#### A90-40601# COMPOSITE ELECTRONIC ENCLOSURES FOR **ENGINE-MOUNTED ENVIRONMENTS**

S. ROWAN (Allied-Signal Aerospace Co., Bendix Engine Controls AIAA, SAE, ASME, and ASEE, Joint Div., South Bend, IN) Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p.

(AIAA PAPER 90-2030) Copyright

Considerations to utilize composite materials for electronic enclosures are presented. Description is given of a typical electronic control/enclosure and the environment in which it must reliably operate. Composite materials are then compared to various aluminum alloys, both in terms of material properties and design/fabrication considerations. Finally, test data and results of environmental testing, which was conducted to verify performance, are given.

#### A90-40602#

#### LIGHTWEIGHT FUEL PUMP AND METERING COMPONENT FOR ADVANCED GAS TURBINE ENGINE CONTROL

MARK A. OVERSTREET, CHARLES J. TEAGUE (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), STEVEN B. ZAKEM, ROBERT TORNABENE (Argo-Tech Corp., Cleveland, OH), JOE BENNETT (Allied-Signal Aerospace Co., Fluid Systems Div., Tempe, AZ) et al. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 5 p. Research supported by USAF.

(AIAA PAPER 90-2032) Copyright

The component development on preliminary design, model testing, and detailed design for a lightweight fuel pump and metering component is presented. During model testing of the preliminary design pump, the critical composite pump subcomponents were tested to over 25,000 rpm and 1300 psi. The detailed design pump incorporates improvements based on model testing experience to meet the program goals of 30,000 rpm and 1400+ psi. The detailed design pump and metering component is now in fabrication, with rig testing (for performance and durability) and analysis to follow. The component is targeted for demonstration on advanced military engines in this decade.

#### A90-40603#

#### FIBER-OPTIC TURBINE INLET TEMPERATURE **MEASUREMENT SYSTEM (FOTITMS)**

VICTOR J. BIRD, PATRICK C. SWEENEY (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and PETER J. KIRBY (Land Infrared, Bristol, PA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. (Contract N00140-86-C-9415)

(AIAA PAPER 90-2033) Copyright

The goals and requirements of the FOTITMS, a program aimed at the development of a long-life, high-temperature gas stream measurement system for gas turbine engine diagnostics and control, are briefly reviewed. In particular, attention is given to the design, fabrication, and testing of the signal processor, temperature sensor design, selection of the FOTITMS configuration, and the operation of the system. Results of laboratory burner rig tests performed on the FOTITMS are reported.

#### A90-40604# HIGH-TEMPERATURE ELECTRONICS FOR AIRCRAFT

STEPHEN J. PRZYBYLKO (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs (AIAA PAPER 90-2035)

Progress is being made in the development of high-temperature electronics. Presented are the implications of these developments for aircraft engine control systems. They offer the greatest challenges in terms of high-temperature environment and long-life requirements and are prime candidates for early application of high-temperature electronic devices. Author

#### THE APPLICATION OF AN EXPERT MAINTENANCE AND **DIAGNOSTIC TOOL TO AIRCRAFT ENGINES**

RONALD L. DE HOFF, LAWRENCE MILLER, and JEFF FRENSTER (Systems Control Technology, Inc., Palo Alto, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs (AIAA PAPER 90-2036) Copyright

This paper describes experiences gained in developing and fielding expert maintenance and diagnostics systems for modern aircraft engines. Specifically, an expert maintenance tool (XMAN) has been developed for several USAF and USMC engines. The architecture and functionality of XMAN are discussed, and its applicability to future engines is presented. Lessons learned are derived which address issues of knowledge acquisition, maintenance training, and insertion into the logistics support infrastructure.

A90-40606#

#### **FULL AUTHORITY DIGITAL ELECTRONIC ENGINE CONTROL** SYSTEM PROVIDES NEEDED RELIABILITY

DAVID A. FIEBIG (Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p.

(AIAA PAPER 90-2037) Copyright
Recent advances in digital electronic control systems for military aircraft engines are discussed, with special attention given to the control system of the F100-PW-100 engine servicing the F-15 aircraft. It is shown that the successful implementation of an improved design process, combined environmental reliability testing, accelerated mission engine testing, field service evaluations, manufacturing process reviews, environmental stress screening, and statistical process control resulted in dramatic improvements in engine control system reliability through the 1980s. Further improvements are anticipated from the new-technology dual-channel full-authority electronic controls and successfull implementation of programs such as the propulsion power system integrity program, concurrent engineering, and total quality management.

A90-40622\*# United Technologies Research Center, East Hartford, CT.

#### **HYDROCARBON-FUELED SCRAMJET COMBUSTOR** INVESTIGATION

I. W. KAY, W. T. PESCHKE, and R. N. GUILE (United Technologies Research Center, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs (Contract NAS1-17794)

(AIAA PAPER 90-2337) Copyright

An experimental program is being conducted for developing the technology required by a hydrocarbon-fueled engine capable of operating as a scramjet in the Mach 5.6-7.0 range. A series of tests have been run to define scramjet combustor design criteria applicable to a scramjet configuration involving a pair of modular, axisymmetric combustors mounted on the lower surface of a supersonic/hypersonic missile. The airbreathing pilot combustor incorporates an external mainstream fuel injector which serves as the primary fuel injection stage for the supersonic combustor; it has been demonstrated that the pilot promotes the efficient combustion of either gaseous ethylene or preheated JP-5, when they are injected into the mainstream flow as a primary fuel.

O.C.

#### A90-40633# DEVELOPMENT OF THE JET-SWIRL HIGH LOADING

YONEZAWA, H. TOH, S. GOTO, and M. OBATA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. (AIAA PAPER 90-2451) Copyright

With the view to accelerating the mixture between fuel and air and the combustion of the resulting mixture, a new concept of high combustion loading 'jet-swirl' combustor was derived from qualitative and quantitative analysis of the pattern of flow through the combustion liner. A prototype model combustor designed to embody the features of the jet-swirl concept, was tested to verify its combustion performance. This test on the jet-swirl combustor confirms the superior combustion characteristics at high combustion loading that can be expected from this new concept of combustor.

#### A90-40636#

#### PRECURSER CONVERTIBLE ENGINE STUDY

J. L. BETTNER (General Motors Corp., Allison Gas Turbine Div.,

Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-2486) Copyright

Ten convertible engine concepts, in the 4000 sph and 8000 shp class engine sizes, were investigated for future high speed rotorcraft applications. Turboprop, propfan, and turbofan engines considered. Specific fuel consumption performance characteristic estimates were developed for high and low altitude cruise along with standard and hot day sea level and 4000 foot altitude hover. Core and bypass residual thrust estimates were evaluated. Candidate convertible engines were weighed. Helicopter manufacturers were polled for their opinions of the candidate engines regarding installation, operability, and maintainability effects. A simple mission analysis demonstrated the impact of the various convertible concepts on aircraft range. Based on performance estimates, weight analysis, and mission analysis, the candidate engines were ranked. The recommended convertible engine concept was a high BPR turbofan incoporating a torque converter in the fan hub which disconnected the fan from the power turbine during hover operations.

#### A90-40637#

#### THE ROLE OF HYDROGEN/AIR CHEMISTRY IN NOZZLE PERFORMANCE FOR A HYPERSONIC PROPULSION SYSTEM

J. J. SANGIOVANNI, T. J. BARBER (United Technologies Research Center, East Hartford, CT), and S. A. SYED (Pratt and Whitney Aircraft, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs

(AIAA PAPER 90-2492) Copyright
A computer model for describing quasi-one-dimensional flow of a gas mixture with area change and finite rate chemical reactions was used to study the role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system. The important results obtained for a typical nozzle at a Mach 18 flight condition are as follows: (1) finite rate chemistry should not be neglected in nozzle performance simulations because beneficial chemical processes persist throughout the entire nozzle length, (2) termolecular recombination reactions represent the principal chemical contribution to nozzle performance, (3) intermediate HNO species have little effect on hydrogen radical recombination, and (4) nitrogen oxides are not involved directly in the hydrogen radical recombination process, but, rather, they provide a source of oxygen for recombination. In addition, the study shows that any major reduction in the detailed reaction mechanism used here may lead to incorrect simulations of nozzle performance.

#### A90-40639#

#### ADJUSTING TURBINE ENGINE TRANSIENT PERFORMANCE FOR THE EFFECTS OF ENVIRONMENTAL VARIANCES

M. A. CHAPPELL and R. S. MCKAMEY (Sverdrup Technology, Inc., AEDC Group, Arnold AFB, TN) AIAA, SAE, ASME, and Inc., AEDC Group, Arnold AFB, TN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18,

(AIAA PAPER 90-2501) Copyright

The effects of typical environmental variances for transient test results obtained in ground test facilities are quantified, and a method of adjusting these test results to correct for the effects of environmental variances is demonstrated. The model representative of a current low-bypass, dual-spool, afterburning turbofan engine and is capable of predicting measured performance throughout the engine operational envelope. A method based on simplified turbine engine cycle interrelationships was adapted for use as a method of adjusting transient performance for the effects of variances in environmental conditions. The adjustment method is applicable to both steady-state and transient performance testing and ground and flight testing.

#### A90-40643\*# General Electric Co., Lynn, MA. CONVERTIBLE ENGINE SYSTEM FOR HIGH SPEED ROTORCRAFT

R. HIRSCHKRON and P. R. HULL (GE Aircraft Engines, Lynn, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference. 26th, Orlando, FL, July 16-18, 1990. 9 p. refs (Contract NAS3-25460)

(AIAA PAPER 90-2512) Copyright

The identification of engine technology needed for high speed rotorcraft and to also provide suitable propulsion data for the High Speed Rotor Craft is presented. The several objectives are: (1) to generate technology planning data for NASA, (2) to help understand the propulsion requirements of new aircraft types being considered, and (3) to have a source of consistent engine data for the airframe companies doing the studies. This study is primarily directed at Folding Tilt Rotor types with some consideration given to the X-Wing type.

#### A90-40927#

### TRANSVERSE FUEL-INJECTION MODEL FOR A SCRAMJET PROPULSION SYSTEM

THOMAS R. A. BUSSING and GARY L. LIDSTONE (Boeing Advanced Systems, Seattle, WA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 355, 356. Abridged. Previously cited in issue 20, p. 3158, Accession no. A87-45393. refs Copyright

#### A90-40934#

### MULTISTEP DUMP COMBUSTOR DESIGN TO REDUCE COMBUSTION INSTABILITIES

K. C. SCHADOW, E. GUTMARK, K. J. WILSON, and R. A. SMITH (U.S. Navy, Naval Weapons Center, China Lake, CA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 407-411. Previously cited in issue 20, p. 3350, Accession no. A88-48029. refs

#### A90-40945#

### INVESTIGATION OF VERY HIGH BYPASS RATIO ENGINES FOR SUBSONIC TRANSPORTS

R. A. ZIMBRICK and J. L. COLEHOUR (Boeing Commercial Airplanes, Seattle, WA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 490-496. Previously cited in issue 18, p. 3002, Accession no. A88-44704. refs Copyright

#### A90-40946#

### INFLUENCE OF FUEL COMPOSITION ON FLAME RADIATION IN GAS TURBINE COMBUSTORS

JU SHAN CHIN (Beijing University of Aeronautics and Astronautics, People's Republic of China) and ARTHUR H. LEFEBVRE (Purdue University, West Lafayette, IN) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 497-503. refs

Previous work on the correlation of flame radiation data from gas turbine combustors is reviewed. A study of the results obtained from the combustion of a wide variety of liquid hydrocarbon fuels in several different types of continuous-flow combustors shows that although content provides a useful general indication of the influence of fuel composition on luminous flame radiation, a better fit to the measured values can be achieved by using the smoke point as the correlating parameter. The best representation of the experimental data is provided by a given two-property parameter that embodies both smoke point and naphthalene content.

Author

#### A90-40947#

### EXPERIMENTAL STUDIES OF COMBUSTOR DILUTION ZONE AERODYNAMICS. II - JET DEVELOPMENT

S. J. STEVENS and J. F. CARROTTE (Loughborough University of Technology, England) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 504-511. Research supported by the Ministry of Defence of England. Previously cited in issue 18, p. 3005, Accession no. A88-44817. refs Copyright

#### A90-41162#

#### THE CHALLENGE OF DEMONSTRATING THE X-30

DAVID L. KORS and R. DOHN KISSINGER (Aerojet, Propulsion

Div, Sacramento, CA) Aerospace America (ISSN 0740-722X), vol. 28, July 1990, p. 22-24. Copyright

The National Aerospace Plane X-30 single-stage-to-orbit horizontal takeoff and landing vehicle will reach Mach 25, operating in an aerothermodynamic environment that no existing wind tunnel can adequately simulate. The X-30's intimately airframe-aerodynamics-integrated propulsion system will accordingly have to be validated through CDF techniques. Especially heavy reliance must be placed on CFD to furnish predictions of hydrogen fuel penetration and mixing at speeds above Mach 8, where scramjet powerplant performance is very sensitive to small changes in component efficiency. Scramjet component performance data for CFD studies are provided by Generic High Speed Scramjet Engine experimental results. O.C.

#### A90-41165#

#### TURBOFANS TURN TO UHB PROPULSION

DAVID E. GRAY (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) and CALVIN H. CONLIFFE (General Electric Co., Fairfield, CT) Aerospace America (ISSN 0740-722X), vol. 28, July 1990, p. 32-35, 86. Copyright

While ducted fan engines typical of current transport aircraft practice are able to achieve bypass ratios of the order of between 10 and 20 at most, the full benefits of bypass ratio maximization are only achievable at ratios of the order of 30 to 50, which require open-fan configurations. An account is presently given of the development status of the two fundamentally different ultrahigh bypass (UHB) engine designs currently undergoing testing: one of which uses a gearbox, while the other relies on a contrarotating turbine configuration to achieve the requisite speed reduction. Both engines have undergone flight testing on an MD-80 airliner. Additional advanced UHB engine development programs undertaken by foreign manufacturers are noted.

#### A90-41166#

#### AIRCRAFT ENGINE TECHNOLOGY GETS A SECOND WIND

DONALD M. DIX (DOD, Washington, DC) and JAMES S. PETTY (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) Aerospace America (ISSN 0740-722X), vol. 28, July 1990, p. 36-39. Copyright

A typical fighter is driven by a propulsion system that weighs 2.5 times more than its payload; an improvement of engine specific thrust performance by only 10 percent yields a 25-percent increase in fighter payload. Much-higher-than-current levels of engine performance are accordingly being sought by the USAF/USN/DARPA/NASA Integrated High Performance Energy Technology (IHPTET) program. The IHPTET program's goals are defined by the requirement that future fighters cruise supersonically without afterburning and possess STOVL capabilities. The engine design practices developed under the aegis of IHPTET are also expected to benefit rotorcraft, transport and patrol aircraft, and cruise missiles. Attention is given to the IHPTET Phase II and III performance goals and component technology development thrusts.

#### A90-41212#

# NOISE-SOURCE MEASUREMENTS BY THIN-FILM PRESSURE TRANSDUCERS IN A SUBSONIC TURBOFAN MODEL [MESURE DES SOURCES SONORES DANS UNE MAQUETTE DE SOUFFLANTE SUBSONIQUE DE TURBOREACTEUR, PAR CAPTEURS DE PRESSION PELLICULAIRES]

S. LEWY (ONERA, Chatillon, France) (Congres Francais d'Acoustique, 1st, Lyons, France, Apr. 10-13, 1990) ONERA, TP no. 1990-36, 1990, 5 p. In French. Research supported by the Service Technique des Programmes Aeronautiques and SNECMA. refs

(ONERA, TP NO. 1990-36)

Thin-film pressure transducers are used to measure unsteady pressures on blades and vanes in a turbofan model at a SNECMA facility. Examples of results showing the effect of an inflow control

device used for simulating flight operations are presented. The data obtained illustrate the effect of upstream obstruction of the rotor and the influence of a silencer on noise attenuation. R.E.P.

#### A90-41758

MILITARY ENGINES - CRADLE OF TECHNOLOGY [LES MOTEURS MILITAIRES - BERCEAU DE LA TECHNOLOGIE

JEAN CALMON (AAAF, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 138, 1989, p. 41-52. In French.

Copyright

Advanced technology of aircraft turbine engines has generally been motivated by the requirements of military aircraft. This is particularly true at SNECMA where large civil transport turbine engines have not been developed solely with the commercial objective in mind. Military engine development is traced for compressors, combustion chambers and fuel injection systems; the evolution of turbines in relation to the continuing increases in turbine operating temperatures; and the mechanical construction of interrelated parts as well as the introduction of composite and advanced materials. Future engine refinements are discussed in relation to the Rafale aircraft requirements that might be superseding the M88 engine. R.E.P.

#### A90-41759

#### CHARACTERIZATION OF HELICOPTER TURBOSHAFT ENGINE NOISE (CARACTERISATION DU BRUIT DES **TURBOMOTEURS D'HELICOPTERES]**

ALAIN FARRANDO (Turbomeca, S.A., Bordes, France) and SERGE (ONERA, Division Acoustique, Chatillon, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 138, 1989, p. 53-62. In French. refs Copyright

Two major areas of noise propagation in helicopter turboshaft engines are investigated. First, the acoustic radiation in the rearward arc due principally to internal sources is examined. These are localized for each frequency band by a three-signal coherent spectrum data process. Third octave results are discussed in the case of a typical engine (TM333). Second, the radiation in the forward arc due mainly to the axial or centrifugal compressor stage is considered. It is indicated that semi-empirical methods for typical turbofans may be applied. However, their validity is limited as the shape of the inlet often complicates the airflow. Lastly, investigations in progress are discussed; acoustic power emitted by various noise sources are presented along with calculations and analysis of the direction of inlet and exhaust radiation.

R.E.P.

#### A90-41760

#### STARTER SYSTEMS AND AUXILIARY POWER UNITS **ISYSTEMES DE DEMARRAGE ET GROUPES AUXILIAIRES DE** PUISSANCE]

CLAUDE DELAMASANTIERE (Microturbo, S.A., Toulouse, L'Aeronautique et l'Astronautique (ISSN 0001-9275), France) no. 138, 1989, p. 63-67. In French. Copyright

The evolution of aircraft starter systems along with their inherent problems and complications is presented. Three main systems are discussed: the cartridge firing starter, the thermochemical (isopropyl nitrate or hydrazine) starter, and the auxiliary power units in principal use today. Attention is also given to the advancement of the auxiliary power unit from a static to an airborne system, its additional capabilities of handling other functions such as air conditioning and pressurization. Finally, future refinements for APUs with regard to weight reduction, increased power output, and durability and ease of maintenance are reviewed.

#### A90-41761

#### DEVELOPMENTAL TESTS ON THE M 88 ENGINE ARE ON TRACK [LES ESSAIS DE DEVELOPPEMENT DU MOTEUR M 88 SONT EN COURS]

ANDRE BARBOT (SNECMA, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 138, 1989, p. 69-72. In French.

Copyright

Three major areas of development for the M 88 Rafale engine are presented: (1) detailing the specific objectives for this compact program, (2) examining the status of progress and specifying the principal results, and (3) defining the principal stages that will be targeted in the follow-on program. Test evaluation parameters, endurance testing, and engine flight simulation are discussed. The development status of major engine sections from the high-pressure compressor to the afterburner is also discussed. Finally, the continued future development and testing through flight test programs is also considered. It is concluded that some 1500 hours of ground test time including 50 hours of endurance running will precede prototype flight testing.

#### A90-41981#

#### **AUTOMATED AIRCRAFT ENGINE COSTING USING ARTIFICIAL INTELLIGENCE**

M. W. BAILEY (GE Aircraft Engines, Cincinnati, OH) and K. S. OVERTON (General Electric Co., Schenectady, NY) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. Research supported by General Electric Co. refs

(AIAA PAPER 90-1887) Copyright

This paper describes a software system that uses a comparative cost estimating approach to cost individual aircraft engine parts and to build this into a complete engine cost. The Assistant Cost Estimator (ACE) program is an AI system that uses object-oriented programming techniques, incorporating rules and algorithms to derive cost from a data base of existing parts. The payoff is consistent accurate costing of preliminary design candidates and cost trades on individual parts in about one/tenth of the time taken by the manual design process. Author

#### A90-41982#

#### FLIGHT TEST RESULTS OF THE F-15 SMTD THRUST VECTORING/THRUST REVERSING EXHAUST NOZZLE

R. BURSEY and R. DICKINSON (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AlAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11. p. refs (AIAA PAPER 90-1906) Copyright

Many of the next generation fighter engines are being developed with advanced multi-function exhaust nozzles. The nozzles with new thrust vectoring and reversing capabilities will be used to augment normal aerodynamic flight control effectors and to enhance rapid thrust response for flight maneuverability and short takeoff and landings. A significant evolution of nozzles will emerge from current practice and control system technology will evolve. to provide optimal management of the propulsion system, utilizing new capabilities as provided by the nozzle revolution. The flight test results presented in this paper demonstrates the first of many barriers that have to be overcome in order to realize the full contributions of future multi-function nozzles. The success to date of the F-15 SMTD aircraft with thrust vectoring and reversing nozzles has proven that these new and innovative control concepts are obtainable. Author

#### A90-41990#

#### DEVELOPMENT OF HIGH TEMPERATURE ACTUATION SYSTEMS FOR ADVANCED AIRCRAFT ENGINES

T. JONES (Sundstrand Advanced Technology Group, Rockford, IL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. (AIAA PAPER 90-2031) Copyright

Improved performance, weight reduction, and greater reliability for control systems will be necessary for advanced aircraft engines operating at higher temperatures. Design concepts for hydromechanical and electromechanical actuation systems as well high-temperature materials must be developed demonstrated in order to attain these requirements. Description of the technologies and design considerations evaluated during the

development of a hydromechanical rotary actuator and a linear electromechanical actuator capable of operating in a 700 degree engine environment is presented. It is concluded, that a high-temperature mechanical engine actuation control system can be achieved as shown by the results of these programs.

#### A90-41992#

#### GE'S CF34 ENGINE FOR BUSINESS AND REGIONAL JETS

H. E. LOWEY (GE Aircraft Engines, Lynn, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 5 p.

(AIAA PAPER 90-2041) Copyright

The use of the CF34 engine for airline service is examined. The specifications for the CF34 RJ engine are presented. Improvements in the CF34 Bizjet engine to enhance durability and maintainability are described. Consideration is given to the turbine blades, lube system, fuel control, and the ignition system. The certification program and accelerated mission testing of the engine are discussed.

#### A90-41993#

#### HIGH TEMPERATURE SOLID LUBRICANT REQUIREMENTS FOR ADVANCED HIGH PERFORMANCE GAS TURBINE

G. PEZZELLA and PAUL A. WARNER (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research sponsored by USAF. refs (AIAA PAPER 90-2042) Copyright

A study has been conducted to quantify thermal property and lubrication performance requirements for the Integrated High Performance Turbine Engine Technology initiative's Phase II and III criteria; without the lubricants in question, speed, range, and payload reductions would result due to the unobtainability of the requisite weight reductions. Parametric analyses have indicated that lubricant bulk oxidative stability, autoignition temperature, and density were the primary contributors to the desired weight savings; lubricant volatility and hot spot stability were additional critical properties. The development goal for Phase II lubricants is a bulk oil temperature of 330 C.

#### A90-42017#

#### SOME GOVERNING PARAMETERS OF PLASMA TORCH IGNITER/FLAMEHOLDER IN A SCRAMJET COMBUSTOR

G. MASUYA, K. KUDOU, A. MURAKAMI, T. KOMURO, K. TANI (National Aerospace Laboratory, Kakuda, Japan) et al. SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs (AIAA PAPER 90-2098) Copyright

Effects of various operational parameters of plasma torch igniters/flameholders were experimentally studied in a hydrogen-fueled supersonic combustor with a rectangular crosssection. The stagnation temperature of the airstream at the ignition limit almost linearly decreased as input electric power increased, while it did not significantly change with the flow rate of feedstock. The effectiveness of the argon plasma torch igniter was remarkably improved by adding small fraction of hydrogen, but it showed rather modest improvement for further increase of the hydrogen contents. Modification of the combustor top wall design led to successful ignition of fuel jets injected from opposing side walls by a single plasma torch igniter and great reduction of airstream temperature at the ignition limit.

#### A90-42038#

#### **VISCOUS FLOW ANALYSIS FOR ADVANCED INLET** PARTICLE SEPARATORS

M. ZEDAN, P. HARTMAN, A. MOSTAFA, and A. SEHRA (Textron Lycoming, Stratford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p.

(AIAA PAPER 90-2136) Copyright

A fully viscous particulated flow analysis for inertial particle separators is presented. It comprises (of) three main elements:

(1) A full Navier-Stokes solver on generalized curvilinear coordinates to map the viscous compressible flow in the IPS, (2) A grid system which is ideally suitable for the IPS split flow, and (3) A particle trajectory analysis that accounts for the effect of gas on the particle motion. This procedure was verified by comparing the predicted results with experimental data obtained from a 5 lb/sec inlet particle separator. Good agreement between the test data and analytical predictions indicates that such a procedure is important in the development process of future high performance inlet particle separators.

#### A90-42050#

#### MULTIPLE SWIRLER DOME COMBUSTOR FOR HIGH **TEMPERATURE RISE APPLICATIONS**

E. J. KRESS, J. R. TAYLOR, and W. J. DODDS (GE Aircraft Engines, Evendale, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. (Contract F33615-86-C-2616)

(AIAA PAPER 90-2159) Copyright

The design and development of a combustor to achieve ultrahigh-temperature rise operation with acceptable combustion-system performance over both high-power and lowpower operating ranges are summarized. As a result of a systematic analysis of several different design concepts, a multiple-swirler combustor-dome concept was selected for sector test evaluation. A preferred combustor configuration in which all of the combustor airflow, except for liner cooling, is admitted through the front end was evolved in low-pressure testing. Low-power performance (including altitude relight, ground start, and combustion efficiency) was shown to be acceptable with the use of in-flight combustion staging, which involves cross-firing between stages during part-power engine operations. At high power conditions, the multiple-swirler dome produced high combustion efficiency levels and low smoke emissions over an extended fuel-air-ratio range.

#### A90-42051#

#### MODELING GAS TURBINE COMBUSTOR PERFORMANCE **UNDER TRANSIENT CONDITIONS**

JIM A. CLARK and JOHN W. GREEN (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs

(Contract F33615-84-C-2432; N00140-87-C-9902) (AIAA PAPER 90-2161) Copyright

This paper describes a time-stepping computer code which models the prediffuser, shroud, fuel nozzle, combustor and turbine inlet vanes for a gas turbine engine. Given fuel type and transient inputs for inlet fuel flow and temperature, prediffuser inlet temperature, and either prediffuser airflow or pressure, the code predicts combustor and shroud pressures (and flowrates), combustor exit temperatures, and flame stability. Code calculations are shown to be in excellent agreement with results from the

#### A90-42053#

#### THE PERFORMANCE OF A COMBUSTOR PRE-DIFFUSER **INCORPORATING COMPRESSOR OUTLET GUIDE VANES**

United Technologies Transient Combustion Facility.

J. CARROTTE, S. J. STEVENS, and A. P. WRAY (Loughborough University of Technology, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. Research supported by the Ministry of Defence of England.

(AIAA PAPER 90-2165) Copyright

An experimental investigation has been carried out to study the performance of an integrated design of compressor outlet guide vane and combustor prediffuser in which the outlet guide vanes extended into the diffuser a distance equal to 27 percent of the diffuser axial length. Particular emphasis was placed on the need to operate with representative inlet and outlet conditions and to this end a rotor providing about 40 degrees of exit swirl and a fully sheared velocity profile was located upstream of the OGVs. In addition, a combustor flame tube was sited downstream

of the pre-diffuser. Compared with the measured performance when the trailing edge of the OGVs are at pre-diffuser inlet, a small increase in loss and a corresponding decrease in pressure recovery was incurred when the OGVs were located part-way into the diffuser. Furthermore, a deterioration in flow conditions was observed along the outer wall, and at diffuser exit the blade wakes were more pronounced with a transitory stall. However, by leaning the OGVs 10 deg, the performance in terms of loss and flow stability was restored to the levels obtained with the OGVs at pre-diffuser inlet.

A90-42054\*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
A SIMPLE DYNAMIC ENGINE MODEL FOR USE IN A REAL-TIME AIRCRAFT SIMULATION WITH THRUST VECTORING

STEVEN A. JOHNSON (NASA, Flight Research Center, Edwards, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 19 p. (AIAA PAPER 90-2166) Copyright

A simple dynamic engine model was developed for use in thrust vectoring control law development and real-time aircraft simulation. Engine dynamics were simulated using a throttle rate limiter and low-pass filter. This paper includes a description of a method to account for axial thrust loss resulting from thrust vectoring and the development of the simple dynamic engine model and its incorporation into the F-18 high alpha research vehicle (HARV) thrust vectoring simulation. The simple dynamic engine model was evaluated at Mach 0.2, 35,000-ft altitude and at Mach 0.7, 35,000-ft altitude. The simple dynamic engine model is within 3 percent of the steady state response, and within 25 percent of the transient response of the complete nonlinear dynamic engine model.

### A90-42055# INCLEMENT WEATHER INDUCED AIRCRAFT ENGINE POWER

KIRK DEVINE (Boeing Commercial Airplanes, Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. (AIAA PAPER 90-2169) Copyright

Aircraft single and multiple engine power losses have occurred during encounters with inclement weather. An Aerospace Industries Association (AIA) committee was formed to study the problem and, if necessary, recommend changes to aviation certification standards and testing procedures. Key topics researched by the committee were airplane service data experience, probability and severity of weather, engine operation in inclement weather, and how to improve current airplane operation in inclement weather. Preliminary recommendations to aviation regulatory agencies were developed based on knowledge of the topics researched.

**Author** 

#### A90-42056#

### DEVELOPMENT OF A HEAVY FUEL ENGINE FOR AN UNMANNED AIR VEHICLE

J. LAWTON (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. (AIAA PAPER 90-2170) Copyright

The development program for a heavy-fuel-burning engine (HFE) for unmanned-air-vehicle (UAV) propulsion systems, undertaken by the Naval Air Propulsion Center, is described with special attention given to the technical challenges and the advancements over the current state of the art which will result from such an effort. The primary advancements will be made in fuel injection, power to weight ratio (as compared with the existing HFE class), turbocharging of lightweight engines, and efficient operation at altitude. The primary focus will be centered around the iterative process of developing and testing new hardware. The operational testing will be done in both sea-level and altitude conditions. I.S.

#### A90-42060#

### THE DEVELOPMENT OF A PROBABILISTIC TURBINE ROTOR DESIGN SYSTEM

J. D. ADAMSON and R. E. DELANEUVILLE (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (AIAA PAPER 90-2176) Copyright

The development of a probabilistic rotor design system is examined as a means of producing lighter weight rotor designs to meet IHPTET thrust to weight goals for future generation engines. The development of this probabilistic rotor design system requires an assessment of rotor design fundamentals, the existing deterministic design system and the 45 years of gas turbine design experience. The evolution of the deterministic systems is discussed and the use of the fundamental rotor design methodology in probabilistic rotor design systems is explained. An experience base of thirteen years has also been gained in the probabilistic analysis of gas turbine components and an explanation of how this experience can now be incorporated into a new design system is discussed. The payoffs for going to a probabilistic rotor design system necessitate this next step in rotor design technology development. The pitfalls of using this new technology are also discussed and finally, the architecture for a proposed probabilistic design system is flow-charted and explained.

#### A90-42155#

### ON AND OFF-DESIGN PERFORMANCE PREDICTION OF SINGLE SPOOL TURBOJETS USING GASDYNAMICS

H. I. H. SARAVANAMUTTOO (Carleton University, Ottawa, Canada) and F. S. MIRZA-BAIG AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs

(AIAA PAPER 90-2393) Copyright

This paper describes a mathematical model by which the off-design performance of a turbojet can be predicted, knowing just the design point parameters. Off-design performance has been estimated by using gasdynamic properties of the exhaust nozzle, which regulates the aerothermodynamic behavior of the upstream components. Approximate overall performance of a turbojet at typical cruising conditions can be estimated, making the use of compressor and turbine maps redundant.

#### A90-42157#

### THE PROMISE OF ADVANCED MATERIALS FOR A 21ST CENTURY UBE

CHRISTOPHER J. SMITH (GE Aircraft Engines, Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. (AIAA PAPER 90-2396) Copyright

The performance gains which may be expected from advanced technologies integrated in the design of ultrahigh bypass engines (UBEs) anticipated to be in service at a target date of 2015 are discussed, with a view to the impact of advanced materials on operational characteristics. The application of advanced polymermatrix and ceramic-matrix composites to nacelle and hot section structures, respectively, are identified as the lines of development of greatest consequence. Comparative data are presented for current-materials and 2015-materials UBE engine operating characteristics, with respect to fan, compressor, high-pressure turbine, and low pressure turbine temperatures.

O.C.

#### A90-42158#

### ULTRA HIGH BYPASS TURBOFAN TECHNOLOGIES FOR THE TWENTY-FIRST CENTURY

R. E. OWENS, K. L. HASEL, and D. E. MAPES (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p.

(AIAA PAPER 90-2397) Copyright

A study conducted under the aegis of NASA's High Technology Ultrahigh Bypass Ratio Turbofan program has given attention to the prospective performance gains of 2010-available technology/2015-initial operation powerplants in the 60,000 lb thrust class for long range, wide body commercial aircraft, relative to current performance levels. The study explored innovative engine configurations expected to positively affect weight and initial cost and/or maintenance cost; the noise and emissions concerns that will be critical in future designs were also addressed. While the overall pressure ratio (OPR) of current turbofans is of the order of 35:1, the next-century designs presently considered were as high as 75:1 and even 100:1, in the case of designs employing ceramic hot-section materials which obviate the use of compressor bleed air for cooling.

#### A90-42159#

#### COMPONENT ARRANGEMENT STUDIES FOR AN 8000 SHP TURBOSHAFT HIGH TECHNOLOGY CORE

JAMES L. BETTNER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. (AIAA PAPER 90-2398) Copyright

Material property projections were formulated for a 8000 shp two-spool, free power turbine, advanced technology core, turboshaft engine with cruise design point conditions of 70:1 overall pressure ratio and 2800 F rotor inlet temperature. The projected material property advancements and component performance levels were based on a year 2015 IOC. An engine arrangement study was carried through aerodynamic, structural, and weight analysis. The projected material property goal expectations were then reduced and the complete design analysis procedure was repeated. The resulting two engine arrangements were compared to identify performance, size, and weight differences.

#### A90-42160#

### PROPULSION CONTROL SYSTEM DESIGNS FOR ADVANCED NAVY MULTIMISSION AIRCRAFT

CHRISTIAN J. COMMON (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), ROBERT E. RAYMOND, ERIC M. ARNETT (Allied-Signal Aerospace Co., Bendix Engine Controls Div., South Bend, IN), and RUSSELL W. VIZZINI (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs

(AIAA PAPER 90-2403) Copyright

A trade-off analysis of conceptual turbofan engine control system designs has been performed to select the systems that will best meet the requirements for a 1995 and a year 2000 U.S. Navy multimission fighter/attack aircraft. The conceptual control systems include complete hydromechanical, all electronic, and hybrid computation. In addition, on- and off-engine controls were investigated with and without dissimilar backup systems. A metholology was developed for selecting the optimum engine control system which can be applicable to any aircraft based on the individual program goals.

#### A90-42167#

### A REMOTE TIP-DRIVEN FAN POWERED SUPERSONIC FIGHTER CONCEPT

D. W. ELLIOTT, P. D. HOSKINS, R. F. MILLER, and J. R. SIMMONS (GE Aircraft Engines, Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p.

(AIAA PAPER 90-2415) Copyright

The supersonic flight-capable STOVL fighter presently proposed as replacement for the Harrier derives its propulsive lift from the vertical-axis flow of a tip-driven fan, whose operating power comes via ducting of engine exhaust gases into the fans' wing installations. This lift installation concept, which was first demonstrated by the XV-5A aircraft of the 1960s, can now take advantage of far more developed materials, structural design, and turbomechanical concepts to reduce fan installation weight and the thickess of the fan that must be accommodated within the supersonic fighter's necessarily thin wings. The mission and maneuvers used to size

these vehicles were air-to-air oriented, with a mandatory vertical landing. O.C.

**A90-42168\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### A MODELING TECHNIQUE FOR STOVL EJECTOR AND VOLUME DYNAMICS

C. K. DRUMMOND and W. S. BARANKIEWICZ (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p. Previously announced in STAR as N90-22566. refs (AIAA PAPER 90-2417) Copyright

New models for thrust augmenting ejector performance prediction and feeder duct dynamic analysis are presented and applied to a proposed Short Take Off and Vertical Landing (STOVL) aircraft configuration. Central to the analysis is the nontraditional treatment of the time-dependent volume integrals in the otherwise conventional control-volume approach. In the case of the thrust augmenting ejector, the analysis required a new relationship for transfer of kinetic energy from the primary flow to the secondary flow. Extraction of the required empirical corrections from current steady-state experimental data is discussed; a possible approach for modeling insight through Computational Fluid Dynamics (CFD) is presented.

#### A90-42169#

### JFS190 TURBINE ENGINE PERFORMANCE OPTIMIZED USING TAGUCHI METHODS

K. WHELESS, M. F. MALAK (Allied-Signal Aerospace Co., Garrett Auxiliary Power Div., Phoenix, AZ), and R. KIKER (USAF, San Antonio Air Logistics Center, Kelly AFB, TX) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990, 13 p.

(AIAA PAPER 90-2419) Copyright

Solving a performance problem with overhauled jet fuel starters (JFS190s) for the F-15 aircraft by using Taguchi methods is presented. These problems were due to rejections caused by high exhaust gas temperatures and low horsepower. To optimize opposing requirements of minimum exhaust gas temperatures and maximum horsepower, parameter design was used. Four arrays were run during the 24 tests performed. High exhaust gas temperature solutions were identified with the first array while low horsepower necessitated the second, third, and fourth arrays for definite results. Finally, five components are identified as factors with significant effects.

#### A90-42170#

### EXPERIMENTAL TURBOFAN USING LIQUID HYDROGEN AND LIQUID NATURAL GAS AS FUEL

V. A. SOSOUNOV (Tsentral'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR) and V. N. ORLOV (Kuibyshev Scientific-Production Association, USSR) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (AIAA PAPER 90-2421) Copyright

The three-turbofan Tu-155 airliner has undergone modifications and experimental development aimed at the near-term use of liquid methan as fuel, with liquid hydrogen being reserved as a longer-term alternative. The NK-80 engines with which these cryogenic fuels are to be used incorporate a heat exchanger for liquid fuel evaporation, turbocryopumps, and modified combustors. A comparative study is presented of kerosene vs liquid hydrogen fuel performance for the NK-80 powerplants, together with an overview of the TU-155 airframe's incorporation of the cryotankage and associated hardware. Attention is given to the comparative volumetric requirements of kerosene, liquid hydrogen, and liquid methane.

#### A90-42176#

### ENGINEERING DESIGN MODELS FOR RAMJET EFFICIENCY AND LEAN BLOWOFF

R. C. PRIOR, A. M. MELLOR (Vanderbilt University, Nashville, TN), and D. K. FOWLER AIAA, SAE, ASME, and ASEE, Joint

Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p.

(AIAA PAPER 90-2453) Copyright

Combustion efficiency and lean blowoff semi-empirical preliminary design models, validated originally for laboratory axisymmetric flameholders and conventional gas turbine combustors, are extended to dump combustor ramjet geometries. The general efficiency model includes effects of fluid mechanics. spray evaporation, and finite chemical kinetics, and its application to ramjets requires inclusion of choked flow due to the downstream nozzle. For the work reported on here, test data employing liquid fuel injection far upstream of the flameholder are utilized, so that the configuration is modeled as prevaporized premixed. The model successfully correlated these data, which include variations in combustor geometry, nozzle area ratio, and overall equivalence ratio. The resulting correlation allows prediction of combustion efficiency for the special case examined to date. Similary, work with the lean blowoff model is limited to comparison of the original model with results presented in the literature.

#### A90-42177#

#### THE INFLUENCE OF SWIRL ON VELOCITY, TEMPERATURE AND SPECIES CHARACTERISTICS IN A CAN COMBUSTOR

K. C. HSU, S. B. TSAY (Chung Shan Institute of Science and Technology, Lungtan, Republic of China), and M. R. WANG (National Cheng-Kung University, Tainan, Republic of China) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs

(AIAA PAPER 90-2454) Copyright Swirling flow effects on liquid fueled spray flame are evaluated. To generate different strengths of swirling flow three vaned swirlers are employed in these tests. JP-5 jet fuel is sprayed into the combustion chamber by a fuel jet surrounded by a swirling flow. Performance measurements are taken for the axial mean velocity, temperature field and four major species concentrations (CO2, CO, O2 and UHC). The tests demonstrate that the distance of penetration of the fuel spray is diminished with increasing swirl level. It is concluded that significant changes become evident in the aerodynamic, thermal and concentrations structure of a swirl-stabilized combustor due to relatively minor changes in the swirl numbers.

#### A90-42188# ON- AND OFF-DESIGN PERFORMANCE ANALYSIS OF HYPERSONIC DETONATION WAVE RAMJETS

T. M. ATAMANCHUK and J. P. SISLIAN (Toronto, University, Downsview, Canada) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs

(AIAA PAPER 90-2473) Copyright

The paper investigates the use of a particular case of shock-induced combustion (a detonation wave) as a means of hypersonic propulsion. A first-order Godunov scheme was used to determine the flowfield generated by a body utilizing such a means of heat addition to supersonic flow. Configurations based on multiple external and multiple internal inlet compression shocks were considered. Pressures, and thus forces, acting on these planar or axisymmetric bodies were calculated and used to determine various performance parameters. Several on-design body geometries were studied at off-design flight conditions, and their performance assessed. In general the largest flight envelopes were obtained for vehicles utilizing an overcompressed detonation wave, or those geometries based on internal compression. Author

#### A90-42197#

#### **CFE738 - A CASE FOR JOINT ENGINE DEVELOPMENT**

DAVID MOSS and G. L. MCCANN (GE Aircraft Engines, Garrett Engine Div., Lynn, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p. (AIAA PAPER 90-2522) Copyright

A new turbofan engine, principally to meet the needs of the business jet market is being developed by the CFE Company. The experience gained from previous programs to develop an

engine that would be economical to operate and purchase, has been used extensively. The high efficiency level of the CFE738 engine is due to the high pressure ratio made possible by using a direct derivative of the gas generator core previously developed for the U.S. Army. This is designed to provide 5600-7000 pounds thrust using a single stage nonboosted twin shaft titanium fan driven by a 3 1/2 stage low pressure turbine. The single spool, five stage axial/one stage centrifugal compressor minimizes rotor part count while giving sturdy blading to resist foreign object damage. The CFE738 will also be capable of meeting the extended cyclic life and rugged reliability of the commuter aircraft requirements. R.F.P.

#### A90-42217#

#### MIXING CHARACTERISTICS OF DILUTION JETS IN SMALL **GAS TURBINE COMBUSTORS**

C. E. SMITH (CFD Research Corp., Huntsville, AL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 14 p. Research supported by the U.S. Army. refs

(AIAA PAPER 90-2728) Copyright

Of critical importance in current and advanced gas turbine combustors is the reduction of exit temperature nonuniformity, commonly referred to as pattern factor. An investigation was performed to study the mixing characteristics of opposed, staggered dilution holes in hopes of reducing pattern factor. A 3-D numerical model of a generic small combustor dilution zone was developed, and parametric testing was performed at simulated full power conditions. Unexpectedly, the computed flow patterns exhibited both symmetric and asymmetric flow characteristics. The influences of hole spacing-to-duct height (S/H) and inlet jet turbulence were parametrically studied. It was shown that pattern factor varied nonlinearly with S/H, and careful attention must be paid to hole spacing for optimum mixing. It was also show that higher jet inlet turbulence substantially improved pattern factor. Further work is required to experimentally verify these findings and to apply them to actual combustor designs.

#### A90-42221#

#### TURBINE CONFIGURATION IMPACT ON ADVANCED IHPTET ENGINE SYSTEM MISSION CAPABILITIES

L. W. DUNBAR (GE Aircraft Engines, Cincinnati, OH) SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 16 p. (AIAA PAPER 90-2739) Copyright

Four turbine configurations are presently evaluated for near-term and far-term performance levels desired in the framework of USAF's Integrated High Performance Turbine Engine Technology initiative. The turbine configurations were single-spool/single stage, two spools whose single stages employ no intermediate stator vane, two spools with single stages incorporating the conventional intermediate vane, and two spools of which the first is single-stages while the second is double-staged, without intervening vanes between the first and second spools. The vaned turbine configurations are found to be aerodynamically inferior, heavier, and impossible to implement in the engines in question without cooling.

#### A90-42226#

#### ADVANCED MATERIAL APPLICATIONS FOR DIRECT LIFT **ENGINES**

ROBERT F. TAPE (Rolls-Royce, Inc., Atlanta, GA) AIAA. SAE. ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p. Research supported by USAF and Rolls-Royce, Inc.

(AIAA PAPER 90-2753) Copyright

The use of direct lift engines is one method of providing lift at low, or zero, forward speed for V/STOL aircraft. A major requirement in direct lift engines, and one that principally determines the viability of this approach to V/STOL, is the need to achieve a very high engine thrust:weight ratio. A preliminary design of a 2005 IOC, 40,000lbf thrust lift engine was performed in support of WRDC Advanced Tactical Transport concept studies under

sponsorship of WRDC Aero Propulsion and Power Laboratory. This paper discusses the advanced material systems projected to be available for this engine and the specific demands placed on the material selection process by a direct lift engine.

#### A90-42485# CO-DEVELOPMENT OF CT7-6 ENGINES - A CONTINUED TRADITION IN TECHNOLOGY AND RELIABILITY

C. MASSARO (Alfa Romeo Avio S.p.A., Pomigliano D'Arco, Italy), R. BONIFACIO (Fiat Aviazione S.p.A., Turin, Italy), and R. SCENNA (GE Aircraft Engines, Lynn, MA) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 20 p.

The general design and performance characteristics of the CT-6/-6A engines are presented, as are the results of factory test and flight test programs. The engines have been developed primarily to meet the needs of civil and utility versions of the EH101 helicopter and other European helicopters. However, they are also considered for growth versions of current T700/CT7 applications. CT7-6/-6A engines represent approximately a 27-percent growth over the base T700-700 engine, which is accomplished through increased air flow by utilizing an improved CT7 turboprop compressor and through improved turbomachinery efficiency/temperature capability by introducing proven technology improvements. The CT7-6/-6A engines also retain many features from the proven T700/CT7 engine family, including its reliability and maintainability characteristics.

#### A90-42486# FULL AUTHORITY DIGITAL ENGINE CONTROL FOR THE AS **355 N TM 319 ENGINES**

BERNARD CERTAIN and PIERRE ROUGIER (Aerospatiale, Division Helicopteres, Marignane, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper, 9 p.

The twin-engine Ecureuil TM 319 engines have allowed upgrading of both performance and safety. In fact, the Full Authority Digital Engine Control (FADEC) of the TM 319 engine features characteristics which are summed with the power level to improve the AS 355 operational range. The control laws for takeoff and contingency power ratings are upgraded with respect to altitude and temperature. These power ratings are calculated so as to take advantage, as far as possible, of the thermodynamic potential of the engine (turbine inlet temperature). The pilot can set the power by either using a synthesized indicator or through automatic rpm limitations. Training for engine failure can be performed without damaging the remaining engine, using a derated contingency power selected on pilot's request. The FADEC computer has fully redundant computation channels.

#### A90-42487#

### A HYDRODYNAMIC TURBO-FAN/SHAFT CONVERTIBLE

R. R. OSSI (Textron Lycoming, Stratford, CT) Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 13 p. refs

The concept of the convertible engine is briefly discussed, and an engine design is proposed which may have important benefits in terms of construction economics, performance flexibility, and operational costs. In particular, it is shown that a simple, effective, and potentially low-cost convertible turbofan/shaft engine can be created by the judicious application of a hydrodynamic drive unit to current configuration turbofan engines. This can be accomplished without recourse to specifically designed aerodynamic components, such as special fan rotors, unloading guide vanes, variable exit stators, actuators, auxiliary inlets, or special hot section developments, such as parallel turbines and variable turbine nozzles. Instead, standard turbofan components can be used.

V.L.

#### A90-42488# CONTRIBUTION OF ENGINE IMPROVEMENT ON NEXT **FUTURE ROTORCRAFT**

DINO DINI (Pisa, Universita, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper, 12 p.

Different compressor and turbine configurations, heat recovery, and material projections are examined from the standpoint of decreasing specific fuel consumption. Based on an analytical study of the improved engine performance, conclusions are made concerning engine and airframe advances and the payload and mission range of future helicopters. All comparisons are made in terms of baseline rotorcraft/engime system, baseline missions for rotorcraft, and technology projections regarding materials, engine cycles, and manufacturing and operating costs.

N90-23401\*# Illinois Univ., Urbana-Champaign. Coordinated Science Lab.

#### AN EXPERIMENTAL STUDY OF FAULT PROPAGATION IN A JET-ENGINE CONTROLLER M.S. Thesis

GWAN SEUNG CHOI May 1990 43 p (Contract NAG1-602)

(NASA-CR-181335; NAS 1.26:181335; UILU-ENG-90-2216; CSG-124) Avail: NTIS HC A03/MF A01 CSCL 21/5

An experimental analysis of the impact of transient faults on a microprocessor-based jet engine controller, used in the Boeing 747 and 757 aircrafts is described. A hierarchical simulation environment which allows the injection of transients during run-time and the tracing of their impact is described. Verification of the accuracy of this approach is also provided. A determination of the probability that a transient results in latch, pin or functional errors is made. Given a transient fault, there is approximately an 80 percent chance that there is no impact on the chip. An empirical model to depict the process of error exploration and degeneration in the target system is derived. The model shows that, if no latch errors occur within eight clock cycles, no significant damage is likely to happen. Thus, the overall impact of a transient is well contained. A state transition model is also derived from the measured data, to describe the error propagation characteristics within the chip, and to quantify the impact of transients on the external environment. The model is used to identify and isolate the critical fault propagation paths, the module most sensitive to fault propagation and the module with the highest potential of causing external pin errors. Author

Air Force Occupational and Environmental Health Lab., Brooks AFB, TX. Human Systems Div.

A/F32T-9 LARGE TURBO FAN ENGINE ENCLOSED NOISE SUPPRESSOR SYSTEM (T-9 NSS), EXTERIOR FAR-FIELD AND INTERIOR NOISE, MCCONNELL AFB, KANSAS Final Report

ALI Y. ALI Feb. 1990 178 p (AD-A220535; USAFOEHL-90-026E100118BNA) Avail: NTIS HC A09/MF A01 CSCL 21/5

Previous reports on the A/F32T-9 Large Turbo Fan Engine Enclosed Noise Suppressor System (T-9 NSS) addressed environmental noise for acceptance test purposes only. This report presents the first article test results for interior and near-field exterior occupational noise exposure during ground runup tests of the following engines: F100, F101-GE-102, F108-CF-100, J57-59W, J85-5, TF30-P7, TF33-P3 and the TF41-A1.

N90-23403\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**EXPERIMENTAL EVALUATION OF A TUNED ELECTROMAGNETIC DAMPER FOR VIBRATION CONTROL** OF CRYOGENIC TURBOPUMP ROTORS

ELISEO DIRUSSO and GERALD V. BROWN Washington

1990 17 p (NASA-TP-3005; E-5012; NAS 1.60:3005) Avail: NTIS HC A03/MF A01 CSCL 21/5

Experiments were performed on a passive tuned electromagnetic damper that could be used for damping rotor vibrations in cryogenic turbopumps for rocket engines. The tests were performed in a rig that used liquid nitrogen to produce cryogenic turbopump temperatures. This damper is most effective at cryogenic temperatures and is not a viable damper at room temperature. The unbalanced amplitude response of the rotor shaft was measured for undamped (baseline) and damped conditions at the critical speeds of the rotor (approx. 5900 to 6400 rpm) and the data were compared. The tests were performed for a speed range between 900 and 10 000 rpm. The tests revealed that the damper is very effective for damping single-mode narrow bandwidth amplitude response but is less effective in damping broadband response or multimode amplitude response.

N90-23404\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ANALYSIS OF INTERNAL FLOW IN A VENTRAL NOZZLE FOR STOVL AIRCRAFT

C. FREDERIC SMITH (Sverdrup Technology, Inc., Brookpark, OH.) and JACK G. MCARDLE 1990 21 p Presented at the 26th Joint Propulsion Conference, Orlando, FL, 16-18 Jul. 1990; cosponsored by AIAA, SAE, ASME, and ASEE LIMITED REPRODUCIBILITY: More than 20% of this document may be affected by color photographs Original contains color illustrations (Contract NAS3-25266)

(NASA-TM-103123; E-5451; NAS 1.15:103123; AIAA-90-1899) Avail: NTIS HC A03/MF A01; 3 functional color pages CSCL 2:/5

Short takeoff and vertical landing (STOVL) aircraft are planned for possible future development. For these aircraft, the same propulsion system will provide power for lift, hover, and horizontal flight. To accomplish this, many designs include a ventral nozzle to provide part of the vertical thrust required. Understanding and predicting the internal aerodynamic flow caused by a single exhaust duct opening are highly desirable in assessing this concept. A numerical simulation of a ventral nozzle is presented and the results are compared with experimental data. Comparisons include visualizations of the flow along the ventral duct walls and in the tailpipe plane of symmetry. Performance calculations are also compared with measured values.

N90-24271# Naval Postgraduate School, Monterey, CA.
APPLICATION OF NEURAL NETWORKS TO THE F/A-18
ENGINE CONDITION MONITORING SYSTEM M.S. Thesis
JOSEPH T. GENGO Sep. 1989 125 p
(AD-A219820) Avail: NTIS HC A06/MF A01 CSCL 21/5

Neural networks were applied to the Engine Condition and Monitoring System of the F/A-18 aircraft. Due to recent fleet experience with compressor blade failures in flight, neural networks were applied to three engine conditions, flameout due to compressor failures, normal operating conditions, and low oil pressure conditions. An attempt was made to predict compressor failure using the neural networks. A back propagation and back propagation/Kohonen network were successfully tested in recognizing the various conditions with data previously unseen by the networks. Both networks demonstrated promise in predicting failures although not enough data was available for conclusive results.

N90-24272# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.

CALCULATION OF THE AEROELASTIC BLADE STABILIZATION WITH LINEARIZED PROCESS [BERECHNUNG DER AEROELASTISCHEN SCHAUFELDAEMPFUNG MIT EINEM LINEARISIERTEN VERFAHREN]

C. POENSGEN Dec. 1987 67 p In GERMAN (MITT-87-01; ETN-90-96475) Avail: NTIS HC A04/MF A01

From the fundamental definitions of aeroelasticity, the process was compared qualitatively to others with regard to its power capacity. It was established that a lot of processes are appropriate to solve the first problem of the turbomachines, but no sufficiently accurate process for the forecasting of unsteady aerodynamic values has yet been achieved. The Smith-Whitehead process was

compared with others and used for the calculation of experimental data and for a transonic profile stream.

N90-24273\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

EXPERIMENTAL AND ANALYTICAL STUDY OF CLOSE-COUPLED VENTRAL NOZZLES FOR ASTOVL AIRCRAFT

JACK G. MCARDLE and C. FREDERIC SMITH (Sverdrup Technology, Inc., Cleveland, OH.) 1990 16 p Proposed for presentation at the International Powered Lift Conference, London, England, 29-31 Aug. 1990; sponsored by Royal Aeronautical Society

(NASA-TM-103170; E-5499; NAS 1.15:103170) Avail: NTIS HC A03/MF A01 CSCL 21/5

Flow in a generic ventral nozzle system was studied experimentally and analytically with a block version of the PARC3D computational fluid dynamics program (a full Navier-Stokes equation solver) in order to evaluate the program's ability to predict system performance and internal flow patterns. For the experimental work a one-third-size model tailpipe with a single large rectangular ventral nozzle mounted normal to the tailpipe axis was tested with unheated air at steady-state pressure ratios up to 4.0. The end of the tailpipe was closed to simulate a blocked exhaust nozzle. Measurements showed about 5 1/2 percent flow-turning loss, reasonable nozzle performance coefficients, and a significant aftward axial component of thrust due to flow turning loss, reasonable nozzle performance coefficients, and a significant aftward axial component of thrust due to flow turning more than 90 deg. Flow behavior into and through the ventral duct is discussed and illustrated with paint streak flow visualization photographs. For the analytical work the same ventral system configuration was modeled with two computational grids to evaluate the effect of grid density. Both grids gave good results. The finer-grid solution produced more detailed flow patterns and predicted performance parameters, such as thrust and discharge coefficient, within 1 percent of the measured values. PARC3D flow visualization images are shown for comparison with the paint streak photographs. Modeling and computational issues encountered in the analytical work are discussed. Author

N90-24274\*# General Motors Corp., Indianapolis, IN. Allison Gas Turbine Div.

ADVANCED GEARBOX TECHNOLOGY Final Report, Aug. 1984 - Jan. 1987

N. E. ANDERSON, R. W. CEDOZ, E. E. SALAMA, and D. A. WAGNER Jun. 1987 142 p Presented at the AIAA/SAE/ASME/ASEE 23rd Joint Propulsion Conference, San Diego, CA, Jun. 1987 (Contract NAS3-24341)

(NASA-CR-179625; NAS 1.26:179625; EDR-12909) Avail: NTIS HC A07/MF A01 CSCL 21/5

An advanced 13,000 HP, counterrotating (CR) gearbox was designed and successfully tested to provide a technology base for future designs of geared propfan propulsion systems for both commercial and military aircraft. The advanced technology CR gearbox was designed for high efficiency, low weight, long life, and improved maintainability. The differential planetary CR gearbox features double helical gears, double row cylindrical roller bearings integral with planet gears, tapered roller prop support bearings, and a flexible ring gear and diaphragm to provide load sharing. A new Allison propfan back-to-back gearbox test facility was constructed. Extensive rotating and stationary instrumentation was used to measure temperature, strain, vibration, deflection and efficiency under representative flight operating conditions. The tests verified smooth, efficient gearbox operation. The highly-instrumented advanced CR gearbox was successfully tested to design speed and power (13,000 HP), and to a 115 percent overspeed condition. Measured CR gearbox efficiency was 99.3 percent at the design point based on heat loss to the oil. Tests demonstrated low vibration characteristics of double helical gearing, proper gear tooth load sharing, low stress levels, and the high load capacity of the prop tapered roller bearings. Applied external

prop loads did not significantly affect gearbox temperature, vibration, or stress levels. Gearbox hardware was in excellent condition after the tests with no indication of distress. Author

#### 80

#### **AIRCRAFT STABILITY AND CONTROL**

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

#### A90-38908

### CONTROL SYSTEM VALIDATION IN THE AUTONOMOUS HELICOPTER

JOHN F. GILMORE, JOHN FUGEDY, and THOMAS FRIEDEL (Georgia Institute of Technology, Atlanta) IN: Applications of artificial intelligence VII; Proceedings of the Meeting, Orlando, FL, Mar. 28-30, 1989. Part 2. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 1090-1100. refs Copyright

A six degree-of-freedom vehicle model for route planning in airborne vehicles is presented. This autonomous helicopter system uses advanced airborne route planning based on pilot heuristics. The vehicle model knowledge source is presented in detail along with results demonstrating its performance.

#### A90-38912#

### FLUTTER OF SHAFT-SUPPORTED LOW ASPECT-RATIO CONTROL SURFACES

AMALESH BARAI and S. DURVASULA (Indian Institute of Science, Bangalore, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 42, Feb. 1990, p. 19-26. refs

The flutter problem of a stub-shaft supported, low aspect-ratio, all-movable aerodynamic surface, typical of control surfaces on some guided rockets is considered. Analysis has been made with respect to an idealized configuration of trapezoidal or triangular plates, a small segment of the root chord which is assumed to be rigidly clamped. This idealization has been found to be reasonably satisfactory in depicting the essential features of the dynamics of such all-movable, thin, low aspect-ratio surfaces. Numerical calculations for vibration and flutter characteristics are made for a particular configurations. Convergence study is also made for a particular configuration. Vibration studies obtained are compared with available results where possible and the agreement is found to be good.

## A90-38965 IMPROVEMENT OF HELICOPTER HANDLING QUALITIES USING H(INFINITY)-OPTIMISATION

A. YUE (Oxford, University, England) and I. POSTLETHWAITE (Leicester, University, England) IEE Proceedings, Part D - Control Theory and Applications (ISSN 0143-7054), vol. 137, pt. D, no. 3, May 1990, p. 115-129. Research supported by the Ministry of Defence Procurement Executive of England. refs Copyright

The results are presented of a study into the use of

H(infinity)-optimization for the design of robust feedback control laws for improving the handling qualities of high-performance helicopters. A low-speed controller was designed to give accurate control of pitch and roll attitude, yaw rate, and heave velocity for a typical combat helicopter. The design was based on a linearized model obtained from a six-degree-of-freedom nonlinear model of a helicopter. Numerical compliance of the design with handling requirements.

model obtained from a six-degree-of-freedom nonlinear model of a helicopter. Numerical compliance of the design with handling qualities requirements was assessed by testing simulated responses against specifications from a proposed airworthiness design standard. Robust stability was assessed from singular-value plots. In addition, the qualitative features of the design were assessed in a piloted flight simulation trial.

#### A90-38966

### IMPLEMENTATION OF A TRANSPUTER-BASED FLIGHT CONTROLLER

F. GARCIA-NOCETTI, H. A. THOMPSON, M. C. F. DE OLIVEIRA, C. M. JONES, and P. J. FLEMING (University of Wales, Bangor) IEE Proceedings, Part D - Control Theory and Applications (ISSN 0143-7054), vol. 137, pt. D, no. 3, May 1990, p. 130-136. Research supported by the Royal Aerospace Establishment, SERC, CONACYT, et al. refs

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Increasingly, as flight-control laws become more complex and sample times shorten, implementation requirements are outstripping the capacity of general-purpose single-processor systems. This has prompted this investigation of the feasibility of using a parallel-processing transputer-based network, programmed in occam, for the implementation of an aircraft-flight-control algorithm. Although the problems of flight-control implementation motivated the study, the research findings have wider applicability. Three techniques to generate the concurrent realization of a typical flight-control law are described and illustrated together with some indications of their strengths and weaknesses. On the basis of this preliminary study, one of these approaches is suggested as a practical way to tackle the problem. Software tools have been used and developed to automate the mapping of control laws onto transputer-based systems. These have proved to be effective and convenient aids, supporting real-time simulation and implementation.

## A90-40557\*# Arizona State Univ., Tempe. ANALYSIS OF AIRFRAME/ENGINE INTERACTIONS - AN INTEGRATED CONTROL PERSPECTIVE

DAVID K. SCHMIDT, JOHN D. SCHIERMAN (Arizona State University, Tempe), and SANJAY GARG (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (Contract NAG3-998)

(AIAA PAPER 90-1918) Copyright

Techniques for the analysis of the dynamic interactions between airframe/engine dynamical systems are presented. Critical coupling terms are developed that determine the significance of these interactions with regard to the closed loop stability and performance of the feedback systems. A conceptual model is first used to indicate the potential sources of the coupling, how the coupling manifests itself, and how the magnitudes of these critical coupling terms are used to quantify the effects of the airframe/engine interactions. A case study is also presented involving an unstable airframe with thrust vectoring for attitude control. It is shown for this system with classical, decentralized control laws that there is little airframe/engine interaction, and the stability and performance with those control laws is not affected. Implications of parameter uncertainty in the coupling dynamics is also discussed, and effects of these parameter variations are also demonstrated to be small for this vehicle configuration. Author

## A90-40689\*# Purdue Univ., West Lafayette, IN. STATIC AEROELASTIC TAILORING FOR OBLIQUE WING LATERAL TRIM

JONATHAN D. BOHLMANN, TERRENCE A. WEISSHAAR (Purdue University, West Lafayette, IN), and CLINTON V. ECKSTROM (NASA, Langley Research Center, Hampton, VA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 402-410) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 558-563. Previously cited in issue 12, p. 1833, Accession no. A88-32220. refs

(Contract NAG1-372) Copyright

A90-40691\*# National Aeronautics and Space Administration.
Ames Research Center, Moffett Field, CA.
HYPERVELOCITY, MINIMUM-RADII, COORDINATED TURNS
MICHAEL E. TAUBER (NASA, Ames Research Center, Moffett

Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 566-569.

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An analytic solution is presented for the most basic powered-flight maneuver, consisting of a constant-altitude coordinated turn and expressions for minimum-turn radii; associated flight conditions are derived. It is shown that the formulation for hypervelocity turns differs from that for subsonic and hypersonic speeds. Illustrative calculations using approximate aerodynamics based on Newtonian theory are presented, and these demonstrate the differences of hypersonic flight conditions and their associated turning radii from those at lower speeds.

O.C.

## A90-40817 HELICOPTER CONTROL DESIGN USING FEEDBACK LINEARIZATION TECHNIQUES

E. LICEAGA-CASTRO, R. CASTRO-LINARES (Instituto Politecnico Nacional, Mexico City, Mexico), and R. BRADLEY (Glasgow, University, Scotland) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 533, 534. refs

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Linear equivalence of nonlinear systems is applied to a helicopter model. The nonlinear control design obtained allows a transformation of the nonlinear helicopter model to a set of four linear controllable and single-input subsystems. The main difference between the application presented and other work is that the diffeomorphic map of the state-input space is presented in explicit form.

#### A90-40833

#### ENERGY BASED STABILITY ANALYSIS OF A FUZZY ROLL CONTROLLER DESIGN FOR A FLEXIBLE AIRCRAFT WING

SUJEET CHAND (Rockwell International Science Center, Thousand Oaks, CA) and STEVE HANSEN (Rockwell International Corp., Los Angeles, CA) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 705-709. Research supported by Rockwell International Corp. refs

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A fuzzy-logic-based roll controller design is presented for the experimental advanced technology wing (ATW). The ATW integrates active controls with flexible structural dynamics for enhanced performance. Controllers were originally designed and tested using classical control design concepts, but the high level of model uncertainties and the many approximations in the real-time system dynamics led to the development of a fuzzy-logic-based system. The design, performance simulation, controller performance, and stability analysis of the fuzzy controller are dynamic model combined with a discrete-time fuzzy controller. An energy-based technique using Liapunov theory is then applied. The analysis shows that the control system is stable.

#### A90-40878#

#### MULTIPLE MODEL ADAPTIVE CONTROLLER FOR THE STOL F-15 WITH SENSOR/ACTUATOR FAILURES

PETER S. MAYBECK and DONALD L. POGODA (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1566-1572. refs

A multiple-model adaptive controller that provides for reconfiguration in response to sensor and/or actuator failures is developed for an approach and landing profile for the STOL F-15 aircraft. Each elemental controller within the multiple model controller is based on a command-generator tracker/proportional-plus-integral/Kalman-filter design employing reduced-order models, and each assumes a particular system status: no failures or a single failed surface or sensor. Filter residual monitoring is used as the mechanism for selecting the appropriate

weighting coefficients for blending the outputs of the elemental controllers. The entire controller is evaluated against a higher order truth model with a selected failure, and the process is repeated for all failure modes of interest.

#### A90-40886

## ULTIMATE BOUNDEDNESS CONTROL OF UNCERTAIN SYSTEMS WITH APPLICATION TO ROLL COUPLED AIRCRAFT MANEUVER

SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1708-1713. refs (Contract DAAL03-87-G-0004)
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The problem of robust trajectory control of a class of nonlinear systems which can be decoupled by state-variable feedback is treated. It is assumed that the system matrices are unknown but bounded. A nonlinear control law is derived so that the tracking error in the closed-loop system is uniformly bounded and tends to a certain small neighborhood of the origin. The error dynamics are asymptotically decoupled in an approximate sense. The controller includes a reference trajectory generator and uses the integral feedback of the tracking error. Using this result, a flight control system is designed for the control of roll angle, angle of attack, and sideslip in rapid, nonlinear aircraft maneuvers. Simulation results are presented to show that large, simultaneous lateral and longitudinal maneuvers can be performed in spite of the uncertainty in the stability derivatives.

#### A90-40912

### DIGITAL CONTROLLER DESIGN FOR THE PITCH AXIS OF THE F-14 USING AN H(INFINITY) METHOD

JIANN-SHIOU YANG (Minnesota, University, Duluth) and WILLIAM S. LEVINE (Maryland, University, College Park) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2325-2330. refs (Contract NSF CDR-88-03012) Copyright

An H(infinity)-based control system design procedure is developed to produce a controller in which the closed-loop system is designed, using H(infinity) methods similar to those of Kwakernaak (1986), to be robust with respect to both disturbance rejection and insensitivity to parameter variations. The H(infinity) design approach is coupled with multicriterion optimization to design a pitch-axis controller for the F-14 aircraft. The design problem is an augmented version of one of two CSS benchmark problems. The authors design a discrete-time controller even though the benchmark is in continuous time. The benchmark, while specifying gain and phase margins, does not specify the expected ranges for the parameters of the plant. Estimates have been obtained of the reasonable ranges of parameter variations, which are checked against the design. The precompensator is used to shape the output response so as to cause the entire system to achieve the desired performance. The robustness of the angle-of-attack response under large parameter variations is examined. A satisfactory design has not yet been obtained. However, these intermediate results are thought to be of value in demonstrating the difficulty of the problem and the thought processes involved in trying to use H(infinity) methods to solve a realistic design problem.

#### A90-40914

### AN IMAGE ANALYSIS METHOD FOR VEHICLE STABILIZATION

M. H. A. DAVIS and M. S. ZUCKER (Imperial College of Science, Technology, and Medicine, London, England) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2371, 2372.

A method for estimating the roll angle of an airborne vehicle

from its video camera is presented. The process is subdivided into three parts: a decision process for locating the reference templates; an improved matching algorithm which is suitable for uniform pictures; and a fast estimator based on the matching techniques. A new, comprehensive approach to the problem is shown.

A90-41632\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### CONCEPT DEVELOPMENT OF AUTOMATIC GUIDANCE FOR ROTORCRAFT OBSTACLE AVOIDANCE

VICTOR H. L. CHENG (NASA, Ames Research Center, Moffett Field, CA) IEEE Transactions on Robotics and Automation (ISSN 1042-296X), vol. 6, April 1990, p. 252-257. refs Copyright

The automatic guidance of rotorcraft for obstacle avoidance in nap-of-the-earth flight is studied. A hierarchical breakdown of the guidance components is used to identify the functional requirements. These requirements and anticipated sensor capabilities lead to a preliminary guidance concept, which has been evaluated via computer simulations.

#### A90-41767

## LARGE RECEIVER AIRCRAFT - THE PERFORMANCE AND LONGITUDINAL STABILITY AND CONTROL DURING AIR TO AIR REFUELLING

ALBERT W. BLOY and VASSILIOS TROCHALIDIS (Manchester, Victoria University, England) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 139, 1989, p. 43-51. Research supported by SERC and the Ministry of Defence of England. refs Copyright

An aerodynamic model is used to obtain drag predictions and the stability and control characteristics of two large receiver aircraft, with particular emphasis on the high T-tail receiver aircraft. The drag predictions agree well with the limited data available and the increase in the receiver drag coefficient in air-to-air refuelling depends on the product of the tanker and receiver lift coefficients. For the hose and drogue method, the horizontal separation between the tanker and the receiver is sufficiently large so that the changes of trim in pitch depend primarily on the vertical separation. Typically, the high-T tail receiver aircraft is found to exhibit static stability with respect to vertical displacement from the normal refuelling position although it is dynamically unstable.

#### A90-41957

SYNTHESIS OF OPTIMAL MULTIDIMENSIONAL DIGITAL SYSTEMS FOR THE SIMULATION OF THE ANGULAR MOTIONS OF A FLIGHT VEHICLE UNDER RANDOM LOADING [SINTEZ OPTIMAL'NYKH MNOGOMERNYKH TSIFROVYKH SISTEM DLIA IMITATSII UGLOVYKH DVIZHENII LETATEL'NOGO APPARATA PRI SLUCHAINYKH VOZDEISTVIIAKH]

V. V. BELAN and A. A. TUNIK (Kievskii Institut Inzhenerov Grazhdanskoi Aviatsii, Kiev, Ukrainian SSR) Kibernetika i Vychislitel'naia Tekhnika (ISSN 0454-9910), no. 83, 1989, p. 28-34. In Russian. refs Copyright

The problem of the synthesis of the optimal structure of a control system for a flight simulator is examined with particular reference to a two-degree-of-freedom simulator of the rolling and pitching motions of a flight vehicle. An algorithm is proposed for the synthesis of a digital simulator of the angular motions of a flight vehicle that is optimal with respect to the quadratic loss functional.

#### A90-42328

## COMPUTER-AIDED ANALYSIS OF THREE-DIMENSIONAL MULTILOOP MECHANISMS [ZUR COMPUTERGESTUETZTEN ANALYSE MEHRSCHLEIFIGER RAEUMLICHER MECHANISMEN]

M. HILLER (Universitaet Duisburg-Gesamthochschule, Federal Republic of Germany) and M. MOELLER (Stuttgart, Universitaet, Federal Republic of Germany) (Gesellschaft fuer angewandte

Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Karlsruhe, Federal Republic of Germany, Mar. 28-31, 1989) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 70, no. 4, 1990, p. T 25-T 28. In German. Copyright

Numerical methods are developed to solve the large systems of nonlinear equations arising in the kinematic analysis of three-dimensional multiloop mechanical systems. The mechanical linkage between the yoke and the main rotor of a helicopter is considered as an example, and it is shown that this 4-DOF system of 26 bodies and 37 joints has 11 kinematic loops and requires solution of a system of 142 nonlinear equations if the absolute coordinates of the members are used. This system is reduced to 11 equations by applying relative joint coordinates based on the use of the loops as 'kinematic transformers.' A general optimization algorithm is used to find the solution path having the most explicit (explicitly soluble) subsystems and the smallest possible implicit subsystems. This approach makes it possible to check all possible combinations of input parameter values in order to find the optimum combination.

#### A90-42367#

### A NEW SIMPLIFICATION METHOD FOR ANALYSING THE RAPID ROLLING STABILITY OF AIRCRAFT

XIONG HE and HAO GAO (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 8, no. 2, 1990, p. 226-230. In Chinese, with abstract in English.

The Bifurcation Analysis and Catastrophe Theory Method (BACTM) is an effective and dependable method to analyze the global stability of nonlinear systems. The BACTM simplification approach to the rapid rolling maneuver is presented. This simplification can play an important role when the complete aerodynamic data or the physical mechanism of aircraft stability are not available at the beginning stage of aircraft design. The results of the method are in good agreement with those of exact solutions.

## A90-42449# THE SUPER PUMA MKII AUTOMATIC FLIGHT CONTROL

A. VAISSIERE (Societe de Fabrication d'Instruments de Mesure, Massy, France) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper.

The Super Puma MKII helicopter's automatic flight control system (AFCS-165) encompasses attitude and heading hold modes, cruise modes, and radionavigation and approach modes. The AFCS-165 uses two identical computers which are simultaneously engaged in normal operation; when a computer senses its own failure, it disengages itself automatically and the remaining computer completes the mission. Attention is given to the software life cycle and support-tool goals. The OSCAR design-support tool used during the design phase ensures the consistency of the data flow required with the actual data flow of the operational software, while the PAGOS tool ensures traceability between the code and the block diagram control law specifications.

#### A90-42461#

### DESIGN METHODOLOGY FOR MULTIVARIABLE HELICOPTER CONTROL SYSTEMS

RICHARD L. BENNETT (Bell Helicopter Textron, Inc., Fort Worth, TX) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 22 p. refs

Results of an evaluation of the Model Based Compensator (MBC), a proposed design methodology for multivariable control systems, are presented. In particular, it is noted that the most attractive feature of the MBC design process is the reduction of the design process to the choice of two scalar parameters. However, this feature may also limit the designer's flexibility. The

MBC design also has the advantage of guaranteeing a stable system at the design point, with the slight disadvantage that additional dynamics associated with the MBC can produce lightly damped stable roots, causing 'ringing'. The use of a nonlinear programming algorithm might solve this problem by formulating an optimal design problem.

## A90-42462\*# California Univ., Los Angeles. A MODEL FOR ACTIVE CONTROL OF HELICOPTER AIR RESONANCE IN HOVER AND FORWARD FLIGHT

M. D. TAKAHASHI and P. P. FRIEDMANN (California, University, Los Angeles) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 24 p. refs

(Contract NAG2-209: NAG2-477)

A coupled rotor/fuselage helicopter analysis is presented. The accuracy of the model is verified by comparing it with the experimental data. The sensitivity of the open loop damping of the unstable air resonance mode to such modeling effects as blade torsional flexibility, unsteady aerodynamics, forward flight, periodic terms, and trim solution is illustrated by numerous examples. Subsequently, the model is used in conjunction with linear optimal control theory to stabilize the air resonance mode. The influence of the modeling effects mentioned before on active air resonance control is then investigated.

## A90-42463\*# Boeing Helicopter Co., Philadelphia, PA. ACTIVE CONTROL OF TILTROTOR BLADE IN-PLANE LOADS DURING MANEUVERS

DAVID G. MILLER (Boeing Helicopters, Philadelphia, PA) and NORMAN D. HAM (MIT, Cambridge, MA) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 20 p. Research sponsored by Boeing Helicopters. refs

(Contract NCC2-366)

The origin of one/rev rotor aerodynamic loads which arise in tiltrotor aircraft during airplane-mode high speed pull-up and push-over maneuvers is examined using a coupled rotor/fuselage dynamic simulation. A modified eigenstructure assignment technique is used to design a controller which alleviates the in-plane loads during high pitch rate maneuvers. The controller utilizes rotor cyclic pitch inputs to restructure the aircraft short period aphugoid responses in order to achieve the coupling between pitch rate and rotor flapping responses which minimizes the rotor aerodynamic loading. Realistic time delays in the feedback path are considered during the controller design. Stability robustness in the presence of high frequency modeling errors is ensured through the use of singular value analysis.

#### A90-42466#

### A HIGHLY MANEUVERABLE HELICOPTER IN-FLIGHT SIMULATOR - ASPECTS OF REALIZATION

H.-J. PAUSDER, G. BOUWER, and W. VON GRUENHAGEN (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 19 p. refs (AIAA PAPER 88-4607)

A high bandwidth model following control system has been developed at DFVLR. The control system has been implemented in a BO 105 helicopter and evaluated in flight tests. The objective of the activity has been to increase the in-flight simulation capability of ATTHeS (Advanced Technology Testing Helicopter System). The realization of ATTHeS is directed to support the basic research for highly augmented helicopters and to evaluate integrated modern cockpit technologies. The aspects of simulator system realization are addressed. The design of the feedforward and feedback control laws is based on an extended linear model of the basic helicopter BO 105. In a preflight phase a nonlinear simulation has been used to evaluate the overall system performance and to expose the influences of the subsystem dynamics on model following

fidelity. Finally, the overall system has been verified in flight tests. The achieved high bandwidth and low time delay capability of the in-flight simulation system ATTHeS is underlined with flight test results.

Author

#### A90-42467#

### A TECHNIQUE FOR THE TUNING OF HELICOPTER FLIGHT CONTROL SYSTEMS

M. A. MANNESS and D. J. MURRAY-SMITH (Glasgow, University, Scotland) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p. Research supported by the University of Glasgow. refs

Helicopter flight control systems can be successfully tuned using sensitivity functions. Systematic adjustments to control system parameters are made on the basis of responses measured from the system to be tuned. The importance of the method lies in its ability to optimize controllers in the presence of unmodelynamics such as those of the rotor. The adjustment procedure will yield a controlled system whose dynamics are as close to those of a reference model as the plant dynamics will allow.

Author

#### A90-42469#

### ANALYTICAL STUDY OF DYNAMIC RESPONSE OF HELICOPTER IN AUTOROTATIVE FLIGHT

YOSHINORI OKUNO, KEIJI KAWACHI (Tokyo, University, Japan), AKIRA AZUMA (Metropolitan Institute of Science and Technology, Japan), and SHIGERU SAITO (National Aerospace Laboratory, Chofu, Japan) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 11 p. refs

A nonlinear optimal control problem minimizing the touchdown speed of a helicopter in the autorotative flight following power failure is studied. The motion of the helicopter is expressed by the longitudinal three-degree-of-freedom equations, and the rotor aerodynamic performance is calculated by using blade element theory combined with empirically modified momentum theory. This modified model has the ability of estimating the rotor thrust, H-force and torque properly even in vortex-ring state, including the effects of blade stall. This optimal control problem is, then, solved by using a numerical solution technique called SCGRA. Results indicate that pilots should postpone the collective pitch flare. The effects of the time delay in the collective pitch reduction and/or of the climbing rate at the moment of power failure on the minimum touchdown speed are also presented. In addition, height-velocity diagrams for various gross weights and density altitudes are calculated by using the other numerical solution technique, dynamic programming. Results show good agreement with flight test data.

Author

#### A90-42470#

#### THE RESPONSE OF HELICOPTER TO DISPERSED GUST

REN LIANG CHEN and XIN YU XU (Nanjing Aeronautical Institute, People's Republic of China) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 11 p. refs

The response of helicopter to dispersed gust is investigated in this paper. An articulated rotor with a blade hinge offset from the shaft and with an elastic restrain about the flap hinge offset from the shaft and with an elastic restrain about the flap hinge is used as the rotary wing dynamic model. The nonuniform distribution of induced velocity on the rotor disk derived from generalized vortex theory is taken into account. A sample calculation of a typical helicopter is made.

#### A90-42471#

#### **UH-60A HELICOPTER STABILITY AUGMENTATION STUDY**

M. A. DIFTLER (Sikorsky Aircraft, Stratford, CT) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed

Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 15 p. refs

The current UH-60A BLACK HAWK stability augmentation system (SAS) is examined using linear analysis techniques on a high order linear helicopter model. Emphasis is placed on understanding SAS roll rate gain limitations historically observed during flight test. A simple rigid body model of the helicopter indicates no limit, but with the inclusion of blade flap and lag and rotor inflow dynamics, high roll rate gains are shown to destabilize blade lag motion. However, adding the servo dynamics, filters and lags present in the flight control system/SAS results in a blade flapping instability. Including engine dynamics does not change the roll rate gain limitation, but does affect helicopter dynamics.

Author

#### A90-42472#

## THE INFLUENCE OF THE INERTIA COUPLING ON THE STABILITY AND CONTROL OF THE HELICOPTER AND THE RESPONSE OF HELICOPTER GUST

XIN-YU XU and REN-LIANG CHEN (Nanjing Aeronautical Institute, People's Republic of China) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p. refs

The influence of the inertia coupling on the stability and control of a helicopter and the response of a helicopter to a dispersed gust are investigated. An articulated rotor with a blade hinge offset and with an elastic restraint about the flap hinge are used as the rotary wing dynamic model. The nonuniform distribution of induced velocity on the rotor disk derived from the generalized vortex theory is taken into account. The model of the dispersed gust is sine-squared, according to the demand of the specification. A sample calculation of a typical helicopter has been made.

**Author** 

## A90-42474\*# Georgia Inst. of Tech., Atlanta. HELICOPTER STABILITY AND CONTROL MODELING IMPROVEMENTS AND VERIFICATION ON TWO HELICOPTERS

D. P. SCHRAGE, D. A. PETERS, J. V. R. PRASAD (Georgia Institute of Technology, Atlanta), W. F. STUMPF, and CHENGJIAN HE Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 27 p. Research supported by the U.S. Army and NASA. refs

A linearized model of helicopter flight dynamics is developed which includes the flapping, lead-lag, and dynamic inflow degrees of freedom (DOF). The model is a combination of analytical terms and numerically determined stability derivatives, and is used to investigate the importance of the rotor DOF to stability and control modeling. The results show that the rotor DOF can have a significant impact on some of the natural modes in a linear model. The flap and dynamic inflow DOF show the greatest influence. Flapping exhibits strong coupling to the body, dynamic inflow, and to lead-lag to a lesser extent. Dynamic inflow tends to damp the high-frequency flapping modes, and reduces the damping on coupled body-flap motion. Dynamic inflow also couples to the flapping motion to produce complex roots. With body-flap and lag regressing modes as exceptions, the results show essentially similar behavior for most modes of articulated and hingeless rotor helicopters.

N90-23409# McDonnell Aircraft Co., Saint Louis, MO.
NONFLAMMABLE HYDRAULIC POWER SYSTEM FOR
TACTICAL AIRCRAFT. VOLUME 1: AIRCRAFT SYSTEM
DEFINITION, DESIGN AND ANALYSIS Final Report, Mar. 1987
- Jun. 1988

J. B. GREENE, A. O. HARMON, J. R. JEFFREY, S. N. LOHE, N. J. PIERCE, J. M. ROACH, J. J. SHEHAN, and J. A. WIELDT May 1989 260 p

(Contract F33615-86-C-2600; AF PROJ. 3035) (AD-A218493; WRDC-TR-89-2026-VOL-1) Avail: NTIS HC A12/MF A01 CSCL 13/7

The purpose of the program was to develop and demonstrate an advanced hydraulic system designed to operate using an Air Force developed, nonflammable fluid, chlorotrifluoroethylene (CTFE), at a maximum operating pressure of 8000 psi. A total quantity of 600 gallons of CTFE base stock was manufactured for this program by Halocarbon Products and blended with a lubricity additive and a corrosion inhibitor by the Air Force Materials Laboratory. A major portion of an advanced aircraft flight control system was duplicated using flightweight, flightworthy hydraulic components developed by twenty four equipment suppliers contracted to support the program. In addition to the high pressure and new fluid, the program integrated several advanced concepts which reduce power consumption and system heat rejection. The most significant of these is variable system pressure which allows the system to remain at a lower power setting (3000 psi); until a demand occurs. The computer controlled variable pressure pumps then respond with only the amount of increased power needed. Energy savings remains a key issue with this new technology as future tactical aircraft are projected to require three times as much hydraulic power at peak periods than conventional aircraft. The increased system pressure serves to reduce component size to accommodate thinner wings and offset the increased weight of CTFE fluid.

N90-23412# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

PREDICTION OF LONGITUDINAL PILOT INDUCED OSCILLATIONS USING THE OPTIMAL CONTROL MODEL M.S. Thesis

STEVEN W. LINDSEY Dec. 1989 194 p (AD-A220593; AFIT/GAE/ENY/90M-1) Avail: NTIS HC A09/MF A01 CSCL 01/4

This thesis evaluates the OCM in predicting handling qualities and PIO pilot ratings during the approach and landing task. Using two existing PIO databases, analytical prediction schemes were developed using the OCM. The prediction schemes used were flight path error and crossover frequency. The prediction schemes were applied to 12 different aircraft/flight control system landing configurations. The 12 configurations were flight tested using a USAF/Calspan variable stability NT-33A. The OCM was able to predict pilot handling qualities ratings (PHQR) accurately (within one pilot rating) 80 percent of the time. PIO ratings were accurately predicted 96 percent of the time. Due to a PIO rating problem in the original databases, the PIO prediction schemes were modified using flight test data. Additional flight test configurations should be flown to verify the revised flight path error and crossover frequency prediction schemes. Because of the subjective nature of PHQRs and PIO ratings, the flight test results varied between pilots. The correlation between multiengine pilots was better than with the fighter pilot. The crossover frequency prediction scheme was the most accurate predictor of pilot ratings, while the flight path error prediction scheme was slightly more accurate for PIO ratings. Both predictors agreed with classical control theory, showing correlation between flight path error, crossover frequency, and pilot/PIO ratings. The flight path error and crossover frequency rating prediction methods should be used as a tool in flight control system design.

N90-23413\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. LATERAL-DIRECTIONAL STABILITY AND CONTROL

CHARACTERISTICS OF THE QUIET SHORT-HAUL RESEARCH AIRCRAFT (QSRA)

JACK D. STEPHENSON, JAMES A. JESKE, and GORDON H. HARDY May 1990 36 p

(NASA-TM-102250; A-90007; NAS 1.15:102250) Avail: NTIS HC A03/MF A01 CSCL 01/3

The results are presented of flight experiments to determine the lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA), an experimental aircraft designed to furnish information on various aerodynamic characteristics of a transport type of airplane that makes use of the upper-surface blown (USB) flap technology to achieve short

takeoff and landing (STOL) performance. The flight program designed to acquire the data consisted of maneuvers produced by rudder and control-wheel inputs with the airplane in several configurations that had been proposed for landing approach and takeoff operation. The normal stability augmentation system was not engaged during these maneuvers. Time-history records from the maneuvers were analyzed with a parameter estimation procedure to extract lateral-directional stability and control derivatives. For one aircraft configuration in which the USB flaps were deflected 50 deg, several maneuvers were performed to determine the effects of varying the average angle of attack, varying the thrust coefficient, and setting the airplane's upper surface spoilers at a 13 deg symmetrical bias angle. The effects on the lateral characteristics of deflecting the spoilers were rather small and generally favorable. The data indicate that for one test, conducted at low thrust (a thrust coefficient of 0.38), compared with results from tests at thrust coefficients of 0.77 and larger, there was a significant decrease in the lateral control effectiveness, in the yaw damping and in the directional derivative. The directional derivative was also decreased (by about 30 percent) when the average angle of attack of the test was increased from 3 to 16 Author deg.

#### N90-24275# Naval Postgraduate School, Monterey, CA. **HELICOPTER CONTROLLABILITY M.S. Thesis** DEAN CARICO Sep. 1989 218 p

(AD-A220078) Avail: NTIS HC A10/MF A02 CSCL 01/3

The concept of helicopter controllability is explained. background study reviews helicopter development in the U.S. General helicopter configurations, linearized equations of motion, stability, and piloting requirements are discussed. Helicopter flight controls, handling qualities and associated specifications are reviewed. Analytical, simulation, and flight test methods for evaluating helicopter automatic flight control systems are discussed. A generic simulation is also conducted. This thesis is intended to be used as a resource document for a helicopter stability and control course at the Naval Postgraduate School.

N90-24276# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, (Germany, Abt. Goettingen fuer F.R.). Strukturdynamik.

#### ON SIMPLIFIED ANALYTICAL FLUTTER CLEARANCE PROCEDURES FOR LIGHT AIRCRAFT

FRITZ KIESSLING Sep. 1989 35 p (DLR-FB-89-56; ISSN-0171-1342; ETN-90-97006) Avail: NTIS HC A03/MF A01; DLR, VB-PL-DO, Postfach 90 60 58, 5000

Cologne, Fed. Republic of Germany, 17.50 DM

For light aircraft, especially gliders, it is too expensive to apply the same extensive flutter analyses which are necessary for high performance civil and military aircraft types. A specific procedure is accepted in Germany which is based on a more or less simplified ground vibration test and, depending on the test results, a statistical evaluation of flutter danger or stability calculations. Together with flight tests conducted by the manufacter, the analytical findings constitute the conditions of flutter clearance. Experiences in applying this concept are presented. **FSA** 

#### 09

#### **RESEARCH AND SUPPORT FACILITIES (AIR)**

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

#### A90-40400#

THE CRYOGENIC WIND TUNNEL AS A TESTING TOOL FOR AIRFRAME/PROPULSION SYSTEMS

KEISUKE ASAI (National Aerospace Laboratory, Tokyo, Japan)

Japan Society for Aeronautical and Space Sciences, Aircraft Symposium, 27th, Kyushu University, Kasuga, Japan, Oct. 18-20, 1989, Paper. 4 p. refs

A new approach to the simulation problems of hot jet exhausts is presented. This method uses the advantages of cryogenic temperatures in wind tunnel testing. Simple theoretical analyses show that hot jet exhausts can be simulated in a cryogenic environment by using a gas at ambient or moderately elevated temperatures. Also, it is shown that in cryogenic wind tunnels, all the similarity parameters including the jet-temperature-related parameters and the Reynolds numbers can be matched to the full-scale flight values. The potential advantages of the cryogenic approach are discussed with emphasis on its applications to the testing of airframe and propulsion systems.

#### A90-40476 A CAPTIVE STORE FLIGHT VIBRATION SIMULATION **PROJECT**

E. A. SZYMKOWIAK and W. SILVER (Westinghouse Electric Corp., Baltimore, MD) (Institute of Environmental Sciences, Annual Technical Meeting, 36th, New Orleans, LA, Apr. 21-27, 1990) IES, Journal (ISSN 0022-0906), vol. 33, May-June 1990, p. 21-28. refs

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Military electronic equipment has become increasingly more sophisticated and, with greater complexity, very often less reliable. The project described here constitutes a complete effort, using as a test-bed an AN/ALQ-131 electronic-countermeasures external store captive to an F-111F aircraft. The project included flight vibroacoustic data acquisition and reduction, development of a simulation approach designed to secure a high degree of matching between field and laboratory environments, flight life simulations in the laboratory using a time compression factor of 20.5 to 1, and comparison of field and laboratory reliability. The simulation, resulted in very high correlation of field and laboratory failure types and a reasonable correlation of reliability. The relationships between vibration response and flight conditions measured during this project were considerably different than those predicted by the generic model for assembled external stores in MIL-STD-810D.

#### A90-40680\*# Vigyan Research Associates, Inc., Hampton, VA. SIDEWALL BOUNDARY-LAYER REMOVAL AND WALL **ADAPTATION STUDIES**

A. V. MURTHY (Vigyan Research Associates, Inc., Hampton, VA) and E. J. RAY (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 495-500. Previously cited in issue 09, p. 1295, Accession no. A89-25131. refs Copyright

A90-40684\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### DRAG MEASUREMENTS ON A MODIFIED PROLATE SPHEROID USING A MAGNETIC SUSPENSION AND BALANCE SYSTEM

DAVID A. DRESS (NASA, Langley Research Center, Hampton, Journal of Aircraft (ISSN 0021-8669), vol. 27, June 1990, p. 523-528. Previously cited in issue 09, p. 1295, Accession no. A89-25512, refs Copyright

#### A90-41113# '

#### **EXPERIMENTAL WINDTUNNEL STUDIES FOR EFA**

LUDWIG SCHAUWECKER and THEO WINDECK Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 34, 35. Copyright

In the international program for the European Fighter Aircraft (EFA) Dornier contributed to windtunnel tests. This comprises design, manufacturing and instrumentation of windtunnel models, the preparation and performance of windtunnel test and the evaluation of test results. The aim of these tests is to support theoretically determined aerodynamic characteristics. In addition to stationary measurements of the EFA partners, Dornier will mainly

investigate highly dynamic processes, such as flutter behavior, dynamic pressures and accelerations on the EFA fin as well as determinations of dynamic derivatives and the deformations on fin and wing due to aerodynamic loads.

Author

#### A90-41725#

### THE SIX COMPONENT MAGNETIC SUSPENSION SYSTEM FOR WIND TUNNEL TESTING

M. J. GOODYER (Southampton, University, England) University of Oregon, Conference on Low Temperature Physics, 7th, Eugene, OR, Oct. 23-25, 1989, Paper. 18 p.

The design and operation of the six-component magnetic suspension and balance system are described. The methods for producing roll control movements are discussed. A delta-winged model for closed-loop control in six degress of freedom and a superconducting solenoid model are presented and examined. Examples displaying the applicability of the system are provided.

i =

#### A90-41726\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. CRYOGENIC WIND TUNNELS

ROBERT A. KILGORE (NASA, Langley Research Center, Hampton, VA) University of Oregon, Conference on Low Temperature Physics, 7th, Eugene, OR, Oct. 23-25, 1989, Paper. 10 p. refs

Cryogenic wind tunnels and their use for high Reynolds number testing are reviewed. Emphasis is given to operational and aerodynamic testing experience in the NASA Langley 0.3-m Transonic Cryogenic Tunnel. Areas covered include development of test techniques and aerodynamic testing in cryogenic tunnels. The use of advanced testing techniques to increase the value of cryogenic tunnels is recommended. These include adaptive wall test sections, using solid but flexible top and bottom walls, and magnetic suspension and balance systems.

#### A90-41986#

### DESIGN AND ANALYSIS OF A LARGE-PLUG INLET ADP NACELLE AND PYLON

A. L. STEINER (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 19 p. refs

(AIAA PAPER 90-2015) Copyright

The development and testing of the Advanced Ducted Prop (ADP) nacelle and pylon are discussed. The ADP nacelle, a standard bypass ratio baseline turbofan, and a ultra-high bypass nacelle are tested in the NASA Langley 16-foot Transonic Tunnel at Mach numbers 0.50-0.80 and at angles of attack from -4 to 8 deg. Static pressure on the wing, pylon, and nacelle and lift and drag are measured. The data reveal that the ADP nacelle predicts aerodynamic performance well and is a viable engine installation.

l.F

## A90-42186# RADIO FREQUENCY (RF) HEATED SUPERSONIC FLOW LABORATORY

PAUL J. WANTUCK and HARRY H. WATANABE (Los Alamos National Laboratory, NM) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research supported by the Los Alamos National Laboratory.

(AIAA PAPER 90-2469) Copyright

A unique supersonic flow apparatus which employs an inductively coupled, radio frequency (RF) torch to supply high enthalpy source gas to the nozzle inlet is described. The main features of this system are the plasma tube, a cooled nozzle assembly, and a combustion/expansion chamber with a heat exchanger. A description of these components with current test data is presented. In addition, a discussion of anticipated experiments utilizing this system is included.

#### A90-42432#

### THE UNIVERSITY OF TORONTO-RYERSON POLYTECHNICAL INSTITUTE HYPERSONIC GUN TUNNEL

R. L. DESCHAMBAULT, R. J. HAWBOLDT, P. A. SULLIVAN (Toronto, University, Canada), and S. MOLDER (Ryerson Polytechnical Institute, Toronto, Canada) IN: Canadian Symposium on Aerodynamics, 1st, Ottawa, Canada, Dec. 4, 5, 1989, Proceedings. Ottawa, Canada, Canadian Aeronautics and Space Institute, 1989, p. 35-1 to 35-23. Research supported by NSERC, Ontario Government's University Research Incentive Fund, Johns Hopkins University, and USAF. refs

A hypersonic gun tunnel is basically a very short duration blow-down wind tunnel which generates high Mach number flows by driving a piston down a barrel to compress and heat the working fluid. The gun tunnel built by the National Aeronautical Establishment of Ottawa in the late 1950s had been in storage since the early 1970s. It has been set up at the University of Toronto's Institute for Aerospace Studies as part of a collaborative project with the Ryerson Polytechnical Institute. The paper describes the refurbishment of the facility, the updating of its instrumentation and data acquisition system, and progress in calibration. The objectives of current research programs are presented, and plans for facility development are discussed.

Author

# N90-24227# Technische Univ., Brunswick (Germany, F.R.). THE GUN TUNNEL OF THE BRUNSWICK INSTITUTE FOR FLUID MECHANICS: CURRENT DEVELOPMENT STATUS [DER GUN-TUNNEL DES INSTITUTS FUER STROEMUNGSMECHANIK DER TU BRAUNSCHWEIG: DERZEITIGER AUSBAUZUSTAND]

D. HUMMEL and H. PETZEL In Technische Univ. Berlin, Test and Measurement Technique in Hypersonics p 7-40 Jun. 1989 In GERMAN

Avail: NTIS HC A04/MF A01

The power consumption of the test installation and the technical problems are discussed by means of simple measurement examples. The test apparatus consisted of a high pressure reservoir, a pipe for conditioning of the test gas mass and the nozzle related to the measurement line, linked above the diffusor with the vacuum box. Pressures, heat transfer, forces and moments are measured. The rest temperature is evaluated by the shock reflexion process. The study parameters are the Knudsen, Mach and Reynolds numbers.

N90-24228# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).

### HIGH ENTHALPY HYPERSONIC WIND TUNNEL F4: GENERAL DESCRIPTION AND ASSOCIATED INSTRUMENTATION

J. P. CHEVALLIER, J. CHRISTOPHE, and A. GIRARD *In* Technische Univ. Berlin, Test and Measurement Technique in Hypersonics p 41-57 Jun. 1989

Avail: NTIS HC A04/MF A01

The previous short arc heated facilities used by ONERA are briefly reviewed and the new hot shot wind tunnel F4, currently under construction, is presented. The running time varies in the interval 20 to 100 ms. The expected reservoir pressure will reach 2000 bar and the expected maximum value of the reduced enthalpy will be 200. The associated instrumentation includes a six-component balance compensated for inertial effects, a Schlieren device, with mirrors included in the vacuum chamber. The real gas effects are especially studied. This includes the electron beam fluorescence technique. The locally measured parameters are flowfield density, flow velocity and rotational and vibrational temperature of nitrogen. Visualization by holographic interferometry, high speed infrared thermography, coherent antistokes Raman NO techniques for concentration other scattering are **ESA** measurements.

N90-24233# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Unternehmensbereich Transport- und Verkehrsflugzeuge.

SHORT TIME FÖRCE AND MOMENT MEASUREMENT SYSTEM FOR SHOCK TUBES (SFS) FOR MEASURING TIMES LESS THAN 10 MS

JOSEF MERTENS and KLAUS KOENIG In Technische Univ. Berlin, Test and Measurement Technique in Hypersonics p 124-144 Jun. 1989 In ENGLISH and GERMAN Avail: NTIS HC A04/MF A01

Usual wind tunnel balances measure 6 independent balance deformations for evaluation of the resulting aerodynamic air-forces and moments. Modal analysis and optimization of the model are made by finite element calculations. The modal characteristics of the model are checked by vibration tests and improvement of the finite element modelization. The representative points for acceleration measurement of the modal motion are selected for the calibration. The influence matrices are calculated taking into account the calibration tests. The transient loads are obtained by acceleration measurement and calculated.

N90-24235# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Hauptabt. Windkanaele. INFRARED THERMOGRAPHY AT HYPERSONIC CHANNEL H2K [EINSATZ DER INFRAROT-THERMOGRAPHIE AM HYPERSCHALLKANAL H2K DER DLR KOELN]

A. HENCKELS and F. MAURER In Technische Univ. Berlin, Test and Measurement Technique in Hypersonics p 155-168 Jun. 1989 In GERMAN

Avail: NTIS HC A04/MF A01

A modern infrared camera system and the digital image processing allow to obtain the surface temperature of the wind tunnel model for the total test time. By representation of the isotherm lines on the model surface a qualitative idea of the areas of low and high heat transfers is obtained. The quantitative estimation of the time dependent heat transfer of the flow in the model surface is made by the thin walls technique. Examples from the area of flow around blunt bodies or near to the boundary layer show the particular importance of the thermography in the processing of the aerothermodynamic problems in the wind tunnel technique.

N90-24277# ARE, Inc., Riverdale, MD.
CRITERIA FOR COAL TAR SEAL COATS ON AIRPORT
PAVEMENTS. VOLUME 2: LABORATORY AND FIELD STUDIES
Final Report

J. E. SHOOK, S. W. JENKINS, M. STROUP GARDINER, D. E. NEWCOMB, and J. A. EPPS Jan. 1990 237 p (Contract DTFA01-86-C-00023)

(AD-A220167; DOT/FAA/PM-87/9-VOL-2) Avail: NTIS HC A11/MF A02 CSCL 11/3

Because coal tars are resistant to gasoline and jet fuel, they have been used for many years as a protective coating on asphalt pavements for airport parking areas, ramps, taxiways and runways. Applications include both coal tar emulsions and rubberized coal tar emulsions, applied with sand to provide skid resistance and stability to the seal costs. Volume 2 of the report includes the results of an experimental Laboratory and field investigation conducted at the University of Nevada at Reno. The focus on the University program was to develop test procedures that would measure workability, scuff, adhesion and fuel resistance properties of coal tar emulsion seal coats. This program developed a method for designing seal coat formulations test procedures that could be used for quality assurance purposes. Volume 2 includes the test data generated in the study, including measurements made on field sections. GRA

N90-24278# National Aeronautical Establishment, Ottawa (Ontario). High Speed Aerodynamics Lab.

NEW TRANSONIC TEST SECTIONS FOR THE NAE 5 FT X 5 FT TRISONIC WIND TUNNEL

L. H. OHMAN, D. BROWN, Y. Y. CHAN, R. D. GALWAY, S. M. HASHIM, M. KHALID, A. MALEK, M. MOKRY, N. TANG, and J.

THAIN Jan. 1990 68 p Submitted for publication (AD-A220933; NAE-AN-62; NRC-31216) Avail: NTIS HC A04/MF A01 CSCL 14/2

The NAE 5 x 5 ft blowdown wind tunnel has undergone a major upgrade of its transonic testing capabilities. Two entirely new test sections, one for testing two-dimensional models (2D) and one for testing three-dimensional models and reflection plane models (3D), were constructed. The two test sections are parts of the so-called Roll-in Roll-out Test Section System, so designed that an interchange between the two sections can be carried out within two days, a process that previously required about three weeks. The new test sections have, as before, perforated walls, but with different hole geometry, viz. slanted holes with splitter plates as opposed to normal holes in the original test sections. The design and manufacturing was carried out by Canadian companies. The two test sections were calibrated with regard to pressure distributions, flow quality (turbulence and pressure fluctuations), side wall boundary layer characteristics (2D), flow angularity and wall interference characteristics. Results from these investigations are presented and compared with corresponding data obtained in the original test sections.

#### 10

#### **ASTRONAUTICS**

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

## A90-40582# ACCELERATORS AND DECELERATORS FOR LARGE, HYPERSONIC AIRCRAFT

EDWARD LANTZ AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (AIAA PAPER 90-1986) Copyright

The characteristics of hypersonic aircraft are such that large ground-based accelerators and decelerators at seacoast sites will be needed to make them economically competitive with other modes of transportation. The design of a ground-based accelerator that can precisely control the attitude of a very large hypersonic aircraft during takeoff is discussed. With this accelerator, a zero lift angle of attack can be maintained until after the aircraft has accelerated through the speed of sound, so that there is no lift force when the center of pressure moves aft to its supersonic position. It is also shown that a rotatable gound-based decelerator can be designed which can easily and safely dissipate the kinetic energy in a very large aircraft descending at a touchdown speed of 450 miles/hr.

## A90-40587\*# Sverdrup Technology, Inc., Brook Park, OH. PRELIMINARY DESIGN OF A LONG-ENDURANCE MARS AIRCRAFT

ANTHONY J. COLOZZA (Sverdrup Technology, Inc., Lewis Research Center Group, Brook Park, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p. Previously announced in STAR as N90-21763. refs

(Contract NAS3-25266)

(AIAA PAPER 90-2000) Copyright

The preliminary design requirements of a long endurance aircraft capable of flight within the Martian environment was determined. Both radioisotope/heat engine and PV solar array power production systems were considered. Various cases for each power system were analyzed in order to determine the necessary size, weight and power requirements of the aircraft. The analysis method used was an adaptation of the method developed by Youngblood and Talay of NASA-Langley used to design a high altitude earth based

aircraft. The analysis is set up to design an aircraft which, for the given conditions, has a minimum wingspan and maximum endurance parameter. The results showed that, for a first approximation, a long endurance aircraft is feasible within the Martian environment. The size and weight of the most efficient solar aircraft were comparable to the radioisotope powered one.

Author

#### A90-41115#

#### AERODYNAMIC WORK FOR HERMES SPACEPLANE

PETER ESCH, HEINRICH LEHRA, HERBERT RIEGER, and BERNHARD WAGNER Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 42, 43.

Copyright

For the Hermes spaceplane, diverse windtunnel tests and calculation methods are used to reduce the aerodynamic risk during the reentry phase which is characterized by very complex flow patterns. Numerical flow calculations are concentrated on the solution of full conservation equations for mass, momentum, and energy, for inviscid (Euler equations) and viscous flows (Navier-Stokes equations). Various windtunnel tests are conducted in different windtunnels depending on the subject of experimental study and the speed range. These experimental results, along with special estimated (not measured) coefficients, are used to establish a full aerodynamic set of data for numerical flight trajectory simulations with six degrees of freedom permitting a definitive evaluation of controllability and stability.

### A90-42147# 5DOF DYNAMIC LOADS ON A JET VANE

M. LAUZON (Defence Research Establishment Valcartier, Quebec, Canada) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs (AIAA PAPER 90-2382) Copyright

A 5DOF force balance was designed to measure jet vane aerodynamic loads in a jet vane thrust vector control (JVTVC) system. Vane lift and drag forces, and moments of roll, yaw and pitch were measured during a series of motor firings to investigate non-linearity and vane interaction phenomena. All the experiments were conducted under hot flow conditions on subscale (70 mm), reduced-smoke solid rocket motors. The shrouded jet vanes were subjected to operating conditions estimated to be 50 percent more severe than the current generation. The lift force and rolling moment were found to vary mostly linearly with incidence, while some nonlinearities were observed with the drag force and yawing moment measurements. Interaction between the vanes was observed to increase the vane loading by as much as 60 percent. A prediction model based on the theory of linearized supersonic flow over thin airfoils showed qualitative agreement for configurations with small interactions between the vanes. Author

#### A90-42189# HYPERSONIC (T-D) 'PINCH' AND AEROSPACEPLANE PROPULSION

L. H. TOWNEND, E. G. BROADBENT, E. G. C. BURT, and G. PAGAN (Apecs, Ltd., Liss, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990, 10 p. refs

(AIAA PAPER 90-2474) Copyright

For a supersonic combustion ramjet to accelerate up to Mach numbers of about 15 implies the preservation of adequate (T-D), even though internal skin friction, mixing losses and the problem of generating flow acceleration through the engine are all likely to increase with flightspeed. Equally, for a vehicle without supersonic combustion, a (T-D) pinch will occur at about Mach number 5 or 6. Thus, in both cases, the provision or additional thrust at high specific impulse becomes important, if premature resort to pure rocket propulsion is to be avoided. The paper studies the potential for external heat and mass addition to be regarded as candidates for combating these thrust-minus-drag 'pinches' at hypersonic flight Mach numbers.

#### 11

#### **CHEMISTRY AND MATERIALS**

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

#### A90-39991#

### THE ANALYSIS AND TESTING OF COMPOSITE PANELS SUBJECT TO MUZZLE BLAST EFFECTS

D. K. MCCARTHY and A. L. DOBYNS (Sikorsky Aircraft, Stratford, CT) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 9 p. Research supported by the U.S. Army. refs

An analysis and test program has been performed to evaluate the effect of 20 and 25 millimeter gun muzzle blast on adjacent composite airframe panels and to qualify analytical techniques for response prediction. Potential failure locations were identified and their respective failure strengths were determined on four candidate panels. These panels were analyzed to obtain predictions of strains, failure location loads, and muzzle standoff failure distance. Test panels of the four candidate designs were subjected to gun blast while strain response and incurred damage was recorded. The analytical predictions were compared with the test results with generally good correlation.

## A90-40047 DAMAGE TOLERANCE OF CARBON FIBRE REINFORCED PLASTIC SANDWICH PANELS

K. LEVIN (Flygtekniska Forsoksanstalten, Bromma, Sweden) IN: ECCM-3 - European Conference on Composite Materials, 3rd, Bordeaux, France, Mar. 20-23, 1989, Proceedings. London, Elsevier Applied Science, 1989, p. 509-514. Research supported by the Forsvarets Materielverk. refs Copyright

This paper presents an experimental evaluation of static strength and damage growth resistance under spectrum loading of impacted carbon fiber reinforced epoxy sandwich panels. The program includes determination of the influence of impact energy on damage visibility, damage size and distribution, and strength losses with respect to different skin thicknesses and core densities. In the case of barely visible impact damage the susceptibility of sandwich panels to impacts is reflected in large strength reduction and furthermore in damage growth during fatigue loading. The visibility of damage during the fatigue loading has been subsequently reduced. Damage growth and failure also occurred for nonvisual impact damages.

**A90-40127\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### TOWARDS A DAMAGE TOLERANCE PHILOSOPHY FOR COMPOSITE MATERIALS AND STRUCTURES

T. KEVIN O'BRIEN (NASA, Langley Research Center; U.S. Army, Aerostructures Directorate, Hampton, VA) IN: Composite materials: Testing and design. Volume 9; Proceedings of the Ninth Symposium, Sparks, NV, Apr. 27-29, 1988. Philadelphia, PA, American Society for Testing and Materials, 1990, p. 7-33. Previously announced in STAR as N88-22949. refs Copyright

A damage-threshold/fail-safe approach is proposed to ensure that composite structures are both sufficiently durable for economy of operation, as well as adequately fail-safe or damage tolerant for flight safety. Matrix cracks are assumed to exist throughout the off-axis plies. Delamination onset is predicted using a strain energy release rate characterization. Delamination growth is accounted for in one of three ways: either analytically, using delamination growth laws in conjunction with strain energy release rate analyses incorporating delamination resistance curves; experimentally, using measured stiffness loss; or conservatively,

assuming delamination onset corresponds to catastrophic delamination growth. Fail-safety is assessed by accounting for the accumulation of delaminations through the thickness. A tension fatique life prediction for composite laminates is presented as a case study to illustrate how this approach may be implemented. Suggestions are made for applying the damage-threshold/fail-safe approach to compression fatigue, tension/compression fatigue, and compression strength following low velocity impact.

#### A90-40215 REDESIGN OF AN ELECTRO-OPTICAL SHROUD IN GRAPHITE/EPOXY

JACK C. ROBERTS, TIM M. FERTIG (Westinghouse Electric Corp., Electronic Systems Group, Baltimore, MD), JOYCE M. MANG (Westinghouse Electric Corp., Oceanic Div., Annapolis, MD), and S. BEN BUEMI (Scheidl Manufacturing Co., Inc., Lindenhurst, NY) SAMPE Journal (ISSN 0091-1062), vol. 26, July-Aug. 1990, p. 29-34.

Copyright

A graphite-epoxy shroud and retainer were designed to replace aluminum components. Internal and external pressure, and thermal loads were applied to a finite element model of the shroud/lens assembly. A lens in a graphite-epoxy/lens assembly showed the minimum margin of safety on stress of 11.2 under operating loads, as compared to 17.7 for the lens in an aluminum/lens assembly. The thermal load showed to be much lower when graphite-epoxy shroud was used, while internal pressure was the largest contributor to stresses for this type of shroud. Although both assembly types are found structurally sound, the use of graphite-epoxy shrouds shows 50 percent weight and 40 percent cost reduction as compared to the use of aluminum.

#### A90-40479 COMBUSTION CHARACTERISTICS OF A MODEL CAN-TYPE **COMBUSTOR**

A. F. BICEN, D. G. N. TSE, and J. H. WHITELAW (Imperial College of Science, Technology, and Medicine, London, England) Combustion and Flame (ISSN 0010-2180), vol. 80, May 1990, p. 111-125. Research supported by Rolls-Royce, PLC and Ministry of Defence Procurement Executive. refs Copyright

Combustion characteristics of a model can-type combustor are reported for inlet temperatures of 315 and 523 K at an air-fuel ratio corresponding to that of takeoff conditions, with gaseous fuel and at near-atmospheric pressure. Temperatures were obtained with fine-wire thermocouples, and concentrations of UHC, H2, CO, CO2, and O2 sampled through a water-cooled probe with a flame ionization detector, a gas chromatograph, and infrared and paramagnetic analyzers. The results indicated combustion efficiencies of approximately 98 percent with 45 percent of the mass flow of the primary jets turned upstream after impingement and combustion in the wakes of the swirler and of the primary jets. The exit-temperature distribution had a maximum value of 1600 K and a pattern factor of 0.46, and the higher inlet air temperature led to flatter scalar profiles and a pattern factor of 0.29. Equilibrium assumptions yielded up to seven times the measured concentrations of CO and H2 in the fuel-rich regions and heat release properties within 10 percent and 5 percent in the stoichiometric and in the fuel-lean regions, respectively.

A90-40570#

**FUEL EFFECTS ON GAS TURBINE COMBUSTOR DYNAMICS** JAYESH M. MEHTA, P. MUNGUR, W. J. DODDS, D. W. BAHR (GE Aircraft Engines, Cincinnati, OH), and S. CLOUSER (U.S. Navy, Naval Air Propulsion Test Center, Trenton, NJ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs

(Contract N00014-87-C-9901)

(AIAA PAPER 90-1957)

An internal feedback mechanism capable of sustaining high amplitude/low frequency combustion instabilities was explored in a 90 degree sector of an advanced gas turbine engine combustor.

The local fluctuating heat release and fluctuating pressure field were examined to delineate the coupling between the two. The results demonstrate that the effects of liquid fuel spray vaporization on the operating characteristics of the combustor are substantial. Controlling spray vaporization by fuel injector design variations to change fuel vaporization rate (drop size) or location of fuel injection (spray angle) or by changing combustion dilution hole pattern may provide an effective means to reduce the level of combustion instabilities in gas turbine combustors.

#### A90-40574#

#### EXPERIMENTAL AND COMPUTATIONAL FLAMMABILITY LIMITS IN A SOLID FUEL RAMJET

P. J. M. ELANDS (TNO, Prins Maurits Laboratoria, Rijswijk, Netherlands), F. DIJKSTRA, and B. T. C. ZANDBERGEN (Delft, Technische Universiteit, Netherlands) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. Research supported by the Stichting voor de Technische Wetenschappen and National Fund Supercomputers, refs

(AIAA PAPER 90-1964) Copyright

An experimental and computational study has been performed to determine the flammability limits in a solid fuel ramjet combustor using polyethylene as a fuel. It was found that the experimentally determined flammability limits agree well with results from other investigators. The available data on flammability limits in SFRJ combustors have been extended. The COPPEF computer code may be used to obtain flammability limits, although the method used is expensive and cumbersome. A reasonable qualitative agreement with the experimental flammability limits was found. Quantitatively the agreement seems good, but cannot be claimed due to uncertainties in the method applied.

#### A90-40594# GLASS-CERAMIC MATRIX COMPOSITES FOR ADVANCED **GAS TURBINES**

KENNETH S. SISKIND (Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. (AIAA PAPER 90-2014) Copyright

A development status evaluation is presented for ceramic fiber-reinforced glass-ceramic matrix composites, with a view to their comparative performance vis a vis superalloy materials currently used in gas turbine engine hot section components. The greatest advantage of the glass-ceramic matrix composites is their substantially lower density, by comparison with superalloys; the conversion of a given component's vitreous matrix to a crystalline ceramic, through carefully controlled thermal cycling, increases the composite's refractoriness. Typical of these novel materials are graphite or SiC continuous fiber reinforcements for borosilicate, aluminosilicate, lithium aluminosilicate, and calcium aluminosilicate matrices, in order of rising refractoriness.

#### A90-41111#

#### STRUCTURAL COMPONENTS OF FIBER-REINFORCED **THERMOPLASTICS**

WINFRIED WERNER Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 20, 21. Copyright

The thermoplastic resins, polyether ketone and polyether imide have been evaluated and deemed suitable for structural applications. These studies have been applied to the Alpha Jet horizontal stabilizer leading-edge box and air brake. The structural components of carbonfiber-reinforced thermoplastics have been developed using a new production process. This program included production development of the thermoplastic leading -edge box and the air brake, component manufacturing, test demonstrations, and flight certification. Finally, the components are being tested in regular flight operations.

#### A90-41336

THE INFLUENCE OF MATERIAL QUALITY ON AIRFRAME STRUCTURAL DURABILITY

P. E. MAGNUSEN, R. J. BUCCI, A. J. HINKLE, R. L. ROLF (Alcoa Laboratories, PA), and M. E. ARTLEY (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 999-1006. refs

Copyright

Previous work on Al-Zn-Cu-Mg alloy 7050-T7451 has shown that improved processing to reduce the size of microporosity results in longer fatigue lifetimes. To differentiate this improvement, Alcoa has implemented smooth specimen fatigue testing on a lot release basis to warranty 7050-T7451 thick (5-6 in., 127-153 mni) plate initial fatigue quality. The present study employs a probabilistic fracture mechanics analysis to demonstrate that the material quality improvement verified in the smooth specimen fatigue tests translates to durability performance in actual structures. Microflaw size distributions measured from failed smooth coupon tests serve as the starting point for probabilistic crack growth analysis. Using crack exceedance probability as a basis for durability performance comparison, a hypothetical calculation shows that a fighter aircraft wing fabricated from improved quality metal outperforms the same wing fabricated from unimproved metal.

#### A90-41338

### RECENT ADVANCES IN FATIGUE LIFE ANALYSIS METHODS FOR AEROSPACE APPLICATIONS

ARVIND NAGAR (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 1015-1027. refs Convirint

The fracture mechanics concepts to predict crack growth behavior under service simulated loads from experimental data are reviewed. The mechanics and mechanisms derived from microscopic and macroscopic crack surface observations and developed from analysis of experimental data under normal and elevated temperatures are discussed. The fracture mechanics parameters for cyclic, time dependent and mixed cyclic-rate dependent damage for airframe crack configurations are presented. A discussion of fatigue life analysis including crack growth behavior due to retardation and acceleration of a steady growing crack is provided. The proposed extensions of existing methods for applications at elevated temperatures are discussed.

#### A90-41900

#### ADVANCED MATERIALS FOR LANDING GEAR

Aerospace Engineering (ISSN 0736-2536), vol. 10, July 1990, p. 17-21.

Copyright

Materials continue to be developed to provide a solution to requirements for weight reduction in composite airframes while permitting reliable operation of landing gear in severe environments. Standard material for landing gear has been 300M steel having an ultimate tensile strength over 1.93 GPA. However, the high specific strength sacrifices other key properties such as resistance to stress corrosion cracking, fracture toughness, and hydrogen embrittlement. A modified AF 1410 steel may provide greater strength and toughness to withstand the hard landings and salt environment of carrier-based aircraft landing gear. A titanium matrix composite material is also being developed that may become a viable alternative to conventional materials and can offer high specific strength and corrosion resistance. It is shown that continued development of these new materials for landing gear will provide accruing benefits from these technology advances.

R.E.P.

#### A90-42059#

### METAL MATRIX COMPOSITES STRUCTURAL DESIGN EXPERIENCE

W. E. KOOP and C. J. CROSS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, SAE,

ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs (AIAA PAPER 90-2175)

The Integrated High Performance Turbine Engine Technology program has given attention to the development prospects of SiC-reinforced Ti-based metal-matrix composites (MMCs). MMC structural design experience to date has indicated that gas turbine engine performance in the future will benefit most from a simultaneous, synergistic development of advanced materials, innovative structures, and improved aerothermodynamics that yields great weight savings. Promising lines of development have been identified for the application of MMCs to bladed rings, fan blades, and spool shafts.

#### A90-42062#

#### METAL MATRIX COMPOSITE FAN BLADE DEVELOPMENT

R. RAVENHALL (GE Aircraft Engines, Cincinnati, OH) and W. E. KOOP (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. Research supported by USAF.

(AIAA PAPER 90-2178)

A hollow fiber reinforced titanium metal matrix composite (MMC) blade was developed to assess and demonstrate the suitability of using MMC's for turbine engine applications. MMC material consisting of continuous silicon carbide fibers in a titanium matrix, along with the superplastic forming and diffusion bonding (SPF/DB) process, was used to produce a lightweight, high stiffness, impact-damage-resistant blade suitable for demonstration testing in an advanced military engine. Additional blades were fabricated and are being finished to permit testing in an engine. The developed design and fabrication process provide an approach that will aid in the design and development of structurally efficient, advanced, impact-damager-resistant blading.

## A90-42117\*# Stanford Univ., CA. MODELING SUPERSONIC COMBUSTION USING A FULLY-IMPLICIT NUMERICAL METHOD

ROBERT W. MACCORMACK (Stanford University, CA) and GREGORY J. WILSON AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 17 p. refe

(Contract NCA2-455; NAGW-965) (AIAA PAPER 90-2307) Copyright

A fully-implicit finite-volume algorithm for two-dimensional axisymmetric flows has been coupled to a detailed hydrogen-air reaction mechanism (13 species and 33 reactions) so that supersonic combustion phenomena may be investigated. Numerical computations are compared with ballistic-range shadowgraphs of Lehr (1972) that exhibit two discontinuities caused by a blunt body as it passes through a premixed stoichiometric hydrogen-air mixture. The suitability of the numerical procedure for simulating these double-front flows is shown. The requirements for the physical formulation and the numerical modeling of these flowfields are discussed. Finally, the sensitivity of these external flowfields to changes in certain key reaction rate constants is examined.

Author

#### A90-42174#

### STRUCTURE ANALYSIS OF BURNING LIQUID-FUELED SPRAY IN A CONFINED COMBUSTOR

GIIN YUAN WU and ALBERT C. C. TAO (Chung Shan Institute of Science and Technology, Lungtan, Republic of China) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research supported by the National Cheng Kung University; National Science Council of the Republic of China. refs

(Contract NSC-77-0210-D006-16)

(AIAA PAPER 90-2444) Copyright

The effects of swirl on the characteristics of liquid burning sprays are analyzed. A combustor composed of a 32-mm replaceable swirler and a stainless steel can combustor 140 mm in diameter is utilized to examine JP-5 fuel at swirler numbers 0.3

and 1.2. The drop size, size distributions, fuel volume flux, and droplet velocities are measured using the phase-Doppler technique. It is observed that all the properties of the burning spray are effected by the strength of the swirl flows. Volume fluxes and axial and tangential velocity profiles are presented.

#### A90-42372

#### **COMPOSITES APPLICATIONS - THE FUTURE IS NOW**

THOMAS J. DROZDA, ED. (Society of Manufacturing Engineers, Dearborn, MI) Dearborn, MI, Society of Manufacturing Engineers, 1989, 475 p. No individual items are abstracted in this volume.

The present volume on the development status of advanced composites discusses resin, ceramic- and metal-matrix composites, as well as tooling practices, testing and inspection methods, and novel applications. Attention is given to interface considerations in ceramic-matrix composites, applications of metal-matrix composites to military aircraft, advanced thermoplastic preforms, tooling for filament-winding processes, trapped-rubber molding methods, pultrusion for automotive applications, and composite-production tooling using CAD/CAM. Also discussed are expert systems for composites inspection and repair, acoustographic high-speed NDE for composites, the design and production of a composite landing gear-retracting beam, braided composite structures, and the uses of composites in orthopedics.

O.C

N90-23475\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

SOME 1-(DIORGANOOXYPHOSPHONYL)METHYL-2,4- AND -2.6-DINITRO-BENZENES Patent

JOHN A. MIKROYANNIDIS, inventor (to NASA) (Patras Univ., Greece ) and DEMETRIUS A. KOURTIDES, inventor (to NASA) 12 Dec. 1989 7 p Filed 28 May 1987 Division of US-Patent-Appl-SN-641152, filed 16 Aug. 1984 which is a continuation-in-part of abandoned US-Patent-Appl-SN-522629, filed 12 Aug. 1983 which is a continuation-in-part of abandoned US-Patent-Appl-SN-493864, filed 12 May 1983 (NASA-CASE-ARC-11425-3; US-PATENT-4,886,896; US-PATENT-APPL-SN-054982; US-PATENT-APPL-SN-641152; US-PATENT-APPL-SN-522629; US-PATENT-APPL-SN-493864; US-PATENT-CLASS-558-193; INT-PATENT-CLASS-C07S-9/40) Avail: US Patent and Trademark Office CSCL 07/1

1-(Diorganooxyphosphonyl)methyl-2,4- and 2,6-dinitro- and diamino benzenes are prepared by nitrating an (organophosphonyl)methyl benzene to produce the dinitro compounds which are then reduced to the diamino compounds. The organo group (alkyl, haloalkyl, aryl) on the phosphorus may be removed to give the free acids, (HO)2P(double bond O) single bond. The diamino compounds may be polymerized with dianhydrides or diacyl halides to produce fire and flame resistant polymers which are useful in the manufacture of aircraft structures.

Official Gazette of the U.S. Patent and Trademark Office

N90-23523# United Kingdom Atomic Energy Authority, Harwell (England). National Nondestructive Testing Centre.

CHARACTERISATION OF FATIGUE OF ALUMINIUM ALLOYS BY ACOUSTIC EMISSION. PART 2: DISCRIMINATION BETWEEN PRIMARY AND OTHER EMISSIONS

D. J. BUTTLE and C. B. SCRUBY Sep. 1988 47 p (AERE-R-13303-PT-2) Avail: NTIS HC A03/MF A01

Two series of acoustic emission (AE) measurements were carried out on 7000 series aluminum alloys. The first series (Part 1, Buttle and Scruby, 1989) investigated the material processes responsible for primary AE during fatigue of compact tension specimens, while the objective of the second series of experiments was to distinguish between different emission sources during high cycle fatigue of riveted test coupons. In the second series of experiments primary (crack growth), secondary (fretting of the rivet), and spurious emission events were all detected. These three sources of AE were characterized using 6 parameters: time dependency/frequency content; relationship to applied cyclic load;

principal wave arrival amplitude; reproducibility; location; and radiation pattern. These results are relevant for airframe monitoring as they offer specific criteria for distinguishing primary from other emissions. However, all except the applied cyclic load and principal wave arrival amplitude require sensors and recording systems of high fidelity and bandwidth. As at least two criteria need to be met for reliable identification, dependable discrimination is only possible if special broadband instrumentation is used.

N90-23538# Dayton Univ., OH.

FATIGUE CRACK GROWTH INVESTIGATION OF A TI-6AL-4V FORGING UNDER COMPLEX LOADING CONDITIONS: NATO/AGARD SUPPLEMENTAL ENGINE DISK PROGRAM Interim Report, Jun. 1988 - Oct. 1989

JOHN J. RUSCHAU and PETER A. KRAWCZYK (Wright Research Development Center, Wright-Patterson AFB, OH.) Feb. 1990 68 n

(Contract F33615-88-C-5437; AF PROJ. 2418)

(AD-A220239; UDR-TR-89-114; WRDC-TR-90-4001) Avail: NTIS HC A04/MF A01 CSCL 11/6

Fatigue crack growth rate testing was performed on a Titanium-6 Aluminum-4 Vanadium engine disk forging as part of the SUPPLEMENTAL Engine Disk Program sponsored by the North Atlantic Treaty Organization's Advisory Group for Aerospace Research and Development (NATO/AGARD). Such data were developed under room temperature conditions under a variety of load histories, ranging from constant amplitude with periodic overload to various forms of the TURBISTAN engine spectrum. The effects of each loading condition are examined with respect to fatigue crack growth rates. Crack growth mechanisms are identified for the various load histories based on SEM examinations. Comparisons are made between crack growth rates determined via electric potential methodology and those from fatigue striation measurements.

N90-23571# Edgerton, Germeshausen and Grier, Inc., Idaho Falls, ID. National Engineering Lab.

THREE-DIMENSIONAL ANALYSIS ON FLOW AND TEMPERATURE DISTRIBUTIONS FOR AIRCRAFT FUEL THERMAL STABILITY Interim Report, Aug. 1988 - Jun. 1989 C. H. OH, B. J. MERRILL, and R. P. WADKINS Jun. 1989 70 p

(Contract FY1455-86-N-0657; AF PROJ. 2480) (AD-A219651; WRDC-TR-89-2138) Avail: NTIS HC A04/MF A01 CSCL 21/4

Flow temperature distributions in the Jet Fuel Thermal Oxidation Tester (JFTOT), a device that has been used in thermal stability research of aircraft fuels are presented. The Computational Fluid Dynamics and Chemistry (CFDC) model used is based on the global Arrhenius type surface temperature dependent correlation because of the lack of the existing experimental data. The initial attempt to calculate the deposit thickness and to simulate flow in the JFTOT is very encouraging.

## N90-24430# Sandia National Labs., Albuquerque, NM. EQUILIBRIUM SWELLING OF ELASTOMERIC MATERIALS IN SOLVENT ENVIRONMENTS

PETER F. GREEN Mar. 1990 25 p (Contract DE-AC04-76DP-00789)

(DE90-010164; SAND-90-0421) Avail: NTIS HC A03/MF A01

The equilibrium swelling of silicones, fluorosilicones, VITON and ethylene-propylene-diene (EPDM) elastomers in an environment of the jet fuel JP4 was investigated. The volume of silicone and DPDM elastomers increased by approximately 100 percent when they were placed in a saturated environment of JP4. Conversely, the volume of the fluorosilicone elastomer increased by approximately 15 percent and that of VITON less than 1 percent. In acetone, a commonly used solvent, the equilibrium swelling of VITON and the fluorosilicone elastomer was excessive, on the order of 100 percent, wheras the silicone and EPDM elastomers exhibited small changes in dimensions. Reasons for these observations are discussed in detail. We also present a simple scheme by which one may, qualitatively, determine the

dimensional stability of these elastomers in different solvents if the cohesive energy density of the solvent, which is readily available in a number of handbooks, is known. We also evaluated the vulnerability of some commonly used engineering thermoplastics to JP4. The results are tabulated.

N90-24451# Naval Postgraduate School, Monterey, CA. METALLIZED FUEL PARTICLE SIZE STUDY IN A SOLID FUEL RAMJET M.S. Thesis

JAMES A. NABITY Sep. 1989 62 p

(AD-A220079) Avail: NTIS HC A04/MF A01 CSCL 21/4

Particle size measurements were obtained at the grain exit and nozzle entrance in a solid fuel ramjet combustor using a boron based fuel. The particle size distributions at the aft end of the fuel grain were generally quadra-modal, with mode peaks at 2, 4, 15, and 25 to 45 microns. At the nozzle entrance the distributions were tri-modal, due to the complete oxidation of the 2 micron particles. Sauter mean diameter and the size of the largest agglomerates increased with increasing equivalence ratio (or grain length), indicating that the longer grains result in more surface agglomeration. Combustion efficiency increased with equivalence ratio. A direct correlation of particle size alone with combustion efficiency was not obvious and may require an accurate measurement of particle concentration.

N90-25049\*# Wichita State Univ., KS. Dept. of Aerospace Engineering.

**DEVELOPMENT OF A FINITE ELEMENT BASED DELAMINATION ANALYSIS FOR LAMINATES SUBJECT TO EXTENSION, BENDING, AND TORSION Abstract Only** 

STEVEN J. HOOPER In Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 81-83 Sep. 1989 Avail: NTIS HC A09/MF A02 CSCL 11/4

Delamination is a common failure mode of laminated composite materials. This type of failure frequently occurs at the free edges of laminates where singular interlaminar stresses are developed due to the difference in Poisson's ratios between adjacent plies. Typically the delaminations develop between 90 degree plies and adjacent angle plies. Edge delamination has been studied by several investigators using a variety of techniques. Recently, Chan and Ochoa applied the quasi-three-dimensional finite element model to the analysis of a laminate subject to bending, extension, and torsion. This problem is of particular significance relative to the structural integrity of composite helicopter rotors. The task undertaken was to incorporate Chan and Ochoa's formulation into a Raju Q3DG program. The resulting program is capable of modeling extension, bending, and torsional mechanical loadings as well as thermal and hygroscopic loadings. The addition of the torsional and bending loading capability will provide the capability to perform a delamination analysis of a general unsymmetric laminate containing four cracks, each of a different length. The solutions obtained using this program are evaluated by comparing them with solutions from a full three-dimensional finite element solution. This comparison facilitates the assessment of three dimensional affects such as the warping constraint imposed by the load frame grips. It wlso facilitates the evaluation of the external load representation employed in the Q3D formulation. Finally, strain energy release rates computed from the three-dimensional results are compared with those predicted using the quasi-threedimensional formulation. Author 12

#### **ENGINEERING**

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

#### A90-38854

#### THREE-DIMENSIONAL MEASUREMENT, DISPLAY, AND INTERPRETATION OF FLUID FLOW DATASETS

MINAMI YODA and LAMBERTUS HESSELINK (Stanford University, CA) IN: Three-dimensional visualization and display technologies; Proceedings of the Meeting, Los Angeles, CA, Jan. 18-20, 1989.
Bellingham, WA, Society of Photo-Optical Instrumentation
Engineers, 1989, p. 112-117. refs
(Contract F49620-86-K-0020)

The three-dimensional structure of the flow around a delta wing with tangential leading edge blowing is visualized. The flow is sliced by a scanning laser light sheet into a set of two-diemsnional cross sections, resulting in a set of three-diemnsional data. The light scattered off smoke particles in the flow during a 30 ns laser pulse is imaged onto a high-speed camera. The resulting cross sections are digitized and filtered to reduce noise. Consideration is given to the software package used to threshold the pictures at a prespecified value, stack the thresholded cross-sections, and reconstruct the three-dimensional flow field at that threshold using cubic B-splines. The resulting structures are displayed in stereo pairs and viewed in three dimensions.

DISCRETE FOURIER TRANSFORM WITH HIGH RESOLUTION FOR LOW FREQUENCIES APPLIED TO THE MODAL ANALYSIS OF AIRCRAFT VIBRATION [DYSKRETNE PRZEKSZTALCENIE FOURIERA O DUZEJ ROZDZIELCZOSCI DLA MALYCH CZESTOSCI W ZASTOSOWANIU DO ANALIZY **MODALNEJ DRGAN SAMOLOTOW]** 

FRANCISZEK LENORT Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 118, 1989, p. 14-25. In Polish.

Consideration is given to the avantages and disadvantages of using the FFT in the analysis of mechanical, electronic, and acoustic vibrations. An alternative form of the discrete Fourier transform is proposed in which the resolution in the frequency domain is increased by increasing the quantization density in the time domain. The algorithm for this form of the discrete Fourier transform is presented, and the application of the algorithm in the modal analysis of aircraft vibrations is discussed.

#### **DEVELOPMENT AND APPLICATION OF AN OPTIMIZATION** PROCEDURE FOR SPACE AND AIRCRAFT STRUCTURES

GUENTER KNEPPE, WOLFGANG HARTZHEIM, and GEORG ZIMMERMANN (MBB GmbH, Munich, Federal Republic of Germany) IN: Discretization methods and structural optimization - Procedures and applications; Proceedings of the GAMM Seminar, Siegen, Federal Republic of Germany, Oct. 5-7, 1988. Berlin and New York, Springer-Verlag, 1989, p. 194-201. refs

The optimization procedure MBB-LAGRANGE allows the optimization of homogeneous isotropic, orthotropic, or anisotropic structures as well as fiber-reinforced materials with respect to weight, static, dynamic, aeroelastic, and manufacturing requirements. Design variables are the sizing and geometric dimensions. The development is focused on three main topics: optimization algorithms, optimization models, and structural analysis with sensitivity analysis. Important for practical applications is the integration into the CAE-environment by the use of standard interfaces. Author

#### A90-39276#

### OPTIMUM DESIGN OF COMPOSITE WING STRUCTURES SUBJECTED TO DISPLACEMENT CONSTRAINTS

CHUANQI HUANG and XIN QIAO (Nanjing Institute of Aeronautics, People's Republic of China) Acta Materiae Compositae Sinica (ISSN 1000-3851), vol. 6, June 1989, p. 84-89. In Chinese, with abstract in English.

A minimum weight design on a composite aircraft wing structure subjected to displacements and size constraints is conducted. The ply-thicknesses of composite skin are stimulated by polynomials. The FEM is used in the structural analysis. A feasible direction approach is applied to the optimum procedures. The coefficients of polynomials and the thicknesses or sectional areas of finite elements are taken as design variables. Examples of a composite material box sector and a composite material wing structure show satisfactory results.

#### A90-39298#

### ANALYSIS OF AEROELASTIC DIVERGENCE FOR THE SLENDER FLIGHT VEHICLES

WENJUN CHEN (Beijing Precision Machinery Overall Design, People's Republic of China) Chinese Society of Astronautics, Journal (ISSN 1000-1328), no. 1, 1989, p. 46-50. In Chinese, with abstract in English.

This paper generalizes an aeroelastic divergence analysis of a rocket applied by two point aerodynamic lifts in two senses to extend the number of the point aerodynamic lifts on a slender flight vehicle from 2 to N. The effect of aerodynamic interference is also included.

Author

**A90-39725\***# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

#### AN INTRODUCTION TO CHAOS THEORY IN CFD

THOMAS H. PULLIAM (NASA, Ames Research Center, Moffett Field, CA) AlAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 21st, Seattle, WA, June 18-20, 1990. 26 p. refs (AIAA PAPER 90-1440)

The popular subject 'chaos theory' has captured the imagination of a wide variety of scientists and engineers. CFD has always been faced with nonlinear systems and it is natural to assume that nonlinear dynamics will play a role at sometime in such work. This paper will attempt to introduce some of the concepts and analysis procedures associated with nonlinear dynamics theory. In particular, results from computations of an airfoil at high angle of attack which exhibits a sequence of bifurcations for single frequency unsteady shedding through period doublings cascading into low dimensional chaos are used to present and demonstrate various aspects of nonlinear dynamics in CFD.

#### A90-39784#

### FLOW VISUALIZATION VIA LASER-INDUCED REFLECTION FROM BUBBLE SHEETS

C. MAGNESS, T. UTSCH, and D. ROCKWELL (Lehigh University, Bethlehem, PA) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1199, 1200. Research supported by USAF, NSF, and U.S. Navy. refs

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The structure of steady and unsteady aerodynamic flows can be characterized by generating fluid markers at desired locations in the flow and tracking them in three-dimensional space. The hydrogen bubble technique allows localized injection of both continuous and interrupted fluid markers. Its advantages and limitations are described in the works of Schraub et al. (1965) and Lusseyran and Rockwell (1985). The technique described herein employs multiple sheets of hydrogen bubbles in conjunction with laser sheet illumination. Arbitrary cross sections of the unsteady flow past an oscillating delta wing can be characterized. By using a phase-referencing technique, it is possible to relate the visualization at various cross sections along the wing at a given value of instantaneous angle of attack.

#### A90-39786#

### BOUNDARY-ELEMENT SHAPE OPTIMIZATION SYSTEM FOR AIRCRAFT STRUCTURAL COMPONENTS

SUNIL SAIGAL and J. H. KANE (Worcester Polytechnic Institute, MA) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1203, 1204.

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An efficient system for the shape optimization of aircraft components based on the boundary-element method is presented. The design sensitivities required by the numerical optimization algorithm are obtained economically by implicit differentiation of the boundary integral equations. The mesh generation and regeneration is done using a parametric and auxiliary geometry concept that allows the original mesh to remain adequate for a wide range of subsequent evolving geometries as the optimization proceeds. The overall system represents an efficient coupling of the geometry definition, mesh generation and regeneration, boundary-element analysis, design sensitivity analysis, geometric consistency maintenance, and numerical optimization. Numerical examples are presented.

#### A90-39977#

### CONSIDERATIONS OF RELIABILITY DESIGN FOR ROTORCRAFT

BARRY S. SPIGEL (U.S. Army, Aviation Applied Technology Directorate, Fort Eustis, VA) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 21 p. refs

The paper discusses the determination of fatigue reliability based on the assumption that the weakest spot is not significantly weaker than the surrounding material and that the cycles to failure are related to the average strength of the specimen. Stress-strength interference (SSI) theory is reviewed and the general expression for reliability in the SSI model is expanded to include time dependency. Random applications of load cycles are examined and reliability expressions are obtained for the cases of aging, cyclic damage, and cumulative damage. The fatigue reliability of a hypothetical rotorcraft component is obtained, assuming cumulative damage and random load cycles based on a typical rotorcraft mission and actual loads data.

#### A90-39979#

### STRESS CONCENTRATION FACTORS - COMPARISON OF THEORY WITH FATIGUE TEST DATA

RUSS BOOCOCK and LYNDON LAMBORN (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 5 p. refs

The stress concentration factors from photoelastic tests and linear elastic finite element analysis are compared with the results of fatigue tests on flawed 9310 gear steel specimens. The flaws consisted of an electron beam impingement and undercut to varied depths and a simulated corrosion pit. The limitations of finite element-derived stress concentration factors are discussed. It is found that the photoelasticity method produces the best estimates of absolute stress concentration.

#### A90-39980#

#### RETIREMENT LIVES OF ROLLING ELEMENT BEARINGS

MICHAEL C. FRENGLEY (McDonnell Douglas Helicopter Co., Structures Dept., Mesa, AZ) IN: Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society, 1989, 8 p.

Consideration is given to methods for maximizing the reliability of roller bearings in the drive, control, and rotor systems of rotorcraft. It is suggested that a safe life based on initial spalling is not a suitable method for determining retirement life. Traditional life prediction methods are discussed. The expected life of a main rotor thrust bearing is examined. Emphasis is placed on the redesign of a tail rotor swashplate using a duplex ball bearing to

reduce the number of field incidents leading to loss of tail rotor control. The importance of designing installations that are tolerant of easily detectable bearing damage is stressed.

#### A90-39987#

#### POTENTIAL APPLICATION OF AUTOMOTIVE FATIGUE **TECHNOLOGY IN ROTORCRAFT DESIGN**

PETER J. FURMAN (MTS Systems Corp., Minneapolis, MN) Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989. Alexandria, VA, American Helicopter Society. 1989, 9 p. refs

Recent changes in fatigue design, analysis, and testing techniques for rotorcraft design and testing programs are reviewed. Consideration is given to the ground vehicle development process, durability assessment, and design techniques to ensure durability. Technologies for analyzing and testing durability are discussed, including service toads, laboratory simulations, materials testing, and damage analysis.

#### A90-40032

#### FINITE ELEMENT ANALYSIS OF COMPOSITE PANEL **FLUTTER**

L. C. SHIAU, D. H. TSAY, and L. J. LEE (National Cheng Kung University, Tainan, Republic of China) IN: ECCM-3 - European Conference on Composite Materials, 3rd, Bordeaux, France, Mar. 20-23, 1989, Proceedings. London, Elsevier Applied Science, 1989, p. 341-346. Sponsorship: National Science Council of the Republic of China. refs

(Contract NSC-77-0210-D006-20)

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A finite element approach to the analysis of composite panel flutter is developed using a linear small-deflections theory and a quasi-steady aerodynamic theory. Flutter solutions are obtained for symmetric laminated plates with material properties typical of graphite-epoxy and boron-epoxy composites. The effects of the fiber orientations, stacking sequences, aspect ratio, and panel configuration were investigated. It is shown that the flutter stability of a panel can be improved if the fiber is properly orientated.

I.S.

#### A90-40109 DYNAMIC FLIR SIMULATION IN FLIGHT TRAINING RESEARCH

RONALD J. EVANS (Dayton, University, Higley, AZ) and PETER M. CRANE (USAF, Human Resources Laboratory, Williams AFB, IN: Imaging infrared: Scene simulation, modeling, and real image tracking; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 11-22. refs Copyright

A dynamic infrared scene simulation system has been developed to support research on simulation requirements for FLIR sensors in flight aircraft. The software, data base, and flight simulator integration are examined along with the postprocessing of simulated FLIR imagery. The validation and shortcomings of the simulated FLIR imagery are addressed. A system for investigating the fidelity requirements for simulation of FLIR in support of a training program is described. C.D.

#### PERFORMANCE OF FULL COLOR ACTIVE-MATRIX-LCD IN THE COCKPIT ENVIRONMENT

ADI ABILEAH, VINCENT CANNELLA, and ZVI YANIV (Ovonic Imaging Systems, Inc., Troy, MI) IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 131-142. refs Copyright

The performance of a display designed for cockpit applications is discussed. This PIN diode driven active matrix LCD is capable of operating over a wide temperature range (-40 C to +85 C). Measurements at different ambient-light levels are presented, both for diffused and specular reflections. Contrast ratios, reflections, and color measurements at different vieweing angles are used for discrimination index calculations. The high performance of the display with special surface treatment in the cockpit environment is discussed based on those measurements and calculations.

**Author** 

#### A90-40393

#### POLYSILICON ACTIVE-MATRIX LIQUID CRYSTAL DISPLAYS FOR COCKPIT APPLICATIONS

BRIAN W. FAUGHNAN, ROGER G. STEWART, ALFRED C. IPRI, WILBER C. STEWART, W. RONALD ROACH (David Sarnoff Research Center, Princeton, NJ) et al. IN: Display system optics II; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 143-154. Research supported by USAF. refs

Copyright

A design analysis for two types of avionic LCD display is presented. The analysis of a 1 x 1 in., 1000 x 1000 pixel helmet mounted display and a 8 x 8 in. 1024 x 1024 suppixel color cockpit display shows that the performance requirements for the displays can be met with polysilicon device perforance and photolithography equipment. A 192 x 192 active matrix LCD array with integrated data and select scanners has been designed to demonstrate the use of polysilicon technology in cockpit displays.

A90-40560\*# McDonnell-Douglas Research Labs., Saint Louis, MO.

#### **EXPERIMENTAL INVESTIGATION OF TERMINAL SHOCK** SENSORS IN MIXED-COMPRESSION INLETS

MIKLOS SAJBEN, JOHN F. DONOVAN, and MARTIN J. MORRIS (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs (Contract NAS3-25446)

(AIAA PAPER 90-1931) Copyright

This paper describes experimental investigations of devices designed for the nonintrusive detection of terminal shock location in mixed-compression inlets at high supersonic flight speeds. Systems based on sensing wall pressures by an array of wall-mounted transducers were selected for detailed study. Pressure signals were processed by three different methods: (1) interpretation of instantaneous pressure distributions. (2) detection of the turbulent intensity amplification occurring at the shock, and (3) determination of the upstream limit to which a search-tone, introduced at the downstream end of the channel, can propagate. The first two of these methods were tested in real time. The third method appeared feasible for weak shocks only; at high shock strengths, propagation upstream of the source could not be detected. Author

### A90-40590# CFD APPLICATIONS IN AN AEROSPACE ENGINE TEST

G. K. COOPER and W. J. PHARES (Sverdrup Technology, Inc., Arnold AFB, TN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 15 p. (AIAA PAPER 90-2003)

The uses of CFD in aerospace engine testing is addressed. Engine test facility CFD codes, the Ingrid grid generator, and the PARC flow solver are described. The results of CFD applications to rocket test facility performance, rocket nozzle failure analysis, and inlet icing test design are reviewed. Work in progress using CFD on freejet testing calibration, hypersonic probe calibration, and rocket stage separation dynamics is discussed.

#### A90-40613#

#### PLANET GEAR SLEEVE SPINNING ANALYSIS

E. S. RODRIGUEZ, III, L. DUONG, and S. ARVANITIS (Pratt and Whitney Canada, Longueuil) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. (AIAA PAPER 90-2154) Copyright

A 3-D finite element analysis of the planet gear and sleeve system under gear loads and centrifugal load, which are reacted by a journal bearing pressure load is presented. A planet gear in which spinning has been observed was analyzed. The results of the analysis suggested that the sleeve should be thickened and the interference fit be increased. Due to the high compressive stresses, induced by the high interference fits required to fix the problem, stronger sleeve materials were developed. Tests were carried out to substantiate the analysis, these were: (1) measurement of the coefficient of friction, (2) measurement of plastic deformation of the sleeve due to the interference fit, and (3) engine tests to verify the analytical prediction. The latter tests were carried out under similar conditions that caused spinning and the results confirm the prediction.

#### A90-40641#

### NON-STEADY FLOW LOSS MECHANISMS ASSOCIATED WITH VANELESS DIFFUSERS

M. I. ANJUM and C. A. GARRIS (George Washington University, Washington, DC) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs (AIAA PAPER 90-2508) Copyright

In small scale turbomachines, there are some distinct advantages to reducing the solidity of the rotor so that the traditional cascade reduces to a small number of nozzles equally spaced around the periphery. Vaneless diffusers followed by volute-shaped collectors have been investigated as a means to recover the kinetic energy of the flow exiting through the rotors with small numbers of vanes. During the course of this research, vaneless diffusers have been tested to provide a basic understanding of how an extremely nonuniform and nonsteady flow converts into a uniform and steady flow. Experiments have been conducted to determine the loss in stagnation pressure and the rise in static pressure of the flow passing through various locations of vaneless diffusers and collectors.

# A90-40650 RECONSTITUTION OF CRACK GROWTH FROM FRACTOGRAPHIC OBSERVATIONS AFTER FLIGHT SIMULATION LOADING

O. PARTL (Ceske Vysoke Uceni Technicke, Prague, Czechoslovakia) and J. SCHIJVE (Delft, Technische Universiteit, Netherlands) International Journal of Fatigue (ISSN 0142-1123), vol. 12, May 1990, p. 175-183. refs

Fatigue crack propagation was studied under random flight simulation loadings and two types of programmed flight sequences. Tests were carried out on 2024-T3 specimens. Fractographic observations in a SEM were made for the reconstitution of crack growth curves. Five types of flights from a total of ten types could be recognized by their characteristic striation patterns, and crack extensions in these flights were determined. The discussion includes the effect of flight sequence and marker loads. Author

#### A90-40712

### DIGITAL CONTROL OF MAGNETIC BEARINGS SUPPORTING A MULTIMASS FLEXIBLE ROTOR

F. J. KEITH, R. D. WILLIAMS, P. E. ALLAIRE (Virginia, University, Charlottesville), and R. M. SCHAFER (Tell Laboratories, Inc., Mishawaka, IN) (STLE, Annual Meeting, 44th, Atlanta, GA, May 1-4, 1989) STLE Tribology Transactions (ISSN 0569-8197), vol. 33, July 1990, p. 307-314. Research supported by the Center for Innovative Technology of Virginia and U.S. Army. refs Copyright

This paper considers the characteristics of magnetic bearings used to support a three mass flexible rotor operated at speeds up to 14,000 RPM. The magnetic components of the bearing are of a type reported in the literature previously, but the earlier analog controls have been replaced by digital ones. Analog-to-digital and digital-to-analog converters and digital control software were installed in a PC. This PC-based digital controller was used to

operate one of the magnetic bearings on the test rig. Basic proportional-derivative control was applied to the bearings, and the bearing stiffness and damping characteristics were evaluated. Particular attention is paid to the frequency dependent behavior of the stiffness and damping properties, and comparisons are made between the actual controllers and ideal proportional-derivative control.

#### A90-40716

### ANALYSIS OF THERMAL GRADIENT EFFECTS IN OIL RING SEALS

STEVEN W. REEDY and R. GORDON KIRK (Virginia Polytechnic Institute and State University, Blacksburg) (STLE, Annual Meeting, 44th, Atlanta, GA, May 1-4, 1989) STLE Tribology Transactions (ISSN 0569-8197), vol. 33, July 1990, p. 425-435. refs Copyright

The analysis of ring type seals is of great concern for the designer of high speed and high pressure contrifugal gas compressors. Computers now play a major role in allowing for a quick evaluation of the floating ring seal. Since the accuracy of the rotor shaft stability evaluation depends on the validity of the dynamic seal characteristics, every step in the evaluation must be carefully scrutinized and updated to include the latest in theory and practical operating experience. This paper presents the theory and results of one such extension to the current published analysis of oil ring seals. The new analysis includes the influence of the sealing fluid temperature gradients on the leakage flow rate and seal dynamic characteristics for multi-land ring configurations. Using classical short bearing theory but allowing for temperature and pressure dependent viscosity variations across the seal, the resulting pressure profiles have been determined numerically utilizing a finite difference solution technique. This paper discusses the method used to calculate the flow and pressure profiles for oil seals, their influence on the seal dynamic characteristics, and the importance of their consideration on actual turbomachinery stability. Author

#### A90-40929#

### LASER DOPPLER VELOCIMETRY INVESTIGATION OF SWIRLER FLOWFIELDS

K. D. KIHM (Texas A & M University, College Station), NORMAN CHIGIER (Carnegie-Mellon University, Pittsburgh, PA), and FRANK SUN (Parker Hannifin Corp., Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 364-374. Research supported by the Parker Hannifin Corp. refs Copyright

Detailed measurements of mean and turbulent velocity components and turbulent shear stress components have been made for jet flows of 20-, 40-, and 60-deg swirlers for 750 and 1500 mm H2O supply air pressure conditions. When the mean velocity components are normalized based on the maximum axial velocity at the nozzle exit, there is a very close similarity between normalized profiles at different supply pressures for each swirler. The recirculation zone, which depends on the degree of swirl and the swirler geometry, is not well established near the nozzle exit for the case of high ratio of the inner to outer radius of the swirler and of low degree of swirl. This can create a serious deposition problem of fuel droplets onto the hub surface. Measurements of turbulent velocity components demonstrate that each jet can be considered to be close to local isotropic turbulence except at the nozzle exit, where the magnitudes and decay of the fluctuations depend strongly on flow direction.

## A90-40930\*# California Univ., Irvine. SYMMETRY ASSESSMENT OF AN AIR-BLAST ATOMIZER SPRAY

V. G. MCDONNELL, C. D. CAMERON, and G. S. SAMUELSEN (California, University, Irvine) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 375-381. refs (Contract NAS3-24350; F08635-86-C-0309) Copyright

This study represents an evaluation of the extent to which conventional and recently introduced modern diagnostics can

assess the symmetry of sprays formed by three atomizers of identical design. The conventional diagnostics include sheet-lit photography, patternation, and laser diffraction. The modern diagnostic is laser interferometry (phase Doppler). Symmetry is assessed in ambient conditions for four atomizer orientations, and comparisons are made between the diagnostic techniques. The results demonstrate that conventional and modern diagnostics are consistent in the assessment of symmetry, patternation and phase Doppler are most effective in establishing symmetry of mass flux, and phase Doppler, although more tedious to employ, provides the additional information necessary to establish the sources of detected asymmetries in terms of nonuniformities in droplet velocities, size distributions, volume flux, and concentration.

Author

#### A90-40938#

### VISCOUS FLOW AROUND A PROPELLER-SHAFT CONFIGURATION WITH INFINITE-PITCH RECTANGULAR BLADES

H. T. KIM and F. STERN (lowa, University, lowa City) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 434-444. refs

(Contract N00014-85-K-0347; N00014-89-J-1342)

Copyright

A viscous-solution method is set forth for calculating incompressible propeller flowfields. An overview of the computational method is given, and some example results for both laminar and turbulent flow are presented and discussed with regard to the flow physics for the idealized geometry of a propeller-shaft configuration with infinite-pitch rectangular blades. It is shown that the flow exhibits many of the distinctive features of interest, including the development and evolution of the shaft and blade boundary layers and wakes and tip, passage, and hub vortices. Comparisons are made with results from a lifting-surface, propeller-performance program to aid in evaluating the present method, which show that the method accurately predicts the blade loading, including viscous effects, and clearly displays the ability to resolve the viscous regions in distinction from the inviscid-flow approach.

#### A90-40939#

### NONLINEAR FINITE-ELEMENT ANALYSIS TO PREDICT FAN-BLADE DAMAGE DUE TO SOFT-BODY IMPACT

N. F. MARTIN, JR. (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 445-450. Previously cited in issue 18, p. 3083, Accession no. A88-44774. refs Copyright

#### A90-40940#

### FINITE-ELEMENT ANALYSIS OF LARGE SPUR AND HELICAL GEAR SYSTEMS

S. SUNDARARAJAN and B. G. YOUNG (Pratt and Whitney Canada, Longueil) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 451-454. Previously cited in issue 20, p. 3240, Accession no. A87-45379. Copyright

#### A90-40943#

### THREE-COMPONENT LDA MEASUREMENTS IN AN AXIAL-FLOW COMPRESSOR

CHRISTOPHER J. CHESNAKAS and CLINTON L. DANCEY (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, July-Aug. 1990, p. 474-481. Research sponsored by the Universal Energy Systems. Previously cited in issue 18, p. 3068, Accession no. A88-44660. refs

(Contract F33615-85-C-2575)

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#### A90-41073

USE OF PULSE RADARS FOR HELICOPTERS DETECTION - DESIGN CONSTRAINTS

DAVO ELIAS DE LOS REYES, ANTONI ELIAS FUSTE, and J. C. ESCANES (Cataluna, Universidad Politecnica, Barcelona, Spain) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 2. Boulogne-Billancourt, France, RADAR 89, 1989, p. 529-534. Copyright

Problems in helicopter detection are discussed, and a method of detection based on the Doppler effect created by the main rotor blades is presented. An analytical study is carried out on the echoes originating from the rotor blades. To remedy the problems of finite pulse radar observation time, spectral estimation techniques are used for pulse integration. Several computerized simulations are presented in order to validate the proposed method. S.A.V.

#### A90-41104

### SUPERSONIC FLUTTER OF SHEAR DEFORMABLE LAMINATED COMPOSITE FLAT PANELS

V. BIRMAN (Missouri-Rolla, University, Engineering Education Center, Saint Louis) and L. LIBRESCU (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Sound and Vibration (ISSN 0022-460X), vol. 139, June 8, 1990, p. 265-275. refs Copyright

Flutter-type instability of cross-ply shear deformable composite flat panels exposed to a supersonic flow is analyzed. The two-dimensional static aerodynamic approximation and a higher order transverse shear deformation theory for the structural plate model are used. Comparisons of the results obtained in this framework with those derived within their first order transverse shear deformation and classical (Kirchhoff) counterparts are presented and a number of conclusions concerning their range of applicability are outlined. The results underline the strong effect played by transverse shear deformation and transverse normal stress, as well as by the higher order effects on the flutter instability of panels made of advanced composite materials.

**A90-41163\***# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### CFD PROPELS NASP PROPULSION PROGRESS

LOUIS A. POVINELLI (NASA, Lewis Research Center, Cleveland, OH), DOUGLAS L. DWOYER (NASA, Langley Research Center, Hampton, VA), and MICHAEL J. GREEN (NASA, Ames Research Center, Moffett Field, CA) Aerospace America (ISSN 0740-722X), vol. 28, July 1990, p. 26, 27, 86. Copyright

The most complex aerothermodynamics encountered in the National Aerospace Plane (NASP) propulsion system are associated with the fuel-mixing and combustion-reaction flows of its combustor section; adequate CFD tools must be developed to model shock-wave systems, turbulent hydrogen/air mixing, flow separation, and combustion. Improvements to existing CFD codes have involved extension from two dimensions to three, as well as the addition of finite-rate hydrogen-air chemistry. A novel CFD code for the treatment of reacting flows throughout the NASP, designated GASP, uses the most advanced upwind-differencing technology.

#### A90-41201#

## RECENT PROPELLER DEVELOPMENT AND STUDIES CONDUCTED AT ONERA [EVOLUTIONS RECENTES DES HELICES ET ETUDES MENEES A L'ONERA]

F. JOUAILLEC (ONERA, Chatillon, France) (DRET and Direction des Constructions Navales, Seminaire Helices Marines, Chamonix, France, Mar. 14-16, 1990) ONERA, TP no. 1990-16, 1990, 31 p. In French. Research supported by DRET, Direction des Constructions Aeronautiques, and DCN. refs (ONERA, TP NO. 1990-16)

Based on recent research, the common interests that exist between aeronautical and naval propeller design is presented. A review of aeronautical propeller evolution up to the introduction of unducted fan technology is offered, along with a history of the marine propeller. Specific areas covered include airflow calculation through Euler three-dimensional methodology, acoustic calculations for discrete-frequency noise of helicopter rotors, and vibration

studies of aircraft and ship propellers. Similarity of test results and possible commonality applications for the two propeller types are discussed.

R.E.P.

#### A90-41334

### APPLICATION OF FRACTURE MECHANICS TO MICROSCALE PHENOMENA IN ELECTRONIC ASSEMBLIES

ALAN H. BURKHARD (USAF, Wright-Patterson AFB, OH), JAMES M. KALLIS, LARRY B. DUNCAN (Hughes Aircraft Co., El Segundo, CA), MELVIN F. KANNINEN (Southwest Research Institute, San Antonio, TX), and DAVID O. HARRIS (Failure Analysis Associates, Palo Alto, CA) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 977-988. refs (Contract F33615-87-C-3403) Copyright

Avionics assemblies are complex hybrid structures formed out of many dissimilar materials which have been joined together to accomplish the desired electronic function. The structural integrity of these complex microscale structures is critical to the reliability of the electronic system. This paper discusses a research program to investigate the application of fracture mechanics techniques for life prediction to these small but highly loaded structures. Author

#### A90-41335

### ESTIMATION OF FATIGUE CRACK GROWTH IN PATCHED CRACKED PANELS

RAMESH CHANDRA (Maryland, University, College Park) and R. SUNDER (National Aeronautical Laboratory, Bangalore, India) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 989-997. refs Copyright

A method is proposed for predicting fatigue crack growth in unpatched and patched panels under conditions of flight simulation loading. The method is demonstrated for center-crack plates with and without symmetric composite patches, and the predicted crack growth rates are found to be in good agreement with experimental data. It is shown that the stress intensity factor due to residual stresses is essential in predicting crack growth for patched cracked plates adhesively bonded with a high-temperature curing system.

V.L

#### A90-41753#

### CRITICAL REVIEW OF DESIGN PHILOSOPHIES FOR RECENT TRANSPORT WIG EFFECT VEHICLES

SHIGENORI ANDO (Nagoya University, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 33, May 1990, p. 28-40. refs

The design philosophies behind various concepts of Wing-In-Ground effect vehicles are reviewed. Consideration is given to the Power Augmented Ram concept, the ability of Off Ground Effect flight, attitude stability, the form of the main wing, aspect ratio, alleviation of wave impact load, allowable altitude at In Ground Effect flight and wave height, block distance, and speed and wing loading.

### A90-41768

### TOWARD TOTAL QUALITY IN INDUSTRY [VERS LA QUALITE TOTALE DANS L'INDUSTRIE]

PIERRE ANDRE (SNECMA, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 139, 1989, p. 52-60. In French.

Copyright

A total quality management methodology is described, and then illustrated by examples from the aircraft industry. In particular, the application of this methodology to SNECMA engines has been shown to be effective.

B.J.

#### A90-41987#

### COMPUTATION OF FLOW THROUGH A CENTRIFUGAL IMPELLER WITH TIP LEAKAGE

PRAKASH BANSOD (Pratt and Whitney Canada, Mississauga) and CHAE M. RHIE (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. refs

(AIAA PAPER 90-2021) Copyright

A numerical solution was obtained for the flow field through a fully-bladed centrifugal impeller. The steady-state Navier-Stokes equations were solved using a pressure-based implicit procedure. A two equation turbulence model was used with wall functions. The method was applied to a centrifugal impeller geometry suitable for turboprop or small turbofan aircraft engines. Attention was paid to the simulation of the tip leakage flow from the pressure side to the suction side of the blade. An appropriate grid was used to represent the region between the blade tip and the stationary casing. The results showed that the predicted flow, including the expected tip vortex adjacent to the suction surface and casing, was qualitatively correct. The results were validated against experimental static pressure distribution on the casing for which good agreement was obtained.

#### A90-41997#

### EVALUATION OF SOLID LUBRICANT POWDER DELIVERY SYSTEM FOR TURBINE BEARING LUBRICATION

S. A. BARBER (Battelle Memorial Institute, Columbus, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. (Contract F33615-86-C-2623)

(AIAA PAPER 90-2046) Copyright

The paper describes a technique for deliverig small measurable quantities of powdered lubricant. The technique employs a slowly rotating scraper blade which removes particulate from a compacted slug of powder and introduces the powder into a carrier air stream. The device was used to deliver quantities of cesium oxythiomolybdate at rates ranging from 2 to 20 gms/hour. This technique shows promise as a possible delivery mechanism for solid lubricants.

#### A90-41999#

### HIGH TEMPERATURE POWDER LUBRICATED DAMPERS FOR GAS TURBINE ENGINES

H. HESHMAT and J. F. WALTON (Mechanical Technology, Inc., Latham, NY) AlAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. Research sponsored by USAF. refs

(AIAA PAPER 90-2048) Copyright

This paper presents a novel powder lubricated rotor bearing system damper concept for use in high temperature, high-speed rotating machinery such as advanced aircraft gas turbine engines. Sub-scale tests of a damper segment were performed to evaluate the feasibility of the high temperature damper concept at temperatures to 800 F and speeds to 10,000 RPM. These tests have shown that the introduction of a lubricating powder into the contact area between the nutating disk and a friction pad has two desirable effects. First, wear is minimized or eliminated, greatly extending damper life. Second, the introduction of powder between the two damper surfaces modifies the energy dissipation mechanism. The shearing of the powder in the contact area produces a damping force that more closely resembles that found in a hydrodynamic damper than that found in a classical Coulomb friction damper. The theoretical model that has been developed is based on a quasi-hydrodynamic lubrication theory and is also presented.

#### A90-42020#

# THE EFFECT OF CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE ON THE DOWNSTREAM DEVELOPMENT OF TWIN JETS IN A CROSSFLOW. II - INTERFERENCE EFFECTS OF ANGULARLY DISPLACED JETS

R. G. DIMICCO, P. J. DISIMILE (Cincinnati, University, OH), and

D. FABRIS AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (AIAA PAPER 90-2107) Copyright

This experimental study focuses on the interaction between two circular jets exhausting into an otherwise undisturbed crossflow. Flow visualization has been used to study the penetration of twin jets transversely injected into a crossflow. Over the jet-spacing/diameter range tested, 2.7 to 12.1, the momentum flux ratio appears not to play a role in the depth penetration as the angular orientation is changed. This observation seems not to be true for the largest spacing tested at the lowest momentum ratio. At the smallest spacing tested, S/D = 2.7, constructive interference dominates as the jets are rotated from their side-by-side configuration to 90 deg. All other jet spacings show a mix of constructive and destructive interference as the angular orientation is changed.

#### A90-42037#

### COMPUTATION OF MULTIPLE NORMAL SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTIONS

B. F. CARROLL (Florida, University, Gainesville) and J. C. DUTTON (Illinois, University, Urbana) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 11 p. Research supported by the U.S. Navy and USAF. refs (AIAA PAPER 90-2133) Copyright

A numerical investigation of a Mach 1.61 multiple normal shock wave/turbulent boundary layer interaction has been completed. The computations used the explicit, time-dependent, second-order accurate MacCormack scheme to solve the mass averaged Navier-Stokes equations. Turbulence was modeled via the Baldwin-Lomax algebraic model and the Wilcox-Rubesin two-equation model. The computation with the Wilcox-Rubesin model was able to capture the major features of the normal shock train and accurately predicted the flow reacceleration mechanisms which occur. This computation failed to accurately predict the level of flow separation under the first shock. The Baldwin-Lomax computation displayed only a limited ability to capture the features of this shock train flow.

#### A90-42040#

# **EVALUATION OF BRUSH SEALS FOR LIMITED-LIFE ENGINES**RAYMOND E. CHUPP (Teledyne CAE, Toledo, OH) and PAUL NELSON (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research supported by Teledyne CAE. refs (Contract F33615-88-C-2836)

(AIAA PAPER 90-2140)

An experimental investigation has been conducted to ascertain the benefits of replacing conventional labyrinth seals with brush seals in small, limited-life gas turbine engines; both subsonic and supersonic conditions have been simulated in these tests. Brush seals are found to yield significant improvements over labyrinth seals, with a factor-of-three (or better) reduction in leakage flow. While brush seals exhibit an initial wear-in period, their leakage-reduction performance is sustained over periods exceeding most limited-life engine applications. Seal design modifications aimed at reducing fabrication costs did not reduce sealing performance.

#### A90-42041#

#### GAS TURBINE ENGINE BRUSH SEAL APPLICATIONS

G. F. HOLLE and M. R. KRISHNAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p.

(Contract N00140-88-C-RE04; F33615-88-C-2846)

(AIAA PAPER 90-2142) Copyright

The evident value of brush seals for significantly improving the efficiency and the behavior of gas turbine engine cooling and leakage airflow has been substantiated by a program of bench and engine testing. Initial cold rig tests produced a performance and design algorithm that identified geometry variations which

enhance the brush seal leakage and endurance characteristics. Advanced brush seal designs with new seal and journal materials have been tested recently in a high temperature rig. The results of these rig tests are discussed in this paper. Gas turbine engine applications were also being pursued concurrently with the bench tests. At 14 stage advanced compressor for component and engine testing was completely equipped with hub interstage brush seals. Brush seals have also been successfully tested in the turbine sections of a 1200 shp class and a 6000 shp class of engines. Allison has plans to prudently incorporate air-to-air brush seals into the internal flow systems of several advanced commercial and military engines.

#### A90-42043#

### THE INVESTIGATION OF HEAT TRANSFER IN COOLED BLADES OF GAS TURBINES

V. A. GORELOV, M. M. GOIKHENBERG, and V. A. MALKOV (Lyulka Scientific and Production Association SATURN, Moscow, USSR) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p. (AIAA PAPER 90-2144) Copyright

The paper is devoted to investigation of internal heat transfer and cooling effectiveness in gas turbines cooled blades. On both sides the experimental models and blades had systems of parallel ribs and channels. Between the channels of the two sides an angle was formed. The investigation of heat transfer was carried out by the method of calorimetry in melted Zn. The dependences of heat transfer and hydraulic resistance on the angle were obtained. The cooling effectiveness was also studied in the installations for external blowing of the models and the blades by gas flow. The results for the models having a symmetric profile are in satisfactory agreement with the data for the blades having a real profile of gas turbines blades.

#### A90-42048#

### GEARBOX SYSTEM DESIGN FOR ULTRA-HIGH BYPASS ENGINES

KAYAALP BUYUKATAMAN and STEPHEN A. WILTON (GE Aircraft Engines, Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs

(AIAA PAPER 90-2152) Copyright

The design of the gearbox system for advanced ultrahigh bypass engines (UBEs) is investigated, using a system simulation to select the optimal gearbox configuration and to accurately predict the system's dynamics and the dynamic loads. The results of the conceptual study showed that, the most appropriate solution for high-efficiency UBE applications exceeding 50,000 shp, is the planetary, double helical star arrangement with journal bearings. The studies to date indicate that such a gearbox can be mechanically designed to survive in the defined environment by using today's materials, lubricants, and design tools. I.S.

#### A90-42052#

### NUMERICAL ANALYSIS OF THE FLOWS IN ANNULAR SLINGER COMBUSTORS

S. HUEBNER and T. EXLEY (Teledyne CAE, Toledo, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. refs (AIAA PAPER 90-2164) Copyright

Improved gas-turbine combustor design techniques are developed through the application of CFD flow predictions. The conservation equations of mass, momentum, and energy are solved using the finite-volume approach of Spalding. The geometry is a three-dimensional region of cyclic symmetry for a selected annular slinger combustor of reasonable performance. The flow is assumed nonreacting, isothermal, and turbulent. Mixing of the dilution jet stream with the bulk combustor flow is simulated by assuming different inlet temperatures for the two mass sources and noting the temperature profile at the combustor exit plane. A flow visualization experiment is performed on cold flow conditions and reasonably corroborates the CFD predictions.

#### A90-42061#

#### BONDED AIRFOIL ATTACHMENTS - A PATH TO ROTOR STRUCTURAL EFFICIENCY

R. R. CAIRO and S. D. JENKEL (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 6 p.

(AIAA PAPER 90-2177) Copyright

This paper will address analytical trade studies aimed at reducing turbine rotor weight comparing bonded attachments to conventional two-tooth firtree attachments. The studies highlight the impact of attachment configuration on disk geometry, weight, and rotor speed. Implicit in the studies is the issue of having a reasonable disk bore width for subsequent heat treatment and retention of mechanical properties. Also included are typical fabrication processes and demonstrated experience. A typical bonded attachment for an LPT will be discussed. Rotor validation spin testing will also be discussed, including test experience with a small engine rotor.

#### A90-42067#

#### FURTHER VALIDATION OF A SEMI-ANALYTICAL APPROACH FOR FUEL INJECTORS OF DIFFERENT CONCEPTS

N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. refs (AIAA PAPER 90-2190) Copyright

A recently developed semi-analytical approach has been used to evaluate the spray characteristics of two significantly different airblast atomizers. The liquid is injected through a number of fine holes into a swirling airstream in the first atomizer, while the second design incorporates a short prefilming device. The calculation approach addresses the processes of liquid preparation within the atomizer and its subsequent breakup in the atomizer flow domain through a disturbance wave growth concept. The measurements of these atomizers covered wide ranges of air/fuel ratio and air pressure drop, and four different liquids were employed in the tests. The calculated mean drop size and drop size distribution for the sprays agreed fairly well with the data. The present approach, which was successfuly applied to four other atomizer configurations in earlier effort, indicates the potential of using such an approach in the development of airblast atomizers.

#### INFLUENCES ON THE UNIFORMITY OF SPRAYS PRODUCED BY GAS TURBINE HIGH SHEAR NOZZLE/SWIRLER **ASSEMBLIES**

J. M. COHEN and T. J. ROSFJORD (United Technologies Research Center, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs

(Contract F33615-85-C-2515)

(AIAA PAPER 90-2193) Copyright

In general, real fuel nozzles do not produce uniform spray patterns. To varying degrees, either because of design or manufacturing defects, asymmetric fuel flux profiles are delivered to the combustor. The resulting fuel-air ratio distributions may promote the production of soot, cause large temperature excursions in the combustor or compromise the operability limits of the combustor. Because modern fuel injectors rely on a delicate balance of fuel and air flows, they are susceptible to perturbations which can result in undesirable fuel spray patterns. An experimental investigation was conducted to determine the effects of a variety of design and manufacturing influences on the spray patterns of a model high shear nozzle/swirler assembly. High resolution patternation data were collected for three groups of perturbations to a baseline assembly. Data were compared on the basis of radial and circumferential fuel flux distributions.

A90-42093# NUMERICAL MODELING OF AN IMPINGING JET IN **CROSS-FLOW** 

D. BRAY and K. KNOWLES (Royal Military College of Science, Shrivenham, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p.

(AIAA PAPER 90-2246) Copyright

The paper deals with the calculations of round compressible turbulent impinging jets in cross flows. A two-dimensional numerical method utilizing a finite-volume code is described. It is shown that the method makes it possible to replicate the effects of parameters such as jet pressure ratio, jet height, jet/cross flow velocity ratio, and ground-plane conditions on the resultant ground vortex. The output demonstrates that the vortex core and maximum penetration points are coincident with ground-plane minimum and maximum pressure coefficient points, respectively. Vortex geometry is also accurately predicted by the numerical modeling, along with the correct trend of increasing vortex penetration with increasing effective velocity ratio. The correct trend regarding moving ground-plane operation and the correct low jet pressure ratio effects are also indicated by the modeling.

#### A90-42110#

#### INITIATION OF SPALLING IN AIRCRAFT GAS TURBINE BEARINGS

B. L. AVERBACH (MIT, Cambridge, MA), S. G. VAN PELT, and P. K. PEARSON (Torrington Co., CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 7 p. Research sponsored by USAF. (AIAA PAPER 90-2291) Copyright

Approximately 200 bearings which had been removed from a variety of current aircraft engines were examined. All of the bearings were made of VIM-VAR M-50 steel. The damage in these bearings seemed to be surface-initiated, and the initiation sites were shallow pits associated with the presence of abrasive particles, dents, grinding scores, skid marks, large carbides, and corroded areas. The damage appeared to have progressed by a mechanism of peeling, where microscopic regions approximately 100 microns deep were removed from the surface, and these peels eventually developed into spalls. Failures of this type were reproduced in 40 mm bore thrust bearings run at 10,000 rpm, where the failure sites were introduced in a 15 min preliminary run with oil contaminated with 2.5 ppm of 20 microns alumina. The peeling mechanism was investigated, and the performance of M-50 and M-50 Nil coated with thin dense chromium (TDC) was observed. In these limited tests, the L10 life of the M-50 NiL, TDC was approximately six times that of M-50. Author

#### A90-42116#

### NUMERICAL SIMULATIONS OF GAS TURBINE COMBUSTOR

D. LEE, C. L. YEH, Y. M. TSUEI, W. T. JIANG, and Y. L. CHUNG. (National Cheng Kung University, Tainan, Republic of China) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. Sponsorship: National Science Council of the Republic of China. refs

(Contract NSC-78-0210-D006-01)

(AIAA PAPER 90-2305) Copyright

A general two-dimensional computer code has been developed for simulating gas turbine combustor flow. The code employs a non-staggered body-fitted coordinate system and the SIMPLE algorithm with power law or second order upwind scheme for the convective terms. Several turbulence models have been implemented and compared. For the reacting cases, three combustion models, namely, laminar combustion model, fast chemistry with assumed probability density function model, and the eddy break-up model have been used. The use of the zonal grid and the adaptive grid methods have also been demonstrated in selected cases. This code can conveniently extend its use to many other internal fluid flow and heat transfer problems.

Author

#### A90-42133#

AIRCRAFT APPLICATIONS OF ADVANCED COMPOSITE FIBER/METAL PRESSURE VESSELS

ALECK PAPANICOLOPOULOS (Structural Composites Industries, Pomona, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs (AIAA PAPER 90-2344) Copyright Typical applications of carbon-wrapped, metal-line pressure

Typical applications of carbon-wrapped, metal-line pressure vessels in aircraft systems requiring lightweight, high-performance tanks are discussed. These applications include an on-board inert gas generating system tank, an emergency pressurization unit tank, a pneumatic air start system (PASS) vessel, and a pneumatic reservoir unit similar to the PASS tank. The design considerations applicable to military aircraft requirements are outlined, and the materials and process development background of a representative military aircraft tank are presented.

#### A90-42163#

## AN EXPERIMENTAL INVESTIGATION OF TURBINE ROTOR WAKES FOR THE DEVELOPMENT OF A FIBER OPTIC PRESSURE SENSOR

M. M. WEIMER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 14 p. (AIAA PAPER 90-2411) Copyright

A fiber optic pressure sensor (FOPS) is being developed to detect turbine rotor speed by counting rotor blade passage through detection of rotor blade wakes in the exit flow field. The FOPS pressure tube, which protrudes into the flow path, transfers the unsteady pressure signal from the flow path to the sensor diaphragm mounted on the turbine shroud. Three phases of the FOPS development are described. These include an experimental investigation of an unsteady turbine exit flow field, a pressure tube optimization study, and a validation of the fiber optic pressure sensor in a component test turbine.

#### A90-42164#

### ELECTRICAL ANALOG CIRCUIT FOR HEAT TRANSFER MEASUREMENTS ON A FLAT PLATE SIMULATING TURBINE VANE HEAT TRANSFER IN TURBULENT FLOW

R. K. ROCKWELL, P. I. KING, and W. C. ELROD (USAF, Institute of Technology, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs (AIAA PAPER 90-2412)

The flow behind a passing shock wave in a shock tube was used to simulate the high temperature ratio flows found in gas turbines. Highly responsive surface mounted thin film heat flux gages were used to measure the temperature history of a flat plate exposed to the flow. An electrical analog converted the thin film gage output to heat flux. Heat transfer results for free stream turbulence of 10-12 percent correlated well with a formulation suggested by earlier researchers.

### A90-42165\*# Allied-Signal Aerospace Co., Phoenix, AZ. DEVELOPMENT OF IMPACT DESIGN METHODS FOR CERAMIC GAS TURBINE COMPONENTS

J. SONG, J. CUCCIO, and H. KINGTON (Allied-Signal Aerospace Co., Garrett Auxiliary Power Div., Phoenix, AZ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 8 p. Research supported by DOE. refs (Contract DEN3-335)

(AIAA PAPER 90-2413) Copyright

Impact damage prediction methods are being developed to aid in the design of ceramic gas turbine engine components with improved impact resistance. Two impact damage modes were characterized: local, near the impact site, and structural, usually fast fracture away from the impact site. Local damage to Si3N4 impacted by Si3N4 spherical projectiles consists of ring and/or radial cracks around the impact point. In a mechanistic model being developed, impact damage is characterized as microcrack nucleation and propagation. The extent of damage is measured as volume fraction of microcracks. Model capability is demonstrated by simulating late impact tests. Structural failure is caused by tensile stress during impact exceeding material strength. The EPIC3

code was successfully used to predict blade structural failures in different size particle impacts on radial and axial blades. Author

#### A90-42166#

### REVIEW OF MIXED FLOW AND RADIAL TURBINE OPTIONS

C. RODGERS (Sundstrand Power Systems, San Diego, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs (AIAA PAPER 90-2414) Copyright

Demands for higher power density and improved thermal efficiency are motivating the development of high specific speed radial inflow and mixed flow turbines capable of improved performance under conditions of higher loading at lower velocity ratios, while employing reduced rotor blade solidities and rotating inertia to reach higher levels of throttle response. A complex iterative design sequence relating to aerodynamic and thermal/structural optimization has been conducted for turbines of these two types, in order to arrive at comparative results. The mixed-flow design option is being addressed to replace two axial turbine stages in high-work gas-generator modules for advanced, small gas turbines.

### A90-42334 MODEL OF A LABYRINTH SEAL WITH FLOW [MODELL EINER DURCHSTROEMTEN LABYRINTHDICHTUNG]

BERND BEHNKE (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Karlsruhe, Federal Republic of Germany, Mar. 28-31, 1989) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 70, no. 4, 1990, p. T 72-T 74. In German.

A simplified mathematical model is developed to describe the flow-induced vibration of an aircraft-engine labyrinth seal. The aim of the model is to facilitate parametric studies of the mechanical stability limits for different flow conditions and labyrinth-seal designs. The formulations for the elastic structure, the steady flow, the effects of structural deformation on the flow, and the corresponding effects of the flow on the elastic structure are given, and numerical results for a sample computation are presented in graphs. It is found that the flow changes the eigenfrequencies of the structure by at most 2 percent, but that the stability is significantly affected, in qualitative agreement with the experimental observations of Abbott (1981).

### A90-42341 UNSTEADY DEFORMATIONS OF ELASTIC ROTOR BLADES [INSTATIONAERE VERFORMUNGEN ELASTISCHER

H.-D. LAUERMANN (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Karlsruhe, Federal Republic of Germany, Mar. 28-31, 1989) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN

0044-2267), vol. 70, no. 4, 1990, p. T 213-T 215. In German. Copyright

The in-flight dynamic behavior of a helicopter rotor blade is investigated analytically, with a focus on the effects of unsteady flows due to blade-vortex interactions. The blade is modeled as a Timoshenko beam (rigid with respect to axial tension), and the propagation of torsion, bending, and shear waves is taken into account. A hyperbolic system of partial differential equations is constructed from the equations of motion and the time-differentiated stress-resultant/strain relations and solved numer-

ically using a second-order characteristic-curve method and a discretization which is adapted to the differing wave propagation speeds. The results of numerical experiments demonstrate that the use of a separate grid for each wave speed eliminates numerical dispersion and physically impossible deformation of the wave

onies.

ROTORBLAETTER]

#### A90-42483# USE OF SMART ACTUATORS FOR THE TAIL ROTOR

### **COLLECTIVE PITCH CONTROL**

P. BOZZOLA and G. JACAZIO (Microtecnica S.p.A., Turin, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 11 p.

The advantages of smart actuators and major problems associated with their use are briefly reviewed, and an advanced design study concerned with the use of smart actuators for the collective pitch control of a tail rotor is reported. The discussion includes system design requirements, system architecture, electrical power supply, and integrated hydraulic supply. It is shown that the system proposed here improves aircraft survivability and is easy to install and maintain.

#### A90-42484#

#### **DIRECT DRIVE SERVOVALVES: WHY AND HOW - THE** MAGNAGHI MILANO ANSWER

D. LAFFRANCHI (Magnaghi Milano S.p.A., Milan, Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 14 p.

General requirements for aircraft servocontrols are briefly examined, and a possible servocontrol scheme using direct drive valves is proposed which is capable of meeting these requirements. The discussion covers the advantages of direct drive valves over electrohydraulic servovalves, general design of direct drive valves, the potential reliability of direct drive valves, examples of applications, and the future of servocontrols.

#### A90-42490#

#### A 'NEW' PHILOSOPHY OF STRUCTURAL RELIABILITY, FAIL SAFE VERSUS SAFE LIFE

KENNETH B. AMER (RAND Corp., Santa Monica, CA) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 15 p. refs

An approach to helicopter design is proposed which combines fail-safe features with enhanced safe-life features and has potential for minimizing or eliminating both weight and cost penalties and reducing the probability of catastrophic failure. In particular, it is shown that the combined fail-safe/enhanced safe-life approach should provide the required 0.999999 reliability against catastrophic failure at no penalty in weight and only a small penalty in cost relative to current procedures. It is recommended that the approach proposed here be considered for all future helicopter developments.

### A90-42491#

#### ANALYSIS OF COMPOSITE ROTOR BLADES VIA SAINT **VENANT'S SOLUTIONS**

J. B. KOSMATKA (Virginia Polytechnic Institute and State University, Blacksburg) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 23 p. Research supported by TRW, Inc. refs (Contract NSF MSM-88-09132)

An analytical model for accurately determining the threedimensional response and stress distribution (including interlaminar shear) of advanced composite rotor blades is presented. This model is developed by formulating Saint Venant's elasticity solutions for the extension, bending, torsion, and flexure of a prismatic beam whose cross section is nonhomogeneous and generally anisotropic. The coupled second order elasticity problem is solved based upon the principle of minimum potential energy and a two-dimensional finite element approach. Derivations are included for calculating the beam twist, Saint Venant torsion warping distribution, torsion constant, and flexural center. Numerical results are presented to illustrate the versatility of this model by analyzing both isotropic and advanced composite airfoil sections.

#### A90-42493#

analytical data base.

#### HYDRAULIC ACCUMULATORS AND HIGH PRESSURE BOTTLES IN COMPOSITE MATERIAL

E. ARTONI (Magnaghi Milano S.p.A., Milan, Italy) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 12 p.

A program aimed at designing, testing, and manufacturing high-pressure hydraulic accumulators and gas bottles in advanced composite materials for aerospace applications is reviewed. The principal design requirements are presented along with test results for filament wound carbon/epoxy and Kevlar/epoxy accumulators with and without a metal liner. It is concluded that the use of carbon and Kevlar fiber composites in high-pressure accumulators and bottles has potential for reducing the weight of the hydraulic circuits of aircraft and helicopters.

N90-23591\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### INTRODUCING THE VRT GAS TURBINE COMBUSTOR

JERRY O. MELCONIAN, ABDU A. MOSTAFA (Textron Lycoming, Stratford, CT.), and HUNG LEE NGUYEN 1990 14 p Presented at the 26th Joint Propulsion Conference, Orlando, FL, 16-18 Jul. 1990; cosponsored by AIAA, SAE, ASME, and ASEE (NASA-TM-103176; E-5554; NAS 1.15:103176; AIAA-90-2452) Avail: NTIS HC A03/MF A01 CSCL 21/5

An innovative annular combustor configuration is being developed for aircraft and other gas turbine engines. This design has the potential of permitting higher turbine inlet temperatures by reducing the pattern factor and providing a major reduction in NO(x) emission. The design concept is based on a Variable Residence Time (VRT) technique which allows large fuel particles adequate time to completely burn in the circumferentially mixed primary zone. High durability of the combustor is achieved by dual function use of the incoming air. The feasibility of the concept was demonstrated by water analogue tests and 3-D computer modeling. The computer model predicted a 50 percent reduction in pattern factor when compared to a state of the art conventional combustor. The VRT combustor uses only half the number of fuel nozzles of the conventional configuration. The results of the chemical kinetics model require further investigation, as the NO(x) predictions did not correlate with the available experimental and

N90-23609# Air Force Inst. of Tech., Wright-Patterson AFB. OH. School of Engineering.

#### THROUGHPUT AND DELAY CHARACTERISTICS FOR A SLOW-FREQUENCY HOPPED AIRCRAFT-TO-AIRCRAFT PACKET RADIO NETWORK M.S. Thesis

SCOTT RUSSELL HARRISON Mar. 1990 123 p (AD-A220525; AFIT/GCS/ENG/90M-01) Avail: NTIS HC A06/MF A01 CSCL 25/2

Current lack of data transfer capability between tactical aircraft results in decreased mission effectiveness or the need to equip every aircraft with all the sensors and data processing equipment to perform each task expected of them. In the Air Force, these developments established the need for aircraft-to-aircraft data communications so that navigation, threat and targeting information could be shared within a flight and so that digital voice communications could also be maintained. Data rates within a flight of fighter aircraft to support these requirements will need to be between 100 and 250 kilobits/second (KBPS) and between 2.4 KBPS and 16 KBPS between the flight and a command and control aircraft. Other sources place the former figure as high as 512 KBPS. To increase the security of these radio channels, against both jamming and intrusion, anti-jam and low probability of interception (LPI) techniques must be used. One method of achieving these capabilities is to use spread spectrum techniques such as frequency hopping. The Air Force is currently concentrating its efforts around the Joint Tactical Information Distribution System (JTIDS).

N90-23687# Cincinnati Univ., OH. Dept. of Aerospace Engineering Engineering Mechanics.

COMPOSITE REDUCED NAVIER STOKES PROCEDURES FOR FLOW PROBLEMS WITH STRONG PRESSURE INTERACTIONS Final Report, 1 Feb. 1985 - 31 Oct. 1989
S. G. RUBIN and P. K. KHOSLA 30 Jan. 1990 41 p
(Contract F49620-85-C-0027; AF PROJ. 2307)
(AD-A219621; AFOSR-90-0296TR) Avail: NTIS HC A03/MF A01 CSCL 20/4

The Reduced Navier Stokes (RNS) formulation for viscous-inviscid interacting flows with significant upstream or elliptic effects was applied for transient flow over airfoils at incidence, and steady 2-D and 3-D flows over cavity, wing and afterbody configurations. The solution technique applies uniformly over the entire Mach number range and allows for shock boundary layer interaction, and for moderate regions of axial and secondary flow recirculation. For 2-D problems with recirculation, it was demonstrated that for laminar flows there exists a critical Reynolds number, that is geometry dependent, above which the solution exhibits a breakdown. This occurs in the region of recirculation and very close to the reattachment point. This phenomena is grid dependent and can be missed with insufficiently refined grids or when artificial viscosity is introduced. It was shown that the pressure-split RNS procedure is in fact a special form of flux vector splitting that has very favorable properties for sharp shock capturing. A sparse matrix direct solver procedure has been applied for both two-dimensional transient flows, and for three-dimensional steady flows with the RNS flux-split strategy. A uni-directional or semi-coarsening multigrid procedure has been further developed for viscous interacting flows, where significant grid stretching is required in order to adequately evaluate both thin viscous layers and large inviscid regions, with and without shock interaction. GRA

N90-23707\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

MINIATURIZATION OF FLIGHT DEFLECTION MEASUREMENT SYSTEM Patent

ROBERT FODALE, inventor (to NASA) and HERBERT R. HAMPTON, inventor (to NASA) (Grumman Aerospace Corp., Bethpage, NY.) 30 Jan. 1990 6 p Filed 30 Sep. 1988 (NASA-CASE-LAR-13628-1; US-PATENT-4,896,533; US-PATENT-APPL-SN-251438; US-PATENT-CLASS-73-147; US-PATENT-CLASS-340-825.69; INT-PATENT-CLASS-G01M-9/00) Avail: US Patent and

INT-PATENT-CLASS-G01M-9/00) · Avail: US Patent and Trademark Office CSCL 14/2

A flight deflection measurement system is disclosed including a hybrid microchip of a receiver/decoder. The hybrid microchip decoder is mounted piggy back on the miniaturized receiver and forms an integral unit therewith. The flight deflection measurement system employing the miniaturized receiver/decoder can be used in a wind tunnel. In particular, the miniaturized receiver/decoder can be employed in a spin measurement system due to its small size and can retain already established control surface actuation functions.

Official Gazette of the U.S. Patent and Trademark Office

**N90-23713\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

REAL-TIME SIMULATION CLOCK Patent

DONALD R. BENNINGTON, inventor (to NASA) and DANIEL J. CRAWFORD, inventor (to NASA) 17 Apr. 1990 12 p Filed 28 Sep. 1988 Continuation-in-part of abandoned US-Patent-Appl-SN-010949, filed 5 Feb. 1987 (NASA-CASE-LAR-14056-1; US-PATENT-4,918,652; US-PATENT-APPL-SN-251073; US-PATENT-APPL-SN-010949; US-PATENT-CLASS-364-903.8;

The invention is a clock for synchronizing operations within a high-speed, distributed data processing network. The clock is actually a distributed system comprising a central clock and multiple

site clock interface units (SCIUs) which are connected by means of a fiber optic star network and which operate under control of separate clock software. The presently preferred embodiment is a part of the flight simulation system now in current use at the NASA Langley Research Center.

Official Gazette of the U.S. Patent and Trademark Office

N90-23752# Pratt and Whitney Aircraft, West Palm Beach, FL. Materials Engineering and Technology Labs.
FAILURE ANALYSIS HANDBOOK Final Report, 1 Sep. 1986 -

29 Apr. 1989
C. R. WALKER and K. K. STARR 18 Aug. 1989 759 p
(Contract F33615-86-C-5007; AF PROJ. 2418)
(AD-A219747; PW/ED/FR-20820; WRDC-TR-89-4060) Avail:
NTIS HC A99/MF A04 CSCL 11/6

Aircraft service failures of any type, from a simple rivet failure to complete engine failure, have the potential to result in loss of the aircraft and personnel. Accurate determination of the cause of the failure may yield information that will prevent similar future failures from occurring. It is helpful for the investigator to have a data base of known failure modes to draw from in forming conclusions. The objective of this program was to update and augment the two primary Air Force failure analysis handbooks, Electron Fractography Handbook and SEM/TEM Fractography Handbook, published in 1965 and 1975, respectively, with a new handbook includes fractography of alloys and conditions not previously covered in other handbooks. The handbook also is a guide for procedures and lists other sources of information.

N90-23760# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.

FRACTOGRAPHIC OBSERVATIONS ON FATIGUE CRACK GROWTH IN 2024-T3 SHEET MATERIAL UNDER FLIGHT-SIMULATION LOADING

O. PARTL (Czech Technical Univ., Prague.) and J. SCHIJVE Apr. 1989 43 p

(LR-592; ETN-90-96350) Avail: NTIS HC A03/MF A01

Fatigue crack propagation is studied under random flightsimulation loading and two types of programmed flight sequences. Tests are carried out on 2024-T3 Alclad specimens. Fractographic observations are made to determine the severity of individual flight types. Seven different flight types from a total of ten can be distinguished on the fatigue failure surfaces. Their severity is determined on the basis of crack extension.

N90-23762# Dayton Univ., OH.
NONDESTRUCTIVE MEASUREMENT OF RESIDUAL
STRESSES IN AIRCRAFT TRANSPARENCIES Final Interim
Report, Dec. 1984 - Feb. 1987

B. BASAVA RAJU and BLAINE S. WEST Nov. 1989 109 p (Contract F33615-84-C-3404; AF PROJ. 1926) (AD-A218680; UDR-TR-88-65; WRDC-TR-89-3099) Avail: NTIS HC A06/MF A01 CSCL 01/3

This program was conducted to: (1) Design, fabricate, and set up a photoelastic test apparatus capable of measuring residual stresses in aircraft transparencies; (2) Evaluate the accuracy of the scattered-light photoelastic technique by conducting scattered-light photoelastic experiments on four-point bending polycarbonate specimens having known analytical solutions and other experimental solutions; (3) Establish a scattered-light photoelastic experimental procedure for monolithic polycarbonate F-16 transparencies by measuring residual stresses at a typical station on the transparency; (4) Evaluate the scattered-light photoelastic properties of acrylic plastic material; and (5) Determine the feasibility of using acoustic wave ultrasonic techniques to determine residual stresses in transparencies.

N90-23768\*# National Aeronautics and Space Administration.
Hugh L. Dryden Flight Research Facility, Edwards, CA.
STARS: AN INTEGRATED GENERAL-PURPOSE FINITE
ELEMENT STRUCTURAL, AEROELASTIC, AND
AEROSERVOELASTIC ANALYSIS COMPUTER PROGRAM

K. K. GUPTA Jun. 1990 167 p (NASA-TM-101709; H-1582; NAS 1.15:101709) Avail: NTIS HC A08/MF A01 CSCL 20/11

The details of an integrated general-purpose finite element structural analysis computer program which is also capable of solving complex multidisciplinary problems is presented. Thus, the SOLIDS module of the program possesses an extensive finite element library suitable for modeling most practical problems and is capable of solving statics, vibration, buckling, and dynamic response problems of complex structures, including spinning ones. The aerodynamic module, AERO, enables computation of unsteady aerodynamic forces for both subsonic and supersonic flow for subsequent flutter and divergence analysis of the structure. The associated aeroservoelastic analysis module, ASE, effects aero-structural-control stability analysis yielding frequency responses as well as damping characteristics of the structure. The program is written in standard FORTRAN to run on a wide variety of computers. Extensive graphics, preprocessing, and postprocessing routines are also available pertaining to a number of terminals.

N90-23769\*# Toledo Univ., OH.

FINITE ELEMENT ANALYSIS OF STRUCTURAL COMPONENTS USING VISCOPLASTIC MODELS WITH APPLICATION TO A **COWL LIP PROBLEM Final Report** 

V. K. ARYA Jun. 1990 19 p ′ Original contains color illustrations

(Contract NCC3-120)

(NASA-CR-185189; E-4920; NAS 1.26:185189) Avail: NTIS HC A03/MF A01; 4 functional color pages CSCL 20/11

The viability of advanced viscoplastic models for nonlinear finite element analyses of structural components is investigated. Several uniaxial and a multiaxial problem are analyzed using the finite element implementation of Freed's viscoplastic model. Good agreement between the experimental and calculated uniaxial results validates the finite element implementation and gives confidence to apply it to more complex multiaxial problems. A comparison of results for a sample structural component (the cowl lip of a hypersonic engine inlet) with the earlier elastic, elastic-plastic, and elastic-plastic-creep analyses available in the literature shows that the elastic-viscoplastic analyses yield more reasonable stress and strain distributions. Finally, the versatility of the finite-element-based solution technology presented herein is demonstrated by applying it to another viscoplastic model.

N90-24514\*# Virginia Univ., Charlottesville. Computer Networks

AIRNET: A REAL-TIME COMUNICATIONS NETWORK FOR **AIRCRAFT Final Report** 

ALFRED C. WEAVER, BRENDAN G. CAIN, M. ALEXANDER COLVIN, and ROBERT SIMONCIC Jun. 1990 47 p (Contract NAG3-630)

(NASA-CR-186140; NAS 1.26:186140; UVA/528238/CS90/101) Avail: NTIS HC A03/MF A01 CSCL 17/2

A real-time local area network was developed for use on aircraft and space vehicles. It uses token ring technology to provide high throughput, low latency, and high reliability. The system was implemented on PCs and PC/ATs operating on PCbus, and on Intel 8086/186/286/386s operating on Multibus. A standard IEEE 802.2 logical link control interface was provided to (optional) upper layer software; this permits the controls designer to utilize standard communications protocols (e.g., ISO, TCP/IP) if time permits, or to utilize a very fast link level protocol directly if speed is critical. Both unacknowledged datagram and reliable virtual circuit services are supported. A station operating an 8 MHz Intel 286 as a host can generate a sustained load of 1.8 megabits per second per station, and a 100-byte message can be delivered from the transmitter's user memory to the receiver's user memory, including all operating system and network overhead, in under 4 milliseconds. Author N90-24557\*# University of the Pacific, Stockton, CA. Dept. of Mechanical Engineering.

FLOW UNSTEADINESS EFFECTS ON BOUNDARY LAYERS Final Report, Oct. 1985 - Sep. 1989

SREEDHARA V. MURTHY 1989 63 p

(Contract NCC2-357)

(NASA-CR-186067; NAS 1.26:186067) Avail: NTIS HC A04/MF A01 CSCL 20/4

The development of boundary layers at high subsonic speeds in the presence of either mass flux fluctuations or acoustic disturbances (the two most important parameters in the unsteadiness environment affecting the aerodynamics of a flight vehicle) was investigated. A high quality database for generating detailed information concerning free-stream flow unsteadiness effects on boundary layer growth and transition in high subsonic and transonic speeds is described. The database will be generated with a two-pronged approach: (1) from a detailed review of existing literature on research and wind tunnel calibration database, and (2) from detailed tests in the Boundary Layer Apparatus for Subsonic and Transonic flow Affected by Noise Environment (BLASTANE). Special instrumentation, including hot wire anemometry, the buried wire gage technique, and laser velocimetry were used to obtain skin friction and turbulent shear stress data along the entire boundary layer for various free stream noise levels, turbulence content, and pressure gradients. This database will be useful for improving the correction methodology of applying wind tunnel test data to flight predictions and will be helpful for making improvements in turbulence modeling laws.

N90-24660\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. UNIQUE FAILURE BEHAVIOR OF METAL/COMPOSITE

AIRCRAFT STRUCTURAL COMPONENTS UNDER CRASH TYPE LOADS

HUEY D. CARDEN May 1990 32 p

(NASA-TM-102679; NAS 1.15:102679) Avail: NTIS HC A03/MF A01 CSCL 20/11 Failure behavior results are presented on some of the crash

dynamics research conducted with concepts of aircraft elements and substructure which have not necessarily been designed or optimized for energy absorption or crash loading considerations. To achieve desired new designs which incorporate improved energy absorption capabilities often requires an understanding of how more conventional designs behave under crash type loadings. Experimental and analytical data are presented which indicate some general trends in the failure behavior of a class of composite structures which include individual fuselage frames, skeleton subfloors with stringers and floor beams but without skin covering. and subfloors with skin added to the frame-stringer arrangement. Although the behavior is complex, a strong similarity in the static/dynamic failure behavior among these structures is illustrated through photographs of the experimental results and through analytical data of generic composite structural models. It is believed that the thread of similarity in behavior is telling the designer and dynamists a great deal about what to expect in the crash behavior of these structures and can guide designs for improving the energy absorption and crash behavior of such structures.

N90-25037\*# Hampton Univ., VA. Airway Science Program. **AUTOMATIC SPEECH RECOGNITION IN AIR-GROUND DATA LINK Abstract Only** 

HERBERT B. ARMSTRONG In Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 46-47 Avail: NTIS HC A09/MF A02 CSCL 17/2

In the present air traffic system, information presented to the transport aircraft cockpit crew may originate from a variety of sources and may be presented to the crew in visual or aural form, either through cockpit instrument displays or, most often. through voice communication. Voice radio communications are the most error prone method for air-ground data link. Voice messages can be misstated or misunderstood and radio frequency congestion can delay or obscure important messages. To prevent proliferation, a multiplexed data link display can be designed to present information from multiple data link sources on a shared cockpit display unit (CDU) or multi-function display (MFD) or some future combination of flight management and data link information. An aural data link which incorporates an automatic speech recognition (ASR) system for crew response offers several advantages over visual displays. The possibility of applying ASR to the air-ground data link was investigated. The first step was to review current efforts in ASR applications in the cockpit and in air traffic control and evaluated their possible data line application. Next, a series of preliminary research questions is to be developed for possible future collaboration.

# N90-25051\*# Maine Univ., Orono. Dept. of Mathematics. AN ANALYTIC STUDY OF NONSTEADY TWO-PHASE LAMINAR BOUNDARY LAYER AROUND AN AIRFOIL Abstract Only

YU-KAO HSU *In* Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 86-88 Sep. 1989
Avail: NTIS HC A09/MF A02 CSCL 20/4

Recently, NASA, FAA, and other organizations have focused their attention upon the possible effects of rain on airfoil performance. Rhode carried out early experiments and concluded that the rain impacting the aircraft increased the drag. Bergrum made numerical calculation for the rain effects on airfoils. Luers and Haines did an analytic investigation and found that heavy rain induces severe aerodynamic penalties including both a momentum penalty due to the impact of the rain and a drag and lift penalty due to rain roughening of the airfoil and fuselage. More recently, Hansman and Barsotti performed experiments and declared that performance degradation of an airfoil in heavy rain is due to the effective roughening of the surface by the water layer. Hansman and Craig did further experimental research at low Reynolds number. E. Dunham made a critical review for the potential influence of rain on airfoil performance. Dunham et al. carried out experiments for the transport type airfoil and concluded that there is a reduction of maximum lift capability with increase in drag. There is a scarcity of published literature in analytic research of two-phase boundary layer around an airfoil. Analytic research is being improved. The following assumptions are made: the fluid flow is non-steady, viscous, and incompressible; the airfoil is represented by a two-dimensional flat plate; and there is only a laminar boundary layer throughout the flow region. The boundary layer approximation is solved and discussed.

N90-25060\*# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.

WODELING GROWTH OF FATIGUE CRACKS WHICH

ORIGINATE AT RIVET HOLES Abstract Only

MARK E. MEAR /n Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 125-126 Sep. 1989
Avail: NTIS HC A09/MF A02 CSCL 20/11

When a structural component is subjected to repeated stress cycles, it can fail at stresses which are well below the tensile strength of the material. The processes leading to this failure are termed fatigue. Instances of fatigue failure in aircraft have become an increasing concern. The crack leading to failure often originate at rivet holes and then grow in response to stress cycles which occur during the operation of the aircraft. A necessary step to preventing failures in todays fleet of aging aircraft is to increase the frequency and quality of inspections; steps were already taken in this direction. There is also a need for modeling of fatigue crack growth in the aircraft structures so that improvements in design can be established and predictions of the life of the components can be made. The purpose is to provide a method to accurately predict the growth of fatigue cracks and to use this method to make predictions about the life of aircraft structural components. The method relies on the formulation and numerical solution of a singular integral equation(s) for an arbitrarily shaped crack(s) which propagate in response to the applied loading. Of special interest to the aging aircraft studies are cracks which originate at circular holes (i.e., rivet holes), but other crack geometries can be treated equally as well.

Author

N90-25062\*# Old Dominion Univ., Norfolk, VA. Dept. of Civil Engineering.

FLEXURAL FATIGUE LIFE PREDICTION OF CLOSED HAT-SECTION USING MATERIALLY NONLINEAR AXIAL FATIGUE CHARACTERISTICS Abstract Only

ZIA RAZZAQ *In its* NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 131-132 Sep. 1989

Avail: NTIS HC A09/MF A02 CSCL 20/5

Straight or curved hat-section members are often used as structural stiffeners in aircraft. For instance, they are employed as stiffeners for the dorsal skin as well as in the aerial refueling adjacent area structure in F-106 aircraft. The flanges of the hat-section are connected to the aircraft skin. Thus, the portion of the skin closing the hat-section interacts with the section itself when resisting the stresses due to service loads. The flexural fatigue life of such a closed section is estimated using materially nonlinear axial fatigue characteristics. It should be recognized that when a structural shape is subjected to bending, the fatigue life at the neutral axis is infinity since the normal stresses are zero at that location. Conversely, the fatigue life at the extreme fibers where the normal bending stresses are maximum can be expected to be finite. Thus, different fatigue life estimates can be visualized at various distances from the neural axis. The problem becomes compounded further when significant portions away from the neutral axis are stressed into plastic range. A theoretical analysis of the closed hat-section subjected to flexural cyclic loading is first conducted. The axial fatigue characteristics together with the related axial fatigue life formula and its inverted form given by Manson and Muralidharan are adopted for an aluminum alloy used in aircraft construction. A closed-form expression for predicting the flexural fatigue life is then derived for the closed hat-section including materially nonlinear action. A computer program is written to conduct a study of the variables such as the thicknesses of the hat-section and the skin, and the type of alloy used. The study has provided a fundamental understanding of the flexural fatigue life characteristics of a practical structural component used in aircraft when materially nonlinear action is present.

N90-25065\*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.

GENERATION OF CIRCUMFERENTIAL VELOCITY CONTOURS ASSOCIATED WITH PULSED POINT SUCTION ON A ROTATING DISK

GREGORY V. SELBY In its NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 137-140 Sep. 1989

Avail: NTIS HC A09/MF A02 CSCL 04/2

Numerous experimental studies were conducted on the steady, three-dimensional boundary layer over a disk rotating at constant angular speed in an otherwise undisturbed fluid. The subject flow geometry is of interest because it provides a relatively simple way to study the cross-flow instability phenomenon which occurs in three-dimensional boundary layers, as on swept wings. This flow instability results in the formation of a stationary spiral vortex flow field over the disk, as shown by Wilkinson and Malik. Using a hot-wire probe, the spatial wave pattern of stationary vortices, which filled the entire circumference of the disk was mapped. The subject flow instability caused transition-to-turbulent flow as the periphery of the disk was approached. The effect on receptivity and transition of discrete disturbance modes, such as three-dimensional toughness elements and acoustic excitation was investigated. The present study (an extension of the work of Wilkinson and Malik) is focused on the effect of pulsed point suction on flow instability and transition, and consequently, on the classical stationary vortical flow pattern. Author

#### 13

#### **GEOSCIENCES**

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

#### A90-39403

#### **AVIATION METEOROLOGY - PANEL REPORT**

JAMES WILSON (NCAR, Boulder, CO) IN: Radar in meteorology. Boston, MA, American Meteorological Society, 1990, p. 682-688. Copyright

The challenge for aviation meteorology over the next decade will be to utilize present technology to develop a system to deliver concise, easily understood and timely weather information to pilots. The areas identified as the most promising for improvement in the near future are: (1) avoidance of heavy precipitation, hail, and storm related turbulence, (2) avoidance of wind shear hazards during takeoff and landing, (3) anticipation of runway changes or closures due to weather, (4) improved enroute winds, and (5) nowcasting for space launch and recovery operations. The following areas are then identified as requiring additional research before significant improvements are possible; detection and forecasting of icing, short-term forecasts of microbursts, forecasts of convective storm initiation, and forecasts of storm intensity change and movement.

#### A90-39702#

### WIND SHEAR AT PANTELLERIA AIRPORT (IL WIND-SHEAR SULL'AEROPORTO DI PANTELLERIA)

LODOVICO LA VALLE Rivista di Meteorologia Aeronautica (ISSN 0035-6328), vol. 49, July-Dec. 1989, p. 91-119. In Italian. refs

Data obtained using a second-generation low-level-wind-shear alarm system (LLWAS), installed with FAA cooperation at the airport on Pantelleria island in the Mediterranean, are reported for the period from July 1988 through April 1989. The development history of LLWAS in the U.S. and the evolution of the Pantelleria installation are reviewed, and the results are presented in tables. Fourteen cases of LLWAS-detected and pilot-confirmed wind shear are characterized in detail with reference to area weather maps. The wind-shear events at Pantelleria are found to be related to orographic and convective effects, with some microbursts but no downbursts. Also discussed are (1) the autodiagnostic software developed to eliminate errors due to variations in LLWAS component performance and (2) future improvements of LLWAS using terminal Doppler weather radars.

#### A90-41315

### THE EFFECTS OF TOUGHENING STRESSES ON LIQUID IMPACT INDUCED FRACTURE

R. J. HAND and J. E. FIELD (Cambridge, University, England) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 1. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 763-770. Research supported by Pilkington Brothers, PLC and Ministry of Defence Procurement Executive. refs

Toughening stresses are induced in glasses to improve their quasi-static fracture properties. The effects of these toughening stresses on the dynamic fracture properties of glasses are investigated in this paper. In particular an experimental study of liquid impact on thermally and chemically toughened glasses is presented. The results are discussed with reference to a theoretical simulation of a Rayleigh wave interacting with surface cracks.

Author

#### A90-41736

HYDROGEN IN FUTURE ENERGY AND PROPULSION TECHNOLOGY [WASSERSTOFF IN DER ZUKUENFTIGEN ENERGIE- UND ANTRIEBSTECHNIK]

WALTER PESCHKA (DLR, Institut fuer technische Thermodynamik, Stuttgart, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), May 1990, p. 51-57. In German. refs Copyright

The use of hydrogen in various types of transport is discussed. The relevant physicochemical characteristics of hydrogen are compared to those of other energy sources. Present research projects on the use of hydrogen in both ground-based and airborne transport are reviewed. Research projects on air transport using liquid hydrogen are discussed.

C.D.

N90-23832# Air Force Geophysics Lab., Hanscom AFB, MA. Atmospheric Sciences Div.

### A COMPARISON OF LIGHTNING NETWORK DATA WITH SURFACE WEATHER OBSERVATIONS Interim Scientific Report

H. A. BROWN 9 May 1989 44 p (Contract AF PROJ. 2688) (AD-A220003; GL-TR-89-0129; ERP-1031) Avail: NTIS HC A03/MF A01 CSCL 04/2

The objective of this study was to demonstrate the effectiveness of a lightning detection network in providing a real-time data base from which automated observations of thunderstorms and lightning in the vicinity of an air base can be derived. A direction-finding cloud-to-ground lightning detection network (LDN) operated by the State Univ. of New York at Albany provided a data base of CG lightning locations in the northeastern United States for July to August, 1986. Copies of the original weather observation forms from 25 AF weather stations in the same area and time period provided a data base of thunderstorm and lightning observations for comparison. The lightning data base was analyzed for strike events located within 15 nm of each weather station. If the 15 minute period lapsed without another strike, the event was ended. Events were categorized as single- or multiple-strike events and the duration of the events tabulated. The weather observation data base was analyzed for thunderstorm events. The beginning time, ending time and duration of the events were tabulated as well as the type of lightning that was reported with each observation. Chronological comparison of the two data bases, using the weather observation data base as ground truth, generated 4 x 4 contingency tables of the combinations of thunderstorm-lightning events. Four parameters were derived from the statistical evaluation of the contingency tables: (1) Probability of detection; (2) False alarm rate; (3) Missed threat rate, and (4) Critical success index.

N90-25040\*# State Univ. of New York, Brockport. Dept. of Earth Sciences.

### A QUANTITATIVE TECHNIQUE TO ESTIMATE MICROBURST WIND SHEAR HAZARD TO AIRCRAFT

GREGORY P. BYRD In Old Dominion Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1989 p 56-59 Sep. 1989
Avail: NTIS HC A09/MF A02 CSCL 04/2

Low-altitude microburst wind shear encounters can significantly affect aircraft performance during approach or takeoff. Over the past 25 years, hazardous wind shear was a contributing factor in over two dozen commercial airline accidents in which there were over 500 fatalities. NASA, the FAA, and the National Center for Atmospheric Research were involved in the design and testing of various sensors to detect the hazard. Among the sensors being tested are the ground-based Terminal Doppler Weather Radar (TDWR) and airborne Doppler radar and LIDAR systems. While these sensor systems do measure horizontal wind shear, they do not adequately account for the vertical wind, which is a key component of the microburst hazard to the aircraft. A technique is defined to estimate aircraft hazard from the combined effects of horizontal and vertical winds, given only horizontal wind information.

#### 15

#### **MATHEMATICAL AND COMPUTER SCIENCES**

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

#### A90-38888

### MULTI-LEVEL MODELS FOR DIAGNOSIS OF COMPLEX ELECTRO-MECHANICAL SYSTEMS

JOHN A. SMITH (Federal Express Corp., Air Ops Information Services, Memphis, TN) and GAUTAM BISWAS (Vanderbilt University, Nashville, TN) IN: Applications of artificial intelligence VII; Proceedings of the Meeting, Orlando, FL, Mar. 28-30, 1989. Part 1. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 346-356. refs

A knowledge-based system for diagnostic problem solving based on a multilevel representational structure and associated reasoning methods is discussed. The motivation behind this approach is to combine shallow evidential models for fault diagnosis with deep qualitative models that derive behavior from structural descriptions. In addition, the reasoning scheme utilizes historical data based on past experience for diagnosis. Using this integrated framework, attention is given to: (1) multilevel knowledge based system design, and (2) reasoning systems that exploit the multilevel representational structure for diagnostic problem solving. This system is applied to the diagnosis of a complex electromechanical system, specifically, the upper cargo door of the DC-10 aircraft.

Author

#### A90-38909

### EXPERT SYSTEM FOR PILOT ASSISTANCE - THE CHALLENGE OF AN INTENSIVE PROTOTYPING

PAOLO GALLO, DANILO DABBENE (CSI-Piemonte, Turin, Italy), FEDERICA LUISE, and PATRIZIA GIORDANENGO (Aeritalia S.p.A., Turin, Italy) IN: Applications of artificial intelligence VII; Proceedings of the Meeting, Orlando, FL, Mar. 28-30, 1989. Part 2. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 1101-1117. refs

The methodologies and techniques employed to develop an expert system for pilot assistance while performing route planning or replanning are described. The functional characteristics of a first prototype working on a Lisp machine are presented, and its current architecture is shown. This prototype can provide the pilot with dynamic information about the terrain geography, the tactical situation, the meteorological conditions, and the current state of the aircraft. Static information about threat characteristics, fuel consumption, aircraft configuration, and preplanned route are also available through an interface simulating a head-down display. The system can plan complete ground attack missions and suggest the most suitable push-up point for the run-in on target.

#### A90-39180

### MULTILEVEL OPTIMIZATION OF LARGE-SCALE STRUCTURES IN A PARALLEL COMPUTING ENVIRONMENT

VINAY BHATT, STEFAN LINDEN (Siegen, Universitaet-Gesamthochschule, Federal Republic of Germany), and K. M. RAGSDELL (Missouri University, Columbia) IN: Discretization methods and structural optimization - Procedures and applications; Proceedings of the GAMM Seminar, Siegen, Federal Republic of Germany, Oct. 5-7, 1988. Berlin and New York, Springer-Verlag, 1989, p. 56-63. refs

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A procedure is described of the automated synthesis of a complete vehicle configuration in a parallel computing environment, using a linear decomposition scheme based on the Sobieski (1982) algorithm. Several example problems, set up in order to check

the validity of the optimum sensitivity analysis algorithm and the multilevel decomposition algorithm of this scheme are presented, including a three-bar truss problem, a portal frame problem, and an optimum vehicle configuration problem.

#### A90-39303#

### A STUDY ON THE APPLICATION OF CONTROLLABILITY AND OBSERVABILITY CONCEPTS IN THE DESIGN OF FLIGHT CONTROL SYSTEMS

ZHIHENG MA (Ministry of Astronautics, Institute 302, People's Republic of China) Chinese Society of Astronautics, Journal (ISSN 1000-1328), no. 1, 1989, p. 99-104. In Chinese, with abstract in English. refs

#### A90-40810

### GUARANTEED COST CONTROL VIA OPTIMAL PARAMETRIC LQ DESIGN

H. X. HU and N. K. LOH (Oakland University, Rochester, MI) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 486-491. refs Copyright

For an optimal parametric linear quadratic (LQ) control problem, a design objective is to determine a controller of constrained structure such that the closed-loop system is asymptotically stable and an associated performance measure is optimized. In the presence of system uncertainty, the system obtained by parametric LQ design is further required to be robust in terms of maintaining the closed-loop stability with a guaranteed cost bound. This problem, referred to as robust optimal parametric LQ control with a guaranteed-cost bound, is addressed. A design method is proposed for finding an optimal controller that simultaneously guarantees robust stability and performance over a specified range of parameter variations. The results generalize some previous work in this area. A versatile numerical algorithm is given for computing the robust optimal gains. The usefulness of the design method is demonstrated by the design of robust control of a VTOL helicopter.

#### A90-40885

### FLIGHT CONTROL APPLICATION OF EIGENSTRUCTURE ASSIGNMENT WITH OPTIMIZATION OF ROBUSTNESS TO STRUCTURED STATE SPACE UNCERTAINTY

KENNETH M. SOBEL and WANGLING YU (City College, New York) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1705-1707. refs

(Contract F49620-88-C-0053)

Copyright

The authors propose a robust eigenstructure assignment design method which optimizes the sufficient condition for robust stability while constraining the dominant eigenvalues to lie within chosen regions in the complex plane. This constrained optimization problem is solved by using the sequential unconstrained minimization technique with a quadratic extended interior penalty function. Also introduced is a similarity transformation on the uncertain plant which can reduce the conservatism of the sufficient condition. The design of a robust eigenstructure assignment controller for a pitch pointing/vertical translation maneuver of the AFTI F-16 aircraft is presented as an example.

#### A90-41184

#### JET ENGINE TECHNICAL ADVISOR (JETA)

SUHAYYA ABU-HAKIMA, PHILIPPE DAVIDSON, MIKE HALASZ, and SIEU PHAN (National Research Council of Canada, Laboratory for Intelligent Systems, Ottawa) IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 1. Tullahoma, TN, University of Tennessee, 1989, p. 154-160. refs Copyright

The paper describes a generalized knowledge-based tool for

diagnosis which is currently being applied to jet engine maintenance. A domain-dependent diagnostic tree is created for a particular jet engine by filling in an empty hypothesis frame for each diagnostic node in the tree. The knowledge in the tree is reasoned about using a generalized and explicit reasoning strategy. This strategy can be guided by rules specific to the activation of a particular diagnostic hypothesis in the tree. The user interacts with the system through a window interface which features definitions, glossary information, schematics and explanations of session reasoning, which are all linked to the knowledge contained in the system.

### A90-41188 DESIGN AND ANALYSIS AID FOR EVALUATING AIRCRAFT STRUCTURES

DIANA C. FISHER and TU D. HGUYEN (General Dynamics Corp., Fort Worth, TX) IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 1. Tullahoma, TN, University of Tennessee, 1989, p. 469-472. Copyright

A prototype system was developed during the definition of the Structural Design Evaluator methodology. The system includes three modules: structural integrity analysis; cost/producibility; and reliability, maintainability, and supportability (RM&S). The structural integrity analysis module provides design prediction through stress fatigue and fracture analysis, and recommendations. The cost/producibility analysis module estimates product cost based on the material cost, the manufacturiang process and the design producibility factors. The RM&S analysis module, on the other hand, assists design engineers to identify potential RM&S weakesses then provides recommendations. The expert design knowledge in the existing prototype system focuses on a machined parts family composed of functional features such as webs, flanges, stiffeners, and circular holes. Author

### A90-41189 APPLYING QUALITATIVE KNOWLEDGE TO AIRCRAFT ENGINE SYSTEM DESIGN

R. E. PHILLIPS, W. W. WILSON, and K. PARMENTER (GE Aircraft Engines, Lynn, MA) IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 1. Tullahoma, TN, University of Tennessee, 1989, p. 473-478. refs

The 'Engineous Design Shell' is a system which (1) automates the process of aircraft engine qualitative analysis and evaluation aimed at determining suitable configurations for stipulated functional constraints and (2) captures the qualitative knowledge needed to produce consistently optimal results. Attention is given to a core engine design study conducted by these means which demonstrates the feasibility of qualitative knowledge exploitation in multicomponent systems design. Substantial time-savings are obtained through the obviation of rpm modeling in the global engine cycle representation.

#### A90-41191

### SMAS - AN EXPERT SYSTEM FOR CONFIGURING A RESEARCH FLIGHT SIMULATOR

P. D. HOUGHTON (Royal Aerospace Establishment, Bedford, England) IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 2. Tullahoma, TN, University of Tennessee, 1989, p. 601-609.

Copyright

Some of the problems uncovered during the development of the Simulator Management Advice System (SMAS) are discussed. SMAS is an expert system which gives advice to aeronautical engineers on the configuration of a research flight simulator. Reasons for the choice of expert systems technology are discussed, and the steps taken during the building of SMAS are described in detail. These include knowledge acquisition, knowledge representation, knowledge structuring, knowledge base debugging, representation mechanisms, user interface design, explanation, and advice. Solutions to some problems in 'real' advisory-type applications are described, and areas requiring further research are highlighted.

#### A90-41343

#### FRACTURE CONTROL VIA DRM-ALGORITHM

E. A. GALPERIN (Quebec, Universite, Montreal, Canada) IN: Advances in fracture research; Proceedings of the Seventh International Conference on Fracture (ICF7), Houston, TX, Mar. 20-24, 1989. Volume 2. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 1165-1169. refs Copyright

A method for automatic fracture control is proposed. The method is based on representative parameters measured continuously or at times which are employed as inputs to the DRM-Algorithm. The algorithm automatically checks the consistency of the input data on the basis of the known past history, forms the predictor-controller regression model and yields, as outputs, predicted values of the same parameters or of certain 'safety' function corresponding to a particular engineering problem. On the basis of DRM-Algorithm the automatic safety control systems can be built to monitor and control the mechanical stress or fatigue situation.

#### A90-42454#

Thesis

### DEVELOPMENT AND VERIFICATION OF SOFTWARE FOR FLIGHT SAFETY CRITICAL STRAPDOWN SYSTEMS

WOLFGANG HASSENPFLUG and HOSSEIN AFZALI (LITEF GmbH, Freiburg im Breisgau, Federal Republic of Germany) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 13 p.

A methodology for software development which has proven to work satisfactorily to produce highly reliable software for critical flight safety applications is presented. Available in-service results indicate that the design goal of no more than 10 to the minus ninth failures per flying hour can be achieved. It is shown that the use of assembler language does not necessarily prevent the production of highly reliable software. Further, it is possible to use redundantly employed equipment based on similar hardware and software that is more cost effective than using dissimilar software on dissimilar hardware.

R.E.P.

# N90-23990 Virginia Univ., Charlottesville. ADAPTIVE CONTROL OF A SYSTEM WITH PERIODIC DYNAMICS: APPLICATION OF AN IMPULSE RESPONSE METHOD TO THE HELICOPTER VIBRATION PROBLEM Ph.D.

CARL RICHARD KNOSPE 1989 363 p Avail: Univ. Microfilms Order No. DA9008170

An adaptive blade control algorithm for helicopter vibration reduction is developed as an application of an impulse response control method. The method is based on an impulse response formulation which is applicable to any linear system with periodic dynamics. For such systems, a matrix of discretized impulse responses defines the relationships between sequences of inputs and outputs sampled throughout a period. Under a nearly constant control vector assumption, the impulse response matrix is shown to be full, and for constant dynamics plants, belong to a class of matrices diagonalizable by Fast Fourier transforms, the circulant matrices. For systems with periodic input coefficients, a circulant/diagonal structure results. Such structures are shown to act as a theoretical link between impulse response control methods and frequency domain techniques. In the investigation of adaptive helicopter vibration control presented, a vertical-axis-only plant is simulated by a model composed of an impulse response matrix and an uncontrolled vibration vector. The adaptive control is implemented by a regulator composed of an estimator and a controller. The model parameters are identified by either Kalman

or batch weighted least squares (WLS) filtering in either global or local form. The resulting estimates are used in an optimal control law obtained by the minimization of a constrained, single-step, quadratic performance function. Four control laws are derived: global certainty-equivalent, local certainty equivalent, global cautious, and local cautious. The filters derived are examined in open loop simulations to determine their identification capabilities independent of the control feedback. Two levels of open loop control variation are used to evaluate estimation performance with constant and time-varying plants. The Kalman filters are found to produce lower estimate errors than the WLS filters. Closed loop simulations of the regulators are then conducted with the filters retuned.

### N90-24103\*# Boeing Advanced Systems Co., Seattle, WA. IAPSA 2 SMALL-SCALE SYSTEM SPECIFICATION Final Report

GERALD C. COHEN and THOMAS C. TORKELSON Mar. 1990 310 p.

(Contract NAS1-18099)

(NASA-CR-182006; NÁS 1.26:182006) Avail: NTIS HC A14/MF A02 CSCL 12/2

The details of a hardware implementation of a representative small scale flight critical system is described using Advanced Information Processing System (AIPS) building block components and simulated sensor/actuator interfaces. The system was used to study application performance and reliability issues during both normal and faulted operation.

Author

#### 16

#### **PHYSICS**

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

### A90-39781# FUSELAGE BOUNDARY-LAYER EFFECTS ON SOUND PROPAGATION AND SCATTERING

H. Y. LU (Boeing Commercial Airplanes, Seattle, WA) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1180-1186. Previously cited in issue 13, p. 2051, Accession no. A89-33738. refs Copyright

# A90-41109 EXPERIMENTS ON THE ACTIVE CONTROL OF THE TRANSMISSION OF SOUND THROUGH A CLAMPED RECTANGULAR PLATE

D. R. THOMAS, P. A. NELSON, and S. J. ELLIOTT (Southampton, University, England) Journal of Sound and Vibration (ISSN 0022-460X), vol. 139, June 8, 1990, p. 351-355. Copyright

In order to investigate the problem of the active control of sound transmission within the cabins of propeller-driven aircraft, a series of experiments involving active control of sound transmission through a clamped rectangular steel plate was conducted. The results, reported here, show that it is possible to use active control forces to control the transmission of sound through such a plate, both when the plate is on-resonance and off-resonance. C.D.

### A90-41205# DIRECTIVITY OF THE NOISE RADIATION EMITTED FROM

THE INLET DUCT OF A TURBOSHAFT HELICOPTER ENGINE [DIRECTIVITE DU RAYONNEMENT SONORE EMIS PAR L'ENTREE D'AIR D'UN TURBOMOTEUR D'HELICOPTERE]
H. GOUNET and S. LEWY (ONERA, Chatillon, France) (Congres

H. GOUNET and S. LEWY (ONERA, Chatillon, France) (Congres Francais d'Acoustique, 1st, Lyons, France, Apr. 10-13, 1990) ONERA, TP no. 1990-26, 1990, 5 p. In French. Research supported

by the Service Technique des Programmes Aeronautiques and Turbomeca, S.A. refs (ONERA, TP NO. 1990-26)

A computation method for analyzing inlet duct noise emitted by a turboshaft helicopter engine is presented. Makila turboshaft engine parameters are used as input data. From the model constructed, satisfactory estimates are obtained for determining the noise emissions of an axial flow engine. The methodology applied is shown to be valid when comparing initial predictions with the test results.

#### A90-41206#

INTERACTION BETWEEN A HIGH-LEVEL STEADY ACOUSTIC FIELD AND A DUCTED TURBULENT FLOW (INTERACTION ENTRE UN CHAMP SONORE STATIONNAIRE INTENSE ET UN ECOULEMENT TURBULENT GUIDE)

L.-C. VALDES (ONERA, Chatillon, France) (Congres Francais d'Acoustique, 1st, Lyons, France, Apr. 10-13, 1990) ONERA, TP no. 1990-27, 1990, 5 p. In French. (ONERA, TP NO. 1990-27)

It is noted that an interaction can develop from a steady standing wave in a ducted turbulent flow and it can cause a strong decrease in pressure loss. This interaction occurs only if the acoustic and aerodynamic velocities have perpendicular components, and if the acoustic field is steady.

R.E.P.

#### A90-41207#

WIND-TUNNEL MEASUREMENT OF NOISE EMITTED BY HELICOPTER ROTORS AT HIGH SPEED [MESURE EN SOUFFLERIE DU BRUIT EMIS PAR DES ROTORS D'HELICOPTERE A GRANDE VITESSE]

J. PRIEUR (ONERA, Chatillon, France) (Congres Francais d'Acoustique, 1st, Lyons, France, Apr. 10-13, 1990) ONERA, TP no. 1990-28, 1990, 5 p. In French. (ONERA, TP NO. 1990-28)

Measurements of high-speed impulsive helicopter rotor noise in a wind-tunnel are presented. High-speed impulsive noise measurements have been performed in 1988 in the ONERA S2ch wind-tunnel, fitted with an acoustic lining, on two types of rotors. They show that substantial noise reduction is obtained with sweptback tips, initially designed for aerodynamic purposes, which lower transonic effects on the advancing blade tip. Emphasis is placed on the necessity of taking into account the acoustic annoyance problem, using noise prediction tools, when designing new helicopter blades.

### A90-41240 REDUCED INSERTION LOSS OF X-BAND RF FIBER OPTIC LINKS

H. BLAUVELT, D. B. HUFF (Ortel Corp., Alhambra, CA), G. J. STERN, and I. L. NEWBERG (Hughes Aircraft Co., Los Angeles, CA) IN: Optical technology for microwave applications IV; Proceedings of the Meeting, Orlando, FL, Mar. 28, 29, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 70-77. Research supported by Ortel Corp. and Hughes Aircraft Co. Copyright

Fiber-optic links offer the promise of providing the microwave system designer with new flexibility and capabilities for use in radar and avionics systems. Results presented in this paper show a significant reduction in link RF insertion loss from the typical 40 dB at X-band (9 GHz) to 7 dB over a 3 dB bandwidth of 800 MHz, while maintaining a signal-to-noise ratio of greater than 125 dBc/Hz. This 33 dB improvement can lead the way to many uses of fiber-optics in microwave designs, especially for short distance applications, where currently used waveguide or coax cables have low insertion loss. The improved link insertion loss was obtained in a research and development project in which both optical performance and RF narrow bandwidth passive reactive matching improvements were made on high frequency laser transmitter and photodiode detector receiver units.

A90-42046#

# TWIN JET SCREECH SUPPRESSION CONCEPTS TESTED FOR 4.7 PERCENT AXISYMMETRIC AND TWO-DIMENSIONAL NOZZLE CONFIGURATIONS

S. H. WALKER (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 13 p. refs

(AIAA PAPER 90-2150)

The sonic fatigue of nozzle flaps on F-15 and B-1 aircraft has demanded an increase in aeroacoustic research. A 4.7 percent scale, cold, static test was conducted at the Wright Research and Development Center (WRDC) to investigate noise suppression concepts on F-15 axisymmetric and two-dimensional nozzle configurations. These concepts included lateral spacing, secondary air jets, and tab suppression. Nozzle orientation parametrics included nozzle canting and pitch deflection. Design guideline charts are presented showing screech amplitude variation for each suppression and orientation concept.

A90-42433\*# National Aeronautics and Space Administration.

Ames Research Center, Moffett Field, CA.

CFD AND TRANSONIC HELICOPTER SOUND

TIMOTHY W. PURCELL (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) Associazione Industrie Aerospaziali and Associazione Italiana di Aeronautica ed Astronautica, European Rotorcraft Forum, 14th, Milan, Italy, Sept. 20-23, 1988, Paper. 17 p. refs

A computational method which predicts far-field impulsive noise from a transonic motor blade is demonstrated. This method couples near-field results from a full-potential finite-difference method with a new Kirchhoff integral formulation to extend the finite-difference results into the acoustic far-field. This Kirchhoff formula is written in a blade-fixed coordinate system. It requires initial data from the potential code on a plane at the sonic radius. A recent hovering rotor experiment is described where accurate pressure measurements were recorded on the sonic cylinder and at 2 and 3 radii. The potential code prediction of sonic cylinder pressures is excellent. Acoustic far-field pressure predictions show good agreement with hover experimental data over the range of speeds from 0.85 to 0.92 tip Mach number, the latter of which have delocalized transonic flow. These results are some of the first successful predictions for peak pressure amplitudes using a computational code.

N90-24852\*# Eagle Engineering, Inc., Hampton, VA.
SUMMARY OF SONIC BOOM RISE TIMES OBSERVED
DURING FAA COMMUNITY RESPONSE STUDIES OVER A
6-MONTH PERIOD IN THE OKLAHOMA CITY AREA

DOMENIC J. MAGLIERI and VICTOR E. SOTHCOTT Washington Apr. 1990 123 p

(Contract NAS9-17900)

(NASA-CR-4277; NAS 1.26:4277) Avail: NTIS HC A06/MF A01 CSCL 20/1

The sonic boom signature data acquired from about 1225 supersonic flights, over a 6-month period in 1964 in the Oklahoma City area, was enhanced with the addition of data relating to rise times and total signature duration. These later parameters, not available at the time of publication of the original report on the Oklahoma City sonic boom exposures, are listed in tabular form along with overpressure, positive impulse, positive duration, and waveform category. Airplane operating information along with the surface weather observations are also included. Sonic boom rise times include readings to the 1/2, 3/4, and maximum overpressure values. Rise time relative probabilities for various lateral locations from the ground track of 0, 5, and 10 miles are presented along with the variation of rise times with flight altitude. The tabulated signature data, along with corresponding airplane operating conditions and surface and upper level atmospheric information, are also available on electronic files to provide it in the format for more efficient and effective utilization.

N90-24853\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

FAA/NASA EN ROUTE NOISE SYMPOSIUM

CLEMANS A. POWELL, comp. Washington Apr. 1990 301 p Symposium held in Hampton, VA, 12-13 Sep. 1989 (NASA-CP-3067; L-16763; NAS 1.55:3067) Avail: NTIS HC A14/MF A02 CSCL 20/1

Aircraft community noise annoyance is traditionally a concern only in localities near airports. The proposed introduction of large commercial airplanes with advanced turboprop propulsion systems with supersonic propellers has given rise to concerns of noise annoyance in areas previously considered not to be impacted by aircraft noise. A symposium was held to assess the current knowledge of factors important to the impact of en route noise and to aid in the formulation of FAA and NASA programs in the area. Papers were invited on human response to aircraft noise in areas with low ambient noise levels, aircraft noise heard indoors and outdoors, aircraft noise in recreational areas, detection of propeller and jet aircraft noise, and methodological issues relevant to the design of future studies.

### N90-24854\*# MAG Consultants, Inc., San Francisco, CA. PROPOSED DEFINITION OF THE TERM EN ROUTE IN EN ROUTE AIRCRAFT NOISE

MAURICE A. GARBELL In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 9-12 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

The problem of en route aircraft noise was examined in a formal, dedicated, setting. Whereas the general meaning of the term en route might be intuitively understood, it is suggested that a precise formal definition of the term en route would be opportune from the outset, especially since the scientific and technical investigation of the problem of noise immissions on the ground from aircraft in flight away from the airspace of an airport may conceivably lead to administrative, regulatory, and legal consequences that would mandatorily require a precise definition of the term en route. Five flight segments, with their differing airframe configurations, engine thrusts, and airspeed management, should form the basis for the differential consideration of the noise immissions perceived on the ground underneath or near the defined segments of the flightpath in en route flight, from the end of the initial climb from an airport after takeoff until the final approach to an airport. Author

N90-24855\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PTA EN ROUTE NOISE MEASUREMENTS

WILLIAM L. WILLSHIRE, JR. and DONALD P. GARBÉR (Planning Research Corp., Hampton, VA.) In its FAA/NASA En Route Noise Symposium p 13-29 Apr. 1990

Avail: NTIS HC A14/MF A02 CSCL 20/1

A long-range advanced turboprop en route noise database was obtained with weather, tracking, and onboard measurements. In-flight noise directivity measurements were made. Data repeatability within a test day was excellent. Day-to-day variability existed and is not completely understood and therefore not predicted. Comparison of a two-dimensional ray-tracing propagation model with the ensemble average ground-measured data was good; however, as stated above, the day-to-day data variability was not completely predicted. Future research will include looking at alternative propagation models. Three-dimensional ray tracing, fast field program, and the parabolic equation are possibilities. The effect of turbulence needs to be accessed.

N90-24856\*# Transportation Systems Center, Cambridge, MA. EN ROUTE NOISE: NASA PROPFAN TEST AIRCRAFT (CORRECTED DATA - SIMPLIFIED PROCEDURE)

E. J. RICKLEY In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 31-40 Apr. 1990 (DOT-TSC-FA953-LR4) Avail: NTIS HC A14/MF A02 CSCL 20/1

Surface noise measurements were made during a joint National Aeronautics and Space Administration (NASA) and Federal Aviation

Administration (FAA) program to study the high-altitude, low-frequency acoustic noise propagation characteristics of the Advanced Turboprop (propfan) Aircraft. The measurements were made on October 26-31, 1987 in Huntsville, Alabama and on April 3-13, 1989 at the White Sands Missile Range (WSMR), New Mexico. To effectively compare flight-to-flight data as received on the ground, the procedures and practices of Federal Air Regulation (FAR) Part 36 were used as a guide in adjusting the measured ground data at the time of LA(sub MAX) to a set of reference conditions. After the data for each event were processed using slow detector characteristics, the data record at LA(sub MAX) was then identified and the coordinates of the aircraft at the time of emission were calculated, taking into account atmospheric refraction effects. The effects of atmospheric absorption through the test day and reference day atmosphere were also taken into account and the 1/3-octave data were adjusted accordingly

### N90-24857\*# Transportation Systems Center, Cambridge, MA. EN ROUTE NOISE: NASA PROPFAN TEST AIRCRAFT (CALCULATED SOURCE NOISE

E. J. RICKLEY In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 41-59 Apr. 1990 (DOT-TSC-FA953-LR5) Avail: NTIS HC A14/MF A02 CSCL 20/1

The second phase of a joint National Aeronautics and Space Administration (NASA) and Federal Aviation Administration (FAA) program to study the high-altitude, low-frequency acoustic noise propagation characteristics of the Advanced Turboprop (propfan) Aircraft was conducted on April 3-13, 1989 at the White Sands Missile Range (WSMR), New Mexico. The first phase was conducted on October 26-31, 1987 in Huntsville, Alabama. NASA (Lewis) measured the source noise of the test aircraft during both phases while NASA (Langley) measured surface noise only during the second phase. FAA/NASA designed a program to obtain noise level data from the propfan test bed aircraft, both in the near field and at ground level, during simulated en route flights (35,000 and 20,000 feet ASL), and to test low frequency atmospheric absorption algorithms and prediction technology to provide insight into the necessity for regulatory measures. The curves of calculated source noise versus emission angle are based on a second order best-fit curve of the peak envelope of the adjusted ground data. Centerline and sideline derived source noise levels are shown to be in good agreement. A comparison of the Alabama chase plane source data and the calculated source noise at centerline for both the Alabama and New Mexico data shows good agreement for the 35,000 and the 20,000 feet (ASL) overflights. With the availability of the New Mexico in-flight data, further in depth comparisons will be made.

N90-24858\*# Hessian Ministry for Economics and Technology, Frankfurt (Germany, F.R.). Noise Abatement Office.

EN ROUTE NOISE OF TURBOPROP AIRCRAFT AND THEIR **ACCEPTABILITY: REPORT OF TESTS** 

WOLF HELD In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 61-80 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

The development of propfan-powered aircraft has been observed with great interest. It is obvious that during cruising flight, the aircraft powerplant (propellers) cause a noise clearly perceivable on the ground. It is the audible frequency spectrum of the propfan powerplants relative to the high tip speeds that presents the problem. A flight test was conducted on 30 April, 1989 at the Frankfurt Airport. Results of the test flight are present.

N90-24859\*# Deutsche Forschungsanstalt fuer Luft- und Brunswick Raumfahrt, (Germany, F.R.). Inst. Entwurfsaerodynamik.

**EN ROUTE NOISE OF TWO TURBOPROP AIRCRAFT** WERNER DOBRZYNSKI In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 81-129 Apr. 1990 (DLR-MITT-89-18) Avail: NTIS HC A14/MF A02 CSCL 20/1

In order to weigh en route noise emissions originating from future propfan powered aircraft, a data base of emission levels from conventional turboprop aircraft is needed. For this reason flyover noise measurements on two twin-engine turboprop aircraft were conducted at flight heights between 17,000 and 21,000 ft. Acoustic data are presented together with propeller operational parameters and environmental meteorological data. Narrowband spectral analyses demonstrate the characteristic features of the measured propeller noise signatures: Noise spectra are dominated by the propeller rotational noise fundamental frequency and pronounced noise beats occur as a consequence of different rotational speeds of the propellers.

N90-24860\*# Landesanstalt fuer Umweltschutz, Baden-Wuerttemberg (Germany, F.R.).

#### NOISE MEASUREMENTS OF TURBOPROP AIRPLANES AT DIFFERENT OVERFLIGHT ELEVATIONS

K. MUELLER In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 131-165 Apr. 1990

Avail: NTIS HC A14/MF A02 CSCL 20/1

In order to establish criteria for the regulation of propfan aircraft engine noise emissions, measurement tests of overhead flights of a METRO-3 and a FOKKER-50 aircraft were performed. The decibel levels captured by the ground car microphone are tabulated according to the height of the microphone from the ground as the recording vehicle followed the aircraft through the test flight patterns. Microphone heights of 1.5 and 10 meters from the ground are recorded and correlated to the flight altitudes of the aircraft. which ranged from 5182-6401 meters.

N90-24861\*# Wyle Labs., Inc., El Segundo, CA. SOUND PROPAGATION ELEMENTS IN EVALUATION OF EN ROUTE NOISE OF ADVANCED TURBOFAN AIRCRAFT

LOUIS C. SUTHERLAND and JOHN WESLER (Wyle Labs., Inc., Arlington, VA.) In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 167-174 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

Cruise noise from an advanced turboprop aircraft is reviewed on the basis of available wind tunnel data to estimate the aircraft noise signature at the source. Available analytical models are used to evaluate the sound levels at the ground. The analysis allows reasonable estimates to be made of the community noise levels that might be generated during cruise by such aircraft, provides the basis for preliminary comparisons with available data on noise of existing aircraft during climb and helps to identify the dominant elements of the sound propagation models applicable to this situation.

N90-24862\*# Forest Service, San Dimas, CA. Technology and Development Center.

#### PRELIMINARY THOUGHTS ON AN ACOUSTIC METRIC FOR THE WILDERNESS AIRCRAFT OVERFLIGHT STUDY

ROBIN T. HARRISON and LAWRENCE HARTMANN (Forest In NASA, Langley Research Center, Service, Missoula, MT.) FAA/NASA En Route Noise Symposium p 175-179 Avail: NTIS HC A14/MF A02 CSCL 20/1

Preliminary thoughts on acoustic metrics are presented which may be appropriate for the measurement of sound caused by aircraft overflights of wilderness areas. The use of parameter d'(measure of an energy flattened signal plus noise to nose relationship in the third octave, corrected for the efficiency of the observer) as a standard is considered.

N90-24864\*# Environmental Protection Agency, Washington, DC.

WHEN PROPFANS CRUISE, WILL LDN 65 FLY FRED MINTZ and WILLIAM DICKERSON In In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 195-206 Apr. 1990

Avail: NTIS HC A14/MF A02 CSCL 20/1

The type and extent of response that may be expected from the persons exposed to the noise of propfans cruising overhead

is examined. The cruise mode is of particular interest because it appears that it is in this mode that the propfan airplane noise differs substantially from the noise of present jet-powered airplanes. Early test data on propfan engines suggests that noise levels on the ground under the flight track of commercial propfan transports may approach 65 decibels. To explore the reaction of the exposed population to repeated noise levels of this magnitude, it may be helpful to review some of the pertinent literature on the effects of environmental noise.

#### M90-24865\*# MAG Consultants, Inc., San Francisco, CA. THE EFFECT OF NOISE-ABATEMENT PROFILES ON NOISE IMMISSIONS AND HUMAN ANNOYANCE UNDERNEATH A SUBSEQUENT CLIMBPATH

In NASA, Langley Research Center, MAURICE A. GARBELL FAA/NASA En Route Noise Symposium p 207-215 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

En route noise emissions on the ground can be affected by the detailed characteristics of intended noise-abatement climb profiles and procedures to an extent of 10 or more nautical miles from the start of the takeoff roll of a large or heavy air-carrier-type aircraft. Suggestions submitted to the noise abatement officials of the airports at Frankfurt, Federal Republic of Germany, and Zurick, Switzerland, and the aircarriers Lufthansa German Airlines and SWISSAIR are explained and discussed.

#### N90-24867\*# Meyer (Thomas J.), Hamburg (Germany, F.R.). **ADDITIVE EVALUATION CRITERIA FOR AIRCRAFT NOISE** THOMAS J. MEYER In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 223-226 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

The occurrence of unexpected aircraft noise events will frequently evoke intense complaints about annoyance over such events. It is recognized that the relationship between the volume of complaints and the corresponding maximum noise levels does in fact depend on the circumstances of the complainants and the time of year. The frequency of occurrence of the respective noise events is also a factor. The possible practical value of the addition of the maximal noise level, to the well-known cumulative noise descriptors L(sub eq), L(sub dn), etc. may be considered. One might start by considering the difference between the L(sub eq) and the average maximal noise level of the twenty loudest single noise events on an average day. A somewhat less sharply focused consideration of the maximum noise levels was adopted. In that standard the scope of noise-mitigation measures is defined generally with reference to L(sub eq). If the average maximal noise level L(sub max) of the entire aircraft fleet mix exceeds the L(sub eq) by more than 20 dB(A) and if more than 20 daily aircraft noise events exceed the L(sub eq) than the difference L(sub max)-20 becomes the key criterion for noise-mitigation measures. A statistical correlation of a large number of data from aircraft-noise-monitoring sensors located both directly underneath and laterally disposed to an aircraft flight-path has supplied a basis for the determination of the distribution of the maximal noise levels about the average value, L(sub max), of each type of aircraft. This distribution is given for the takeoff climb and for the landing approach. Author

#### N90-24868\*# Fields (James M.), Silver Spring, MD. SOCIAL SURVEY FINDINGS ON EN ROUTE NOISE **ANNOYANCE ISSUES**

JAMES M. FIELDS In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 227-252 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

Most surveys of residents' reactions to aircraft noise were conducted in the vicinity of airports. The findings in those surveys have supported planning and regulatory actions for the airport noise environment. Now, however, aircraft noise planning and regulations are being considered for a new environment, the en route environment. As policy makers search for bases for public policy in these new noise environments, it is appropriate to ask whether the same scientific evidence which supports airport noise policy can also support en route noise policy. Several aspects of

that question are considered. An introduction establishes the scope of the present study and examines alternative study methodologies. Next, the selected study methodology is described and important assumptions are listed. The body of the paper then consists of the findings on en route issues. The final section presents findings on relevant research methods and considers priorities for further research.

N90-24870\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

EN ROUTE NOISE ANNOYANCE LABORATORY TEST: PRELIMINARY RESULTS

In its FAA/NASA En Route Noise DAVID A. MCCURDY Symposium p 269-281 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

Until recently concerns about the impact of aircraft noise on people have centered around the takeoff and landing operations of aircraft in the vicinity of airport terminals. The development of the advanced turboprop (propfan) engine, modifications to air corridors, and the desire to maintain a natural environment in national parks and recreation areas have now focused attention on the impact at ground level of the en route noise produced by aircraft at cruise conditions and altitudes. Compared to terminal area noise, en route noise is characterized by relatively low noise levels, lack of high frequency spectral content, and long durations. Much research has been directed towards understanding and quantifying the annoyance caused by terminal area aircraft noise. but relatively little research has been conducted for en route noise. To address this need, a laboratory experiment was conducted to quantify the annoyance of people on the ground to en route noise generated by aircraft at cruise conditions. The objectives of the experiment are to determine the annoyance prediction ability of noise measurement procedures and corrections when applied to en route noise; to determine differences in annoyance response to en route noise and takeoff/landing noise; and to determine differences in annoyance response to advanced turboprop en route noise and conventional jet en route noise. Author

N90-24871\*# Geneva Univ. (Switzerland). Centre Univ. d'Ecologie Humaine et des Sciences de l'Environnement. PROBLEMS RELATED TO AIRCRAFT NOISE IN

SWITZERLAND

J. RABINOWITZ In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 283-287 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

Some of the problems related to aircraft noise such as aircraft noise indices, immission standards, land use planning, en route noise and general sensitivity to noise are briefly discussed.

Author

#### N90-24872\*# Norges Tekniske Hoegskole, Trondheim. AN AIRCRAFT NOISE STUDY IN NORWAY

TRULS T. GJESTLAND, KARE H. LIASJO, and HANS EINAR BOHN (Civil Aviation Administration, Oslo, Norway ) Langley Research Center, FAA/NASA En Route Noise Symposium p 289-302 Apr. 1990

Avail: NTIS HC A14/MF A02 CSCL 20/1

An extensive study of aircraft noise is currently being conducted in Oslo, Norway. The traffic at Oslo Airport Fornebu that includes both national and international flights, totals approximately 350 movements per day: 250 of these are regular scheduled flights with intermediate and large size aircraft, the bulk being DC9 and Boeing 737. The total traffic during the summer of 1989 was expected to resemble the maximum level to which the regular traffic will increase before the new airport can be put into operation. The situation therefore represented a possibility to study the noise impact on the communities around Fornebu. A comprehensive social survey was designed, including questions on both aircraft and road traffic noise. A random sample of 1650 respondents in 15 study areas were contacted for an interview. These areas represent different noise levels and different locations relative to the flight paths. The interviews were conducted in a 2 week period just prior to the transfer of charter traffic from Gardemoen to

Fornebu. In the same period the aircraft noise was monitored in all 15 areas. In addition the airport is equipped with a permanent flight track and noise monitoring system. The noise situation both in the study period and on an average basis can therefore be accurately described. In August a group of 1800 new respondents were subjected to identical interviews in the same 15 areas, and the noise measurement program was repeated. Results of the study are discussed.

N90-24873\*# Army Construction Engineering Research Lab., Champaign, IL.

**HUMAN RESPONSE RESEARCH UPDATE** 

PAUL D. SCHOMER In NASA, Langley Research Center, FAA/NASA En Route Noise Symposium p 303-309 Apr. 1990 Avail: NTIS HC A14/MF A02 CSCL 20/1

The methods, sources, instrumentation, the new facility at Aberdeen Proving Grounds, (APG) performance tests, and APG sources are briefly outlined. This presentation is represented by viewgraphs only.

Author

N90-24876# Centro Italiano Ricerche Aerospaziali, Naples. PROBLEMS OF INTERNAL ACOUSTICS IN TWO AND THREE DIMENSIONAL CAVITIES WITH DEFORMABLE WALLS USING THE MSC/NASTRAN CODE [PROBLEMI DI ACUSTICA INTERNA IN CAVITA' 2D E 3D A PARETI DEFORMABILI CON MSC/NASTRAN]

S. DEROSA and M. CAVALIERE 14 Feb. 1989 194 p Partly in ENGLISH and ITALIAN

(DLC/STR-INT-TN-004; ETN-90-96565) Avail: NTIS HC A09/MF A01

A finite element computer code is used to examine the acoustic fields in typical aircraft cabins. Nastran and Patran codes are used because of their versatility and worldwide utilization. Experimental results and comparison with analytical methods are presented. The interactions between the vibrating structure and the induced pressure field in the cavity fluid are demonstrated.

ESA

19

#### **GENERAL**

A90-41769

THE AIRBUS... A CHALLENGE LAUNCHED TWENTY YEARS AGO [L'AIRBUS... UN DEFI LANCE IL Y A VINGT ANS]
JACQUES NOETINGER L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 139, 1989, p. 63-67. In French.
Copyright

The history of the development of the Airbus is briefly reviewed, with emphasis on the events of 1968. Successful solution of the problems surrounding the Airbus development is highlighted.

B.J.

N90-24221\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. LANGLEY AEROSPACE TEST HIGHLIGHTS, 1989

May 1990 175 p

(NASA-TM-102631; NAS 1.15:102631) Avail: NTIS HC A08/MF A01 CSCL 05/4

The role of the NASA Langley Research Center is to perform basic and applied research necessary for the advancement of aeronautics and spaceflight, to generate new and advanced concepts for the accomplishment of related national goals, and to provide research advice, technological support, and assistance to other NASA installations, other government agencies, and industry. Some of the significant tests that were performed during calendar year 1989 in the NASA Langley Research Center test facilities are highlighted. Both the broad range of the research and

technology activities at the NASA Langley Research Center are illustrated along with the contributions of this work toward maintaining United States leadership in aeronautics and space research. Other highlights of Langley research and technology for 1989 are described in Research and Technology 1989 - Langley Research Center.

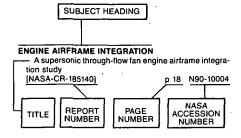
N90-24224# National Aerospace Lab., Amsterdam (Netherlands).

ACTIVITIES REPORT IN AEROSPACE AND AERODYNAMICS Annual Report, 1987 [STICHTING NATIONAAL LUCHT- EN RUIMTEVAARTLABORATORIUM, VERSLAG OVER HET JAAR 1987]

1987 104 p In DUTCH Original contains color illustrations (ETN-90-96774) Avail: NTIS HC A06/MF A01

The flow studies were focused on applied aerodynamic investigations in the fields of propeller propulsion, improvement of the aerodynamic efficiency, and aircraft configurations. The development of the measuring, registration and processing system for the Fokker-50 and Fokker-100 aircrafts was accomplished. Complementary nonlinear calculations were performed concerning the behavior in the Fokker-100 fuselage. Contributions were made to the preparation of the Italian x ray satellite SAX. Basic elements for a computer aided engineering infrastructure were developed. Calculations concerning the noise pollution of large aircrafts were performed. Technical equipment was manufactured for each of the above mentioned research fields.

#### Typical Subject Index Listing



The subject heading is a key to the subject content of the document. The title is used to provide a description of the subject matter. When the title is insufficiently descriptive of document content, a title extension is added, separated from the title by three hyphens. The (NASA or AIAA) accession number and the page number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document. Under any one subject heading, the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

#### **ACCELERATION (PHYSICS)**

Short time Force and moment measurement System for shock tubes (SFS) for measuring times less than 10 p 674 N90-24233

#### **ACCELERATORS**

Accelerators and decelerators for large, hypersonic

[AIAA PAPER 90-1986]

p 674 A90-40582

#### ACCELEROMETERS

Measurement of angles and angle characteristics with accelerometers and gyroscopes p 653 A90-41730

#### ACCEPTABILITY

En route noise of turboprop aircraft and their p 697 N90-24858 acceptability: Report of tests

#### ACCIDENT PREVENTION

Results of TCAS-2 simulations in reconstructed dangerous encounters (Jul. 1986 to Jun. 1989) [ETN-90-96474] p 636 N90-23375

### **ACCIDENTS**

#### [AD-A218544]

Peacetime replacement and crash damage factors for army aircraft p 636 N90-23372

#### **ACCUMULATORS**

Hydraulic accumulators and high pressure bottles in p 688 A90-42493 composite material

#### ACOUSTIC COUPLING

The sensitivity of near-field acoustics to the orientation of twin two-dimensional supersonic nozzles

[AIAA PAPER 90-2149] p 625 A90-42045

#### ACOUSTIC EMISSION

Directivity of the noise radiation emitted from the inlet duct of a turboshaft helicopter engine

[ONERA, TP NO. 1990-26] p 695 A90-41205 Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary

and other emissions [AERE-R-13303-PT-2]

p 678 N90-23523

#### ACQUISTIC FATIGUE

Twin jet screech suppression concepts tested for 4.7 percent axisymmetric and two-dimensional nozzle configurations

[AIAĂ PAPER 90-2150]

p 696 A90-42046

ACOUSTIC MEASUREMENT Helicopter Airborne Laser Positioning System (HALPS) p 654 N90-23399 [NASA-TM-102814] Preliminary thoughts on an acoustic metric for the p 697 N90-24862 wilderness aircraft overflight study Problems of internal acoustics in two and three dimensional cavities with deformable walls using the MSC/Nastran code

[DLC/STR-INT-TN-004]

p 699 N90-24876

**ACOUSTIC PROPERTIES** Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530 ACOUSTIC SCATTERING

Fuselage boundary-layer effects on sound propagation p 695 A90-39781 and scattering

#### ACOUSTIC VELOCITY

Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area

[NASA-CR-4277]

p 696 N90-24852

#### **ACTIVE CONTROL**

Experiments on the active control of the transmission of sound through a clamped rectangular plate

p 695 A90-41109 ATTHeS - A helicopter in-flight simulator for ACT

p 643 A90-41727 testing Active control of helicopter cabin noise

p 645 A90-42434 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 Active control of tiltrotor blade in-plane loads during p 670 A90-42463 maneuvers

#### ACTUATORS

Development of high temperature actuation systems for advanced aircraft engines

[AIAA PAPER 90-2031] p 660 A90-41990 Use of smart actuators for the tail rotor collective pitch p 688 A90-42483 control

#### ADAPTIVE CONTROL

Adaptive control of a system with periodic dynamics: Application of an impulse response method to the p 694 N90-23990 helicopter vibration problem ADHESION TESTS

#### Criteria for coal tar seal coats on airport pavements.

Volume 2: Laboratory and field studies p 674 N90-24277

#### **AEROACOUSTICS**

Investigation of the near wake of a propfan

p 622 A90-40686 Interaction between a high-level steady acoustic field and a ducted turbulent flow

[ONERA, TP NO. 1990-27] Noise-source measurements by thin-film pressure

transducers in a subsonic turbofan model p 659 A90-41212 [ONERA, TP NO. 1990-36] Experimental performance and acoustic investigation of

modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 PTA en route noise measurements

#### p 696 N90-24855

AERODYNAMIC BALANCE Drag measurements on a modified prolate spheroid ·

using a magnetic suspension and balance system p 672 A90-40684

#### **AERODYNAMIC CHARACTERISTICS**

Aerodynamic detuning for control of supersonic rotor forced response

[AIAA PAPER 90-2018] p 621 A90-40596 Preliminary characterization of parachute wake

p 622 A90-40681 recontact Numerical simulation of the growth of instabilities in

supersonic free shear layers p 623 - A90-40941 Aerodynamic work for Hermes spaceplane

p 675 A90-41115

Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its p 623 A90-41740 aerodynamic characteristics

Application of a new adaptive grid for aerodynamic analysis of shock containing single jets [AIAA PAPER 90-2025] p 624 A90-41988

Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings

[AIAA PAPER 90-2126] p 625 A90-42033

The application of concentric vortex simulation to calculating the aerodynamic characteristics of bodies of p 627 A90-42357 revolution at high angles of attack

Comparison with experiment of various computational methods of airflow on three helicopter fuselages p 630 A90-42436

Computation of viscous aerodynamic characteristics of

2-D airfoils for helicopter applications p 631 A90-42440

Improving helicopter aerodynamics - A step ahead p 631 A90-42443

A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed-

p 632 N90-23359 (DLC-EST-TN-030) Experimental performance and acoustic investigation of

modern, counterrotating blade concepts p 649 N90-23393 [NASA-CR-185158]

AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

aircraft [NASA-CR-186663] p 649 N90-23395

Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA) p 671 N90-23413 [NASA-TM-102250]

Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets

p 632 N90-24237 [NASA-TM-4201]

Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade

[NASA-TP-3009] p 633 N90-24239 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base

ogive-cylinders [NASA-CR-4299] p 633 N90-24242

Wind tunnel tests of a 20-gore disk-gap-band parachute

AD-A2213261 New transonic test sections for the NAE 5 ft x 5 ft trisonic

wind tunnel [AD-A2209331 An analytic study of nonsteady two-phase laminar

boundary layer around an airfoil AERODYNAMIC COEFFICIENTS p 691 N90-25051 Determination of aerodynamic sensitivity coefficients

based on the transonic small perturbation formulation p 622 A90-40682 Aerodynamic characteristics of two rotorcraft airfoils

designed for application to the inboard region of a main rotor blade p 633 N90-24239 [NASA-TP-3009]

An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model

p 634 N90-24250 AD-A221220] AFRODYNAMIC CONFIGURATIONS

Navier-Stokes solutions for vortical flows over a tangent-ogive cylinder p 620 A90-39780 Actuated forebody strakes [NASA-CASE-LAR-13983-1]

p 648 N90-23390 Activities report in aerospace and aerodynamics

p 699 N90-24224 [ETN-90-96774] Static wind-tunnel and radio-controlled flight test investigation of a remotely piloted vehicle having a delta

wing planform [NASA-TM-4200] p 632 N90-24238

#### **AERODYNAMIC DRAG**

On the use of external burning to reduce aerospace vehicle transonic drag [AIAA PAPER 90-1935] p 656 A90-40562

#### [AD-A219545] **AERODYNAMIC FORCES**

Counter-rotating propellant analysis using a frequency p 623 A90-40937 domain panel method

Preliminary airworthiness evaluation of the RC-12K

p 648 N90-23387

Coupled aerodynamic forces due to unsteady stall on	STARS: An integrated general-purpose finite element	AIR SAMPLING
a high-aspect-ratio wing oscillating at high amplitude	structural, aeroelastic, and aeroservoelastic analysis	Feasibility study for a microwave-powered ozone sniffer
[ONERA, TP NO. 1990-24] p 623 A90-41203	computer program	aircraft
Aerodynamics of store separation p 629 A90-42418	(NASA-TM-101709) p 689 N90-23768	[NASA-CR-186660] p 650 N90-23397
Measurements of aerodynamic forces on aircraft	Calculation of the aeroelastic blade stabilization with	NASA/USRA high altitude reconnaissance aircraft
external stores in the NAE trisonic blowdown	linearized process	[NASA-CR-186685] p 650 N90-24266
wind-tunnel p 629 A90-42419	[MITT-87-01] p 666 N90-24272	AIR TO AIR MISSILES
STARS: An integrated general-purpose finite element structural, aeroelastic, and aeroservoelastic analysis	AEROSPACE ENGINEERING	The Franco-German helicopter programme HAP,
	Eurofar - Status of the European tilt-rotor project	PAH-2/HAC p 618 A90-42478 AIR TO AIR REFUELING
computer program [NASA-TM-101709] p 689 N90-23768	p 645 A90-42441	
	Langley aerospace test highlights, 1989	Large receiver aircraft - The performance and
AERODYNAMIC INTERFERENCE	[NASA-TM-102631] p 699 N90-24221	longitudinal stability and control during air to air
Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298	AEROSPACE INDUSTRY	refuelling p 669 A90-41767 AIR TRAFFIC
vehicles p 680 A90-39298  Large receiver aircraft - The performance and	Euromart - The European aviation research and	IFR aircraft handled forecast by air route traffic control
longitudinal stability and control during air to air	technology program p 617 A90-41112	
refuelling p 669 A90-41767	AEROSPACE PLANES	center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263
• • • •	Hypersonic (T-D) 'pinch' and aerospaceplane	
The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.	propulsion	An aircraft noise study in Norway p 698 N90-24872 AIR TRAFFIC CONTROL
Il - Interference effects of angularly displaced jets	[AIAA PAPER 90-2474] p 675 A90-42189	Air traffic control Russian book
[AIAA PAPER 90-2107] p 684 A90-42020	AEROSPACE TECHNOLOGY TRANSFER	p 638 A90-39581
Wind tunnel wall interference investigations in NAE/NRC	. Technological preparations of civil aircraft programs	The TVD 900 - A modern signal processing applied to
High Reynolds Number 2D Facility and NASA Langley 0.3m	p 617 A90-41110	primary civilian ATC radar p 638 A90-41034
Transonic Cryogenic Tunnel p 628 A90-42404	AEROSPACE VEHICLES	Design of new Polish primary radars AVIA DM/CM
An experimental investigation of support strut	On the use of external burning to reduce aerospace	p 638 A90-41035
interference on a three-percent fighter model at high angles	vehicle transonic drag	Performances and new surveillance possibilities in SSR
of attack	[AIAA PAPER 90-1935] p 656 A90-40562	- Mode S p 639 A90-41036
[AD-A219793] p 631 N90-23353		Applications of Mode S secondary surveillance radar
AERODYNAMIC LOADS	Conceptual design for aerospace vehicles	to civil air traffic control - Studies, experiments, and policy
Lift response of a rectangular wing undergoing a step	p 651 N90-25043	of the French Direction de la Navigation Aerienne
change in forward speed p 620 A90-39801	AEROTHERMOCHEMISTRY	
Synthesis of optimal multidimensional digital systems	The role of hydrogen/air chemistry in nozzle	p 639 A90-41056 Experiments on Mode S secondary surveillance radar
for the simulation of the angular motions of a flight vehicle	performance for a hypersonic propulsion system	The participation of the French Direction de la Navigation
under random loading p 669 A90-41957	[AIAA PAPER 90-2492] p 658 A90-40637	
5DOF dynamic loads on a jet vane	AEROTHERMODYNAMICS	Aerienne in the European effort p 639 A90-41057 The development result of SPEKTR automated air traffic
[AIAA PAPER 90-2382] p 675 A90-42147	Experimental studies of combustor dilution zone	control (ATC) system with extended grade of automation
A review of tilt rotor download research	aerodynamics. II - Jet development p 659 A90-40947	
p 630 A90-42437	The challenge of demonstrating the X-30	for terminal and hub areas p 639 A90-41058 The GE solid state air defence/ATC radar
Active control of tiltrotor blade in-plane loads during	p 659 · A90-41162	
maneuvers p 670 A90-42463	CFD propels NASP propulsion progress	p 639 A90-41062
AERODYNAMIC NOISE	p 683 A90-41163	Analysis of sequencing and scheduling methods for arrival traffic
Summary of sonic boom rise times observed during FAA	On and off-design performance prediction of single spool	[NASA-TM-102795] p 636 N90-23373
community response studies over a 6-month period in the	turbojets using gasdynamics	Simulator evaluation of the final approach spacing tool
Oklahoma City area	[AIAA PAPER 90-2393] p 662 A90-42155	[NASA-TM-102807] p 636 N90-23374
[NASA-CR-4277] p 696 N90-24852		IFR aircraft handled forecast by air route traffic control
AERODYNAMIC STABILITY	Infrared thermography at hypersonic channel H2K p 674 N90-24235	center: Fiscal years 1990 to 2005
A new simplification method for analysing the rapid	•	· [AD-A220312] p 641 N90-24263
rolling stability of aircraft p 669 A90-42367	AFTERBODIES  Drag reduction by controlling flow separation using	Automatic speech recognition in air-ground data link
rolling stability of allorate p 000 750-42007		Automatic speech recognition in an ground data link
Actuated forebody strakes		600 N00 25027
Actuated forebody strakes [NASA_ASE_I AR_13983_1] p.648_Ngn_23390	stepped afterbodies p 622 A90-40690	p 690 N90-25037
[NASA-CASE-LAR-13983-1] p 648 N90-23390	stepped afterbodies p 622 A90-40690 AFTERBURNING	AIR TRAFFIC CONTROLLERS (PERSONNEL)
[NASA-CASE-LAR-13983-1] p 648 N90-23390 AERODYNAMIC STALLING	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by	stepped afterbodies p 622 A90-40690 AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581
[NASA-CASE-LAR-13983-1] p 648 N90-23390 AERODYNAMIC STALLING Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting	stepped afterbodies p 622 A90-40690 AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761 AH-64 HELICOPTER	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581 AIR TRANSPORTATION
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope p 644 A90-41899	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Purma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope - p 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments [DOT7FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMICS TALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TNO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope p 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349 Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE  The GE solid state air defence/ATC radar	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroptanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope p 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMICS TALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes [OGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE  The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW  Gas turbine engine brush seal applications	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroptanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS)
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroptanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring	stepped atterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE  The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES  Viscous flow analysis for advanced inlet particle	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [OGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 560 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer [NASA-CR-186660] p 650 N90-23397 NASA-USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186680] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [OGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE  The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight	stepped afterbodies p 622 A90-40690  AFTERBURNING  Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER  Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO  Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING  Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE  The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION  Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS  Aviation meteorology - Panel report
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroptanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004 Experiments on Mode S secondary surveillance radar	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMICS TALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [CGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION  Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources  p 638 A90-41004  Experiments on Mode S secondary surveillance radar The participation of the French Direction de la Navigation	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449  Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacle warning system for helicopters
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-23397 NASA-CR-186685] p 650 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186680] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [CGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing  p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels A90-41104	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments  [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION  Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar  The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacte warning system for helicopters p 653 A90-41114  Aeronautical decisionmaking for air ambulance program
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349 Aerodynamic development perspective for traffic aeroptanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915 Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975 The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286 Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298 Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166 Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689 Supersonic flutter of shear deformable laminated	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449  Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacte warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349 Aerodynamic development perspective for traffic aeroptanes [DGLR-89-141] p 637 N90-24260  AEROELASTICITY Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915 Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975 The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286 Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298 Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166 Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689 Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104 Linearized unsteady aerodynamics for turbomachinery aeroelastic applications	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR IRACY	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS  Aviation meteorology - Panel report p 692 A90-39403  Obstacle warning system for helicopters p 653 A90-41114  Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368  Unique failure behavior of metal/composite aircraft
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMICS TALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349 Aerodynamic development perspective for traffic aeroplanes [OGLR-89-141] p 637 N90-24260  AEROELASTICITY Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915 Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975 The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286 Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298 Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166 Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689 Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104 Linearized unsteady aerodynamics for turbomachinery aeroelastic applications [AIAA PAPER 90-2355] p 626 A90-42137	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY Aviation security: Corrective actions underway, but better	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [CGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing  p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 690 N90-24660
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing  p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring  p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim  p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades  p 687 A90-42341	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 690 N90-24660 AIRCRAFT APPROACH SPACING
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroptanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbormachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42341  An experimental and analytical investigation of the buffet	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations,	Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186680] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 Cander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionrmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 659 N90-24660 AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMICS TALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [OGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades p 687 A90-42341  An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairworman, Government Activities and Transportation, House of Representatives	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacle warning system for helicopters p 653 A90-41114  Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 690 N90-24660  AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for arrival traffic
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing  p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring  p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades  p 687 A90-42341  An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417  Aeroelastic response characteristics of a rotor executing	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-23399 AIRCRAFT-ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 690 N90-24660  AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades p 687 A90-42341  An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417  Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367  AIR POLLUTION	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186680] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters  Lace Apolity December 12, 1985 - Gander, Newfoundland p 635 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 650 N90-24660 AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 AIRCRAFT COMMUNICATION
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles [AIAA PAPER 90-1912] p 656 A90-40554 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203 Expanding the B-1B flight envelope  P 644 A90-41899  AERODYNAMICS A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349 Aerodynamic development perspective for traffic aeroplanes [OGLR-89-141] p 637 N90-24260  AEROELASTICITY Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915 Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975 The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286 Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298 Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166 Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689 Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104 Linearized unsteady aerodynamics for turbomachinery aeroelastic applications [AIAA PAPER 90-2355] p 626 A90-42341 An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417 Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations p 646 A90-42464	stepped atterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-99/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar -The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367  AIR ONDITION Aerodynamic development perspective for traffic	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736  The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687  AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403  Obstacle warning system for helicopters p 653 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368  Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 690 N90-24660  AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  AIRCRAFT COMMUNICATION AIRNET: A real-time comunications network for
[NASA-CASE-LAR-13983-1] p 648 N90-23390  AERODYNAMIC STALLING  Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting angles  [AIAA PAPER 90-1912] p 656 A90-40554  Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude  [ONERA, TP NO. 1990-24] p 623 A90-41203  Expanding the B-1B flight envelope  p 644 A90-41899  AERODYNAMICS  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  AEROELASTICITY  Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975  The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286  Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39288  Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104  Linearized unsteady aerodynamics for turbomachinery aeroelastic applications  [AIAA PAPER 90-2355] p 626 A90-42137  Unsteady deformations of elastic rotor blades p 687 A90-42341  An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417  Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations	stepped afterbodies p 622 A90-40690  AFTERBURNING Developmental tests on the M 88 engine are on track p 660 A90-41761  AH-64 HELICOPTER Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237  AIR CARGO Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369  AIR CONDITIONING Starter systems and auxiliary power units p 660 A90-41760  AIR DEFENSE The GE solid state air defence/ATC radar p 639 A90-41062  AIR FLOW Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  AIR INTAKES Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038  AIR NAVIGATION Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 638 A90-41004  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  Application of optimal tracking methods to aircraft terrain following [AD-A221099] p 641 N90-24264  AIR PIRACY  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367  AIR POLLUTION	AIR TRAFFIC CONTROLLERS (PERSONNEL) Air traffic control Russian book  p 638 A90-39581  AIR TRANSPORTATION Hydrogen in future energy and propulsion technology p 692 A90-41736 The Airbus a challenge launched twenty years ago p 699 A90-41769  AIRBORNE EQUIPMENT The Super Puma MKII automatic flight control system p 669 A90-42449 Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450 New systems for helicopter and aircraft vibration monitoring p 653 A90-42477 Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186680] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 AIRBORNE LASERS Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 AIRCRAFT ACCIDENT INVESTIGATION Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 AIRCRAFT ACCIDENTS Aviation meteorology - Panel report p 692 A90-39403 Obstacle warning system for helicopters  Lace Apolity December 12, 1985 - Gander, Newfoundland p 635 A90-41114 Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368 Unique failure behavior of metal/composite aircraft structural components under crash type loads [NASA-TM-102679] p 650 N90-24660 AIRCRAFT APPROACH SPACING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 AIRCRAFT COMMUNICATION

•	·
AIRCRAFT COMPARTMENTS	Airframe/propulsion integration of supersonic cruise
Active control of helicopter cabin noise	vehicles
p 645 A90-42434	(AIAA PAPER 90-2151] p 644 A90-42047
The all glass helicopter cockpit p 653 A90-42447	Exploration of concepts for multi-role fighters
Fire hazards of aerosol cans in aircraft cargo	[AIAA PAPER 90-2276] p 644 A90-42104 Integrated air vehicle/propulsion technology for a
compartments [DOT/FAA/CT-89/32] p 636 N90-23369	multirole fighter - A MCAIR perspective
[DOT/FAA/CT-89/32] p 636 N90-23369 Problems of internal acoustics in two and three	[AIAA PAPER 90-2278] p 644 A90-42105
dimensional cavities with deformable walls using the	Propulsion system-flight control integration-flight
MSC/Nastran code	evaluation and technology transition
[DLC/STR-INT-TN-004] p 699 N90-24876	[AIAA PAPER 90-2280] p 644 A90-42106
AIRCRAFT CONFIGURATIONS	A remote tip-driven fan powered supersonic fighter
Boundary-element shape optimization system for aircraft	concept
structural components p 680 A90-39786	[AIAA PAPER 90-2415] p 663 A90-42167 Preliminary design and analysis of propellers
YF-23A previews design features of future fighters	p 645 A90-42407
p 643 A90-40344	Eurofar - Status of the European tilt-rotor project
A modeling technique for STOVL ejector and volume	p 645 A90-42441
dynamics	Aircraft drawings index p 618 N90-23340
[AIAA PAPER 90-2417] p 663 A90-42168	Preliminary design of a supersonic Short Takeoff and
Application of the KTRAN transonic small disturbance	Vertical Landing (STOVL) fighter aircraft
code to the complete CF-18 aircraft with stores	[NASA-CR-186670] p 649 N90-23394
p 629 A90-42416	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport
The influence of adjacent seating configurations on egress through a type 3 emergency exit	a re-passenger, high-eniclency, commercial transport
[AD-A218393] p 636 N90-23371	[NASA-CR-186663] p 649 N90-23395
Actuated forebody strakes	High speed civil transport
[NASA-CASE-LAR-13983-1] p 648 N90-23390	[NASA-CR-186661] p 649 N90-23396
Preliminary design of a supersonic Short Takeoff and	Feasibility study for a microwave-powered ozone sniffer
Vertical Landing (STOVL) fighter aircraft	aircraft
[NASA-CR-186670] p 649 N90-23394	[NASA-CR-186660] p 650 N90-23397
Composite reduced Navier Stokes procedures for flow	Nonflammable hydraulic power system for tactical
problems with strong pressure interactions	aircraft. Volume 1: Aircraft system definition, design and analysis
[AD-A219621] p 689 N90-23687	
Activities report in aerospace and aerodynamics	[AD-A218493] p 671 N90-23409 Conceptual design for aerospace vehicles
[ETN-90-96774] p 699 N90-24224	p 651 N90-25043
NASA/USRA high altitude reconnaissance aircraft	AIRCRAFT DETECTION
[NASA-CR-186685] p 650 N90-24266	Neural networks for adaptive shape tracking
Helicopter controllability	p 638 A90-39959
[AD-A220078] p 672 N90-24275	Use of pulse radars for helicopters detection - Design
AIRCRAFT CONSTRUCTION MATERIALS	constraints p 683 A90-41073
The mechanisms and benefits of aeroelastic tailoring	AIRCRAFT ENGINES
p 641 A90-39286	UV spectroradiometric output of an F404 turbojet aircraft engine p 652 A90-40195
The influence of material quality on airframe structural durability p 676 A90-41336	engine p 652 A90-40195 Application of leaned blades to an aeroengine
Advanced materials for landing gear	p 654 A90-40503
p 677 A90-41900	Acoustic characteristics of a research step combustor
Advanced material applications for direct lift engines	[AIAA PAPER 90-1851] p 655 A90-40530
[AIAA PAPER 90-2753] p 664 A90-42226	Numerical simulation of the behaviour of internal
Eight years of flight operations with composite	combustion supercharged engines
rotorblades , p 635 A90-42481	[AIAA PAPER 90-1873] p 655 A90-40539
AIRCRAFT CONTROL	Identification of multivariable models of jet engines [AIAA PAPER 90-1874] p 655 A90-40540
Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632	Design of digital self-selecting multivariable controllers
MLS - A total system approach p 640 A90-41710	for jet engines
Large receiver aircraft - The performance and	[AIAA PAPER 90-1875] p 655 A90-40541
longitudinal stability and control during air to air	Computational modeling of inlet hammershock wave
refuelling p 669 A90-41767	generation
Computation of vectoring nozzle performance	[AIAA PAPER 90-2005] p 621 A90-40592
[AIAA PAPER 90-2752] p 627 A90-42225	Glass-ceramic matrix composites for advanced gas
Development of the stall warning/stick pusher system	turbines [AIAA PAPER 90-2014] p 676 A90-40594
for the Boeing/de Havilland Dash 8 Series 300 p 645 A90-42420	[AIAA PAPER 90-2014] p 676 A90-40594 Fiber-optic turbine inlet temperature measurement
Direct drive servovalves: Why and how - The Magnaghi	system (FOTITMS)
Milano answer p 688 A90-42484	[AIAA PAPER 90-2033] p 657 A90-40603
Preliminary airworthiness evaluation of the RC-12K	High-temperature electronics for aircraft engines
[AD-A219545] p 648 N90-23387	[AIAA PAPER 90-2035] p 657 A90-40604
Actuated forebody strakes	The application of an expert maintenance and diagnostic
[NASA-CASE-LAR-13983-1] p 648 N90-23390	tool to aircraft engines [AIAA PAPER 90-2036] p 657 A90-40605
AIRCRAFT DESIGN Boundary-element shape optimization system for aircraft	Full authority digital electronic engine control system
structural components p 680 A90-39786	provides needed reliability
Fatigue methodology III; Proceedings of the AHS	[AIAA PAPER 90-2037] p 658 A90-40606
National Technical Specialists' Meeting on Advanced	Convertible engine system for high speed rotorcraft
Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989	[AIAA PAPER 90-2512] p 658 A90-40643
p 641 A90-39976	Rationale for determining information associated with
Considerations of reliability design for rotorcraft	aircraft gas turbine engines that is of historical
p 680 A90-39977	importance
Designing rotorcraft dynamic components to reliability requirements p 641 A90-39978	[AIAA PAPER 90-2754] p 617 A90-40648
YF-23A previews design features of future fighters	Aircraft engine technology gets a second wind
p 643 A90-40344	p 659 A90-41166
Strake camber and thickness design procedure for low	Applying qualitative knowledge to aircraft engine system
alpha supersonic flow p 622 A90-40678	design p 694 A90-41189
Static aeroelastic tailoring for oblique wing lateral trim	Developmental tests on the M 88 engine are on track
p 667 A90-40689	p 660 A90-41761
Technological preparations of civil aircraft programs	Automated aircraft engine costing using artificial intelligence
p 617 A90-41110	[AIAA PAPER 90-1887] p 660 A90-41981
Design and analysis aid for evaluating aircraft structures p 694 A90-41188	Design and analysis of a large-plug inlet ADP nacelle
	and pylon Advanced Ducted Prop

[AIAA PAPER 90-2015]

advanced aircraft engines

[AIAA PAPER 90-2031]

Development of high temperature actuation systems for

WIG effect vehicles --- Wing-in Ground

[AIAA PAPER 90-2038]

Requirements for business jet aircraft

p 684 A90-41753

p 644 A90-41991

p 673 A90-41986

p 660 A90-41990 -

```
GE's CF34 engine for business and regional jets
                                     p 661 A90-41992
  [AIAA PAPER 90-2041]
    Viscous flow analysis for advanced inlet particle
   separators
  [AIAA PAPER 90-2136]
                                      p 661 A90-42038
    Inclement weather induced aircraft engine power loss
  [AIAA PAPER 90-2169]
                                     p 662 A90-42055
    Direct lift STOVL engine integration
  [AIAA PAPER 90-2274] p 644 A90-42103
Initiation of spalling in aircraft gas turbine bearings
[AIAA PAPER 90-2291] p 686 A90-42110
    Trend analysis and diagnostics codes for training
  [AIAA PAPER 90-2394]
    The promise of advanced materials for a 21st century
  UBE --- ultrahigh bypass ratio engine
  [AIAA PAPER 90-2396]
                                      p 662 A90-42157
    Ultra high bypass turbofan technologies for the
  twenty-first century
  [AIAA PAPER 90-2397]
                                      p 662 A90-42158
    Propulsion control system designs for advanced Navy
  multimission aircraft
  [AIAA PAPER 90-2403]
    JFS190 turbine engine performance optimized using
  Taguchi methods
  [AIAA PAPER 90-2419]
    Engineering design models for ramjet efficiency and lean
  blowoff
  [AIAA PAPER 90-2453]
                                      p 663 A90-42176
    CFE738 - A case for joint engine development
  [AIAA PAPER 90-2522]
                                     p 664 A90-42197
    Turbine configuration impact on advanced IHPTET
  engine system mission capabilities
[AIAA PAPER 90-2739]
                                      p 664 A90-42221
    Co-development of CT7-6 engines - A continued tradition
                                     p 665 A90-42485
  in technology and reliability
    Preliminary airworthiness evaluation of the RC-12K
  [AD-A219545]
                                     p 648 N90-23387
    Fatigue crack growth investigation of a Ti-6AI-4V forging
  under complex loading conditions: NATO/AGARD
  supplemental engine disk program
  [AD-A220239]
                                      p 678 N90-23538
AIRCRAFT EQUIPMENT
    Failure analysis handbook
  (AD-A219747)
                                      p 689 N90-23752
AIRCRAFT FUELS
    Development of a heavy fuel engine for an unmanned
  (AIAA PAPER 90-2170)
                                     p 662 A90-42056
   Experimental turbofan using liquid hydrogen and liquid
  natural gas as fuel
                                     p 663 A90-42170
  [AIAA PAPER 90-2421]
AIRCRAFT HAZARDS
    Fire hazards of aerosol cans in aircraft cargo
  compartments
  [DOT/FAA/CT-89/32]
                                     p 636 N90-23369
    A quantitative technique to estimate microburst wind
                                     p 692 N90-25040
  shear hazard to aircraft
AIRCRAFT INDUSTRY
    Toward total quality in industry
                                     p 684 A90-41768
AIRCRAFT INSTRUMENTS
    The EH101 electronic instrument system
                                     p 652
                                            A90-40462
    Multiple model adaptive controller
                                     for the STOL F-15
                                     p 668 A90-40878
  with sensor/actuator failures.
   Dual cross-polarization planar arrays in the C and X
                                     p 638 A90-40979
   Demonstration of MLS advanced approach techniques
                                     p 640 A90-41711
    Continued development and analysis of a new extended
  Kalman filter for the Completely Integrated Reference
  Instrumentation System (CIRIS)
  [AD-A220106]
                                     p 654 N90-23400
AIRCRAFT LANDING
   Influence of ground effect on helicopter takeoff and
   inding performance p 645 A90-42278
Preliminary airworthiness evaluation of the RC-12K
  landing performance
                                     p 648 N90-23387
 [AD-A219.345]
AIRCRAFT LAUNCHING DEVICES
   Accelerators and decelerators for large, hypersonic
  aircraft
 [AIAA PAPER 90-1986]
                                     p 674 A90-40582
AIRCRAFT MAINTENANCE
    Transport aircraft corrosion control
                                     p 617 A90-40345
    The application of an expert maintenance and diagnostic
 tool to aircraft engines
[AIAA PAPER 90-2036]
                                     p 657 A90-40605
    Concept demonstration of the use of interactive fault
  diagnosis and isolation for TF30 engines
                                     p 617 A90-41177
    Jet Engine Technical Advisor (JETA)
                                     p 693 A90-41184
    The modular HUM system --- Health and Usage
  Monitoring instruments for rotary wing aircraft failure
                                     p 618 A90-42476
```

SUBJECT INDEX

Preliminary design of a long-endurance Mars aircraft
[AIAA PAPER 90-2000] p 674 A90-40587

Use of smart actuators for the tail rotor collective pitch

The effect on fatigue crack growth under spectrum

Preliminary airworthiness evaluation of the RC-12K

Aviation security: Corrective actions underway, but better

inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation

Subcommittee, Committee on Government Operations,

Aeronautical decisionmaking for air ambulance program

A novel synthetic method for studying nonlinear flight

A new simplification method for analysing the rapid

olling stability of aircraft p 669 A90-42367
The influence of the inertia coupling on the stability and

control of the helicopter and the response of helicopter

Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474

ust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless

p 688 A90-42483

p 617 A90-40345

p 643 A90-41339

p 694 A90-41343

p 635 A90-42456

o 635 N90-23367

p 635 N90-23368

p 645 A90-42355

p 647 A90-42473

p 691 N90-25062

subsequent climboath

An aircraft noise study in Norway

results

AIRSPACE

AIRSPEED

aircraft noise

speed envelope

p 698 N90-24865

p 698 N90-24870

p 698 N90-24872

p 696 N90-24854

p 647 A90-42498

En route noise annoyance laboratory test: Preliminary

Proposed definition of the term en route in en route

Flight tests to explore tail rotor limitations in the low

N90-23387

p 648

AIRCRAFT POWER SUPPLIES

Transport aircraft corrosion control

loading of an imposed placard 'G' limit

Fracture control via DRM-Algorithm

The safety analysis approach for the EH101

AIRCRAFT RELIABILITY

[AD-A219545]

AIRCRAFT SAFETY

House of Representatives [GAO/RCED-88-160]

administrators [DOT/FAA/DS-88/8]

rolling stability of aircraft

AIRCRAFT STABILITY

rotor helicopters

stability

control

#### **AIRCRAFT MANEUVERS** AIRCRAFT MANEUVERS Hypervelocity, minimum-radii, coordinated turns p 667 A90-40691 Flight control application of eigenstructure assignment with optimization of robustness to structured state ncertainty p 693 A90-40885 Ultimate boundedness control of uncertain systems with uncertainty application to roll coupled aircraft maneuver ρ 668 Α90-40886 Active control of tiltrotor blade in-plane loads during p 670 A90-42463 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and p 647 strains in flight A90-42497 A study of supermanuever aerodynamics o 631 N90-23349 [AD-A218378] Fighter agility metrics, research, and test p 648 (NAŠA-CR-186118) N90-23386 AIRCRAFT MODELS Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the spatial network method p 638 A90-39855 AIRCRAFT NOISE Fuselage boundary-layer effects on sound propagation p 695 A90-39781 p 643 A90-40685 and scattering Acoustics of ultralight airplanes Experiments on the active control of the transmission of sound through a clamped rectangular plate p 695 A90-41109 Wind-tunnel measurement of noise emitted by helicopter rotors at high speed [ONERA, TP NO. 1990-28] p 695 A90-41207 A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728 Twin jet screech suppression concepts tested for 4.7 percent axisymmetric and two-dimensional . configurations [AIAA PAPER 90-2150] p 696 A90-42046 Evaluation of speech recognizers for use in advanced combat helicopter crew station research and development [NASA-CR-177547] p 650 N90-24265 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route p 696 aircraft noise N90-24854

PTA en route noise measurements

En route noise of two turboprop aircraft [DLR-MITT-89-18] p 69

When propfans cruise, will LDN 65 fly

An aircraft noise study in Norway

Additive evaluation criteria for aircraft noise

wilderness aircraft overflight study

source noise

issues

results

MSC/Nastran code

AIRCRAFT PARTS

Redesign

graphite/epoxy

(AD-A2195451

[AD-A219584]

[NASA-TM-101722]

[NASA-TM-102250]

AIRCRAFT PILOTS

[AD-A218544]

shear hazard to aircraft

Kalman filter

refuelling

[DLC/STR-INT-TN-004]

AIRCRAFT PERFORMANCE

Large receiver aircraft

longitudinal stability and control

[DOT-TSC-FA953-LR5]

En route noise: NASA propfan test aircraft (calculated

Sound propagation elements in evaluation of en route

Preliminary thoughts on an acoustic metric for the

Social survey findings on en route noise annoyance

En route noise annoyance laboratory test: Preliminary

dimensional cavities with deformable walls using the

electro-optical

The

Preliminary airworthiness evaluation of the RC-12K

Estimating short-period dynamics using an extended

Lateral-directional stability and control characteristics of

A quantitative technique to estimate microburst wind

Peacetime replacement and crash damage factors for

the Quiet Short-Haul Research Aircraft (QSRA)

Initial flight test of half-scale unmanned air vehicle

Problems related to aircraft noise in Switzerland

Problems of internal acoustics in two

noise of advanced turbofan aircraft p 697 N90-24861

p 696 N90-24855

p 697 N90-24857

p 697 N90-24859

p 697 N90-24862

p 697 N90-24864

p 698 N90-24867

N90-24870

N90-24871

N90-24872

and three

p 699 N90-24876

shroud

p 676 A90-40215

performance and

during air to air p 669 A90-41767 during

p 648 N90-23387

p 648 N90-23388

p 648 N90-23392

p 671 N90-23413

p 692 N90-25040

p 636 N90-23372

p 698

p 698

ρ 698

p 698

Helicopter controllability [AD-A220078] p 672 N90-24275 AIRCRAFT STRUCTURES Multi-level models for diagnosis of complex p 693 A90-38888 electro-mechanical systems Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft p 679 A90-38975 vibration Multilevel optimization of large-scale structures in a parallel computing environment p 693 A90-39180 Development and application of an optimization procedure for space and aircraft structures

p 679 A90-39186 Boundary-element shape optimization system for aircraft structural components n 680 A90-39786 Stress concentration factors - Comparison of theory with p 680 A90-39979 fatique test data Certification testing methodology for fighter hybrid tructure p 642 A90-40128 structure Design and analysis aid for evaluating aircraft p 694 A90-41188 structures Estimation of fatigue crack growth in patched cracked p 684 A90-41335 Some 1-(diorganooxyphosphonyl)methyl-2,4- and 2,6-dinitro-benzenes

p 678 N90-23475 [NASA-CASE-ARC-11425-3] Modeling growth of fatigue cracks which originate at p 691 N90-25060 Flexural fatigue life prediction of closed hat-section using materially nonlinear axial fatigue characteristics

AIRCRAFT WAKES

Vorticity distribution of vortex street in the wake of a circular cylinder p 623 A90-41751 AIRFOIL OSCILLATIONS

Flow visualization studies of the Mach number effects on dynamic stall of an oscillating airfoil p 622 A90-40683

Flow induced forced response of an incompressible radial cascade including profile and incidence effects p 626 A90-42136 [AIAA PAPER 90-2352] An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model

[AD-A221220] p 634 N90-24250

**AIRFOIL PROFILES** 

Mathematical modeling of plane parallel separated flows past bodies --- Russian book p 619 A90-39475 An introduction to chaos theory in CFD

[AIAA PAPER 90-1440] AIAA PAPER 90-1440] p 680 A90-39725 Transonic flow around airfoils with relaxation and energy supply by homogeneous condensation

p 620 A90-39782 A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41119 Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design

[AIAA PAPER 90-2129] p 625 A90-42035

Bonded airfoil attachments - A path to rotor structural efficienc [AIAA PAPER 90-2177] p 686 A90-42061 Wind tunnel results and numerical computations for the NAE deHavilland series of natural laminar flow airfoils p 628 A90-42403 Determination of aerodynamic sensitivity coefficients based on the transonic small perturbation formulation p 622 A90-40682 A transonic airfoil design method and examples p 627 A90-42351 boundary-layer Higher-order approximations interactive airfoil calculations p 628 A90-42402 Application of the moving surface boundary layer control to a two dimensional airfoil p 628 A90-42405 Nonlinear unsteady airfoil response studies p 628 A90-42406 Automated generation of two-dimensional non-overlapping structured grids for multiple element p 629 A90-42422 airfoils with Euler solutions Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed [DLC-EST-TN-030] p 632 N90-23359 Prediction of aerodynamic performance of airfoils in low Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Euler code predicted separation at the airfoil trailing [FFA-TN-1989-30] p 632 N90-23364 The computation of turbulent thin shear flows associated with flow around multielement aerofoils p 633 N90-24240 An analytic study of nonsteady two-phase laminar o 691 N90-25051 boundary layer around an airfoil AIRFRAME MATERIALS Usage monitoring of military helicopters p 651 A90-39984 SH-2F airframe fatigue test program p 642 A90-39989 The analysis and testing of composite panels subject to muzzle blast effects p 675 A90-39991 The influence of material quality on airframe structural durability p 676 A90-41336 AIRFRAMES The cryogenic wind tunnel as a testing tool for airframe/propulsion systems p 672 A90-40400
Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41338 Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary and other emissions [AERE-R-13303-PT-2] p 678 N90-23523 AIRLINE OPERATIONS Transport aircraft corrosion control p 617 A90-40345 The effect of noise-abatement profiles on noise immissions and human annoyance subsequent climbpath underneath p 698 N90-24865 AIRPORT SECURITY Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367 AIRPORTS Wind shear at Pantelleria airport p 692 A90-39702 MLS mathematical model validation study using airborne MLS data from Midway Airport engineering flight tests, August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 Synthetic aperture radar imagery of airports and surrounding areas: Denver Stapleton International Airport [NASA-CR-4305] p 637 N90-24257 Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies p 674 N90-24277 [AD-A220167] FAA/NASA En Route Noise Symposium
[NASA-CP-3067] p 696 N90-24853
The effect of noise-abatement profiles on noise immissions and human annoyance underneath a

**ALGORITHMS** 

Fracture control via DRM-Algorithm

p 694 A90-41343 Application of optimal tracking methods to aircraft terrain

[AD-A2210991 p 641 N90-24264

En route noise: NASA propfan test aircraft (calculated source noise

(DOT-TSC-FA953-LR5) p 697 N90-24857 ALKYL COMPOUNDS

Some 1-(diorganooxyphosphonyl)methyl-2,4- and

-2,6-dinitro-benzenes [NASA-CASE-ARC-11425-3] p 678 N90-23475

ALL-WEATHER AIR NAVIGATION

Position computation without elevation information for computed centerline operations

[DOT/FAA/CT-TN89/42] p 640 N90-23379 ALTITUDE CONTROL

Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499

ALUMINUM Fatigue crack growth investigation of a Ti-6AI-4V forging

under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538

ALUMINUM ALLOYS

Reconstitution of crack growth from fractographic observations after flight simulation loading

p 682 A90-40650 The influence of material quality on airframe structural p 676 A90-41336 durability

Aircraft applications of advanced composite fiber/metal pressure vessels
[AIAA PAPER 90-2344]

p 686 A90-42133 Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary and other emissions

[AERE-R-13303-PT-2] p 678 N90-23523 Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simulation loading p 689 N90-23760

**ANALOG CIRCUITS** 

Electrical analog circuit for heat transfer measurements on a flat plate simulating turbine vane heat transfer in turbulent flow

[AIAA PAPER 90-2412] p 687 A90-42164

**ANALOGS** 

Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 p 688 N90-23591 ANGLE OF ATTACK

Comparison of high-angle-of-attack slender-body theory

and exact solutions for potential flow over an ellipsoid p 622 A90-40692 The influence of control-surface compensation

parameters on the hinge moment characteristics p 643 A90-41737 An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack

[AD-A219793] p 631 N90-23353

ANGLES (GEOMETRY)

Measurement of angles and angle characteristics with p 653 A90-41730 accelerometers and gyroscopes

ANGULAR VELOCITY Synthesis of optimal multidimensional digital systems

for the simulation of the angular motions of a flight vehicle under random loading p 669 A90-41957 ANNULAR FLOW

Experimental studies of combustor dilution zone aerodynamics. II - Jet development p 659 A90-40947 Numerical analysis of the flows in annular slinger

[AIAA PAPER 90-2164]

p 685 A90-42052 ANTENNA ARRAYS

Dual cross-polarization planar arrays in the C and X p 638 A90-40979

ANTENNA RADIATION PATTERNS Applications of slotted cable antennas in the instrument

landing system p 639 A90-41708 ANTITANK MISSILES

The Franco-German helicopter programme HAP. PAH-2/HAC p 618 A90-42478

APPROACH AND LANDING TESTS (STS) Prediction of longitudinal pilot induced oscillations using

the optimal control model p 671 N90-23412 [AD-A220593]

APPROACH CONTROL

Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373

ARCHITECTURE (COMPUTERS) AIRNET: A real-time comunications network for aircraft

[NASA-CR-186140] p 690 N90-24514 Conceptual design for aerospace p 651 N90-25043 AREA NAVIGATION

An evaluation of the accuracy of a microwave landing system area navigation system at Miami/Tamiami Florida

p 640 N90-23377 IDOT/FAA/CT-TN89/401 ARTIFICIAL INTELLIGENCE

A study of supermanuever aerodynamics

p 631 N90-23349 [AD-A218378] ASPHALT

Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies [AD-A220167] p 674 N90-24277

ATMOSPHERIC ATTENUATION En route noise: NASA propfan test aircraft (calculated

source noise [DOT-TSC-FA953-LR5] p 697 N90-24857

ATMOSPHERIC TURBULENCE

The response of helicopter to dispersed aust p 670 A90-42470

**ATOMIZERS** Symmetry assessment of an air-blast atomizer spray

p 682 A90-40930 ATTACK AIRCRAFT

Development of a least squares time response lower-order equivalent systems technique p 648 N90-23389 (AD-A220527)

**ATTENUATORS** Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259

ATTITUDE CONTROL

A study on the application of controllability and observability concepts in the design of flight control systems p 693 A90-39303

AUTOMATED RADAR TERMINAL SYSTEM

The development result of SPEKTR automated air traffic control (ATC) system with extended grade of automation p 639 A90-41058 for terminal and hub areas

AUTOMATIC CONTROL

Concept development of automatic guidance for otorcraft obstacle avoidance p 669 A90-41632 rotorcraft obstacle avoidance

**AUTOMATIC FLIGHT CONTROL** 

p 653 A90-42448 Digital map reader for helicopters The Super Puma MKII automatic flight control system p 669 A90-42449

Helicopter controllability

[AD-A220078] p 672 N90-24275 **AUTOMATIC PILOTS** 

Digital autopilot for light aircraft p 653 A90-41741

The Super Puma MKII automatic flight control system p 669 A90-42449 **AUTONOMOUS NAVIGATION** 

Control system validation the autonomous

helicopter p 667 A90-38908 **AUTOROTATION** 

Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469

**AUXILIARY POWER SOURCES** Starter systems and auxiliary power units

p 660 A90-41760

**AVIATION METEOROLOGY** 

Aviation meteorology - Panel report

p 692 A90-39403

AVIONICS Polysilicon active-matrix liquid crystal displays for cockpit applications p 681 A90-40393

Holographic combiner design to obtain uniform symbol brightness at head-up display video camera p 652 A90-40394

Application of fracture mechanics to microscale phenomena in electronic assemblies

p 684 A90-41334 Correlation/validation of finite element code analyses for vibration assessment of avionic equipment

[AD-A220393] p 654 N90-23398

**AXIAL STRAIN** 

Finite element analysis of structural components using viscoplastic models with application to a cowl lip NASA-CR-1851891 p 690 N90-23769

В

B-1 AIRCRAFT

Expanding the B-1B flight envelope

p 644 A90-41899

Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23369

**BALL BEARINGS** 

Retirement lives of rolling element bearings

p 680 A90-39980

BEARINGS

Evaluation of solid lubricant powder delivery system for

turbine bearing tubrication [AIAA PAPER 90-2046] p 684 A90-41997

**BEND TESTS** 

Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556

BENDING

Development of a finite element based delamination analysis for laminates subject to extension, bending, and torsion p 679 N90-25049

BENDING FATIGUE

Rotating system load monitoring using minimum fixed system instrumentation p 651 A90-39982 Flexural fatigue life prediction of closed hat-section using materially nonlinear axial fatigue characteristics

p 691 N90-25062

Some 1-(diorganooxyphosphonyl)methyl-2,4- and -2.6-dinitro-benzenes

[NASA-CASE-ARC-11425-3] p 678 N90-23475

**BIRD-AIRCRAFT COLLISIONS** 

Forward canopy feasibility and Thru-The-Canopy (TTC) ejection system study [AD-A220360] p 637 N90-24258

**BLADE SLAP NOISE** 

CFD and transonic helicopter sound

p 696 A90-42433

BLADE TIPS Computation of flow through a centrifugal impeller with

tip leakage [AIAA PAPER 90-2021] p 684 A90-41987

**BLADE-VORTEX INTERACTION** 

CFD and transonic helicopter sound

p 696 A90-42433

A study of the influence of a helicopter rotor blade on the following blades using Euler equations p 630 A90-42435

Estimation of rotor blade incidence and blade deformation from the measurement of pressures and p 647 A90-42497 strains in flight Extension of a three-dimensional viscous wing flow

analysis [NASA-CR-182023] p 631 N90-23348

**BLAST LOADS** 

The analysis and testing of composite panels subject p 675 A90-39991 to muzzle blast effects

BLOWDOWN WIND TUNNEL'S

New transonic test sections for the NAE 5ftx5ft trisonic p 630 A90-42431

The University of Toronto-Ryerson Polytechnical p 673 A90-42432 Institute hypersonic gun tunnel

**BLUNT BODIES** 

Comments on 'Effect of nose bluntness and cone angle on slender-vehicle transition p 620 A90-39814

**BO-105 HELICOPTER** 

Usage monitoring of military helicopters

p 651 A90-39984 Influence of ground effect on helicopter takeoff and p 645 A90-42278 landing performance

BODY KINEMATICS

Computer-aided analysis of three-dimensional multiloop p 669 A90-42328 mechanisms

**BODY-WING CONFIGURATIONS** 

Initial flight test of half-scale unmanned air vehicle [AD-A219584] p 648 N90-23388 **BOEING 747 AIRCRAFT** 

An experimental study of fault propagation in a jet-engine

controller [NASA-CR-181335] p 665 N90-23401

**BOLTED JOINTS** Fatigue evaluation of C/MH-53E main rotor damper

threaded joints

p 642 A90-39988 **BORON COMPOUNDS** 

Metallized fuel particle size study in a solid fuel ramjet p 679 N90-24451 (AD-A220079)

**BOUNDARY ELEMENT METHOD** Boundary-element shape optimization system for aircraft structural components p 680 A90-39786

Calculation of stability derivatives for slender bodies using boundary element method p 620 A90-40181 **BOUNDARY LAYER CONTROL** 

Application of the moving surface boundary layer control to a two dimensional airfoil p 628 A90-42405

A study of supermanuever aerodyn p 631 N90-23349 [AD-A218378]

**BOUNDARY LAYER EQUATIONS** 

Higher-order boundary-layer interactive airfoil calculations nteractive airfoil calculations p 628 A90-42402
Experimental study of the flow around an helicopter fuselage - Comparison with three-dimensional boundary layer calculations p 630 A90-42438

p 647 A90-42494

CHAOS

BOUNDARY LAYER FLOW

Relationship between velocity circulation around a wing	Feasibility study for a microwave-powered ozone snifter	[Alaa Paper 90-1440] p 680 A90-39725
profile and vorticity dispersion in a boundary layer p 620 A90-39539	aircraft [NASA-CR-186660] p 650 · N90-23397	CHARACTERIZATION
The influence of the inlet Mach number on the boundary	CANOPIES	Characterisation of fatigue of aluminium alloys by
layer development on turbomachinery blade surfaces	Nondestructive measurement of residual stresses in	acoustic emission, Part 2: Discrimination between primary
p 621 A90-40504	aircraft transparencies	and other emissions
Non-steady flow loss mechanisms associated with	[AD-A218680] p 689 N90-23762	[AERE-R-13303-PT-2] p 678 N90-23523
vaneless diffusers	Forward canopy feasibility and Thru-The-Canopy (TTC)	CHARGE COUPLED DEVICES
[AIAA PAPER 90-2508] p 682 A90-40641	ejection system study	A daylight stellar sensor using a charge-coupled
Sidewall boundary-layer removal and wall adaptation	[AD-A220360] p 637 N90-24258	device p 637 A90-39002
studies p 672 A90-40680	CANS	CHEMICAL ANALYSIS
Investigations of the influence of stot blowing from the	Fire hazards of aerosol cans in aircraft cargo	HPLC analysis of helicopter rotor blade materials
upper wing surface on the flow around the wing and its	compartments	[AD-A221121] p 650 N90-24270
aerodynamic characteristics p 623 A90-41740	[DOT/FAA/CT-89/32] p 636 N90-23369	CHEMICAL COMPOSITION
Modelling of boundary layer and trailing edge thickness	CARBON FIBER REINFORCED PLASTICS	Influence of fuel composition on flame radiation in gas
effects for the Euler equations using surface	Damage tolerance of carbon fibre reinforced plastic	turbine combustors p 659 A90-40946 HPLC analysis of helicopter rotor blade materials
transpiration p 629 A90-42412 Low-density flow effects for hypervelocity vehicles,	sandwich panels p 675 A90-40047	[AD-A221121] p 650 N90-24270
phase 2	Structural components of fiber-reinforced	CHIPS (ELECTRONICS)
[AD-A221034] p 634 N90-24249	thermoplastics p 676 A90-41111	An experimental study of fault propagation in a jet-engine
An interactive boundary-layer method for unsteady airfoil	EH-101 main rotor hub application of thick carbon fiber	controller
flows. Part 1: Quasi-steady-state model	unidirectional tension bands p 618 A90-42489	[NASA-CR-181335] p 665 N90-23401
[AD-A221220] p 634 N90-24250	CARBON FIBERS	Miniaturization of flight deflection measurement
BOUNDARY LAYER SEPARATION	Aircraft applications of advanced composite fiber/metal	system
Mathematical modeling of plane parallel separated flows	pressure vessels	[NASA-CASE-LAR-13628-1] p 689 N90-23707
past bodies Russian book p 619 A90-39475	[AIAA PAPER 90-2344] p 686 A90-42133	CHLORINE FLUORIDES
Drag reduction by controlling flow separation using	CASCADE FLOW	Nonflammable hydraulic power system for tactical
stepped afterbodies p 622 A90-40690	Simulation of inviscid blade-row interaction using a	aircraft. Volume 1: Aircraft system definition, design and
Boundary-layer transition and separation on a turbine	linearised potential code	analysis
blade in a plane cascade	[AIAA PAPER 90-1916] p 621 A90-40555	[AD-A218493] p 671 N90-23409
[AIAA PAPER 90-2263] p 625 A90-42102	Three-component LDA measurements in an axial-flow	CIRCUIT BOARDS
A study of supermanuever aerodynamics	compressor p 683 A90-40943	Correlation/validation of finite element code analyses
[AD-A218378] p 631 N90-23349	Viscous-inviscid interaction method for calculating the	for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398
Euler code predicted separation at the airfoil trailing	flow in compressor cascade blade passages and wake	[AD-A220393] p 654 N90-23398 CIRCULAR CYLINDERS
edge [FFA-TN-1989-30] p 632 N90-23364	with separation	Vorticity distribution of vortex street in the wake of a
An interactive boundary-layer method for unsteady airfoil	[AIAA PAPER 90-2125] p 624 A90-42032 Inviscid and viscous flows in transonic and supersonic	circular cylinder p 623 A90-41751
flows. Part 1: Quasi-steady-state model	cascades using an implicit upwind relaxation algorithm	CIRCULATION DISTRIBUTION
[AD-A221220] p 634 N90-24250	[AIAA PAPER 90-2128] p 625 A90-42034	Relationship between velocity circulation around a wing
BOUNDARY LAYER STABILITY	Application of 3-D Navier-Stokes computation to bowed	profile and vorticity dispersion in a boundary layer
Boundary layer stability in the case of transonic external	stacking turbine vane design	p 620 A90-39539
flow p 619 A90-39514	[AIAA PAPER 90-2129] p 625 A90-42035	CIVIL AVIATION
Comments on 'Effect of nose bluntness and cone angle	Boundary-layer transition and separation on a turbine	Technological preparations of civil aircraft programs
on slender-vehicle transition' p 620 A90-39814	blade in a plane cascade	p 617 A90-41110
BOUNDARY LAYER TRANSITION	[AIAA PAPER 90-2263] p 625 A90-42102	Euromart - The European aviation research and
Comments on 'Effect of nose bluntness and cone angle	Flow induced forced response of an incompressible	technology program p 617 A90-41112
on slender-vehicle transition' p 620 A90-39814	radial cascade including profile and incidence effects	Aerodynamic development perspective for traffic
Boundary-layer transition and separation on a turbine	[AIAA PAPER 90-2352] p 626 A90-42136	aeroplanes
blade in a plane cascade	Linearized unsteady aerodynamics for turbomachinery	[DGLR-89-141] p 637 N90-24260
[AIAA PAPER 90-2263] p 625 A90-42102	aeroelastic applications	The 30th Airlines International Electronics Meeting Proceedings
Flow unsteadiness effects on boundary layers	[AIAA PAPER 90-2355] p 626 A90-42137	[ETN-90-96973] p 637 N90-24261
[NASA-CR-186067] p 690 N90-24557	Investigation of unsteady flow through a transonic turbine	The effect of noise-abatement profiles on noise
BOUNDARY LAYERS	stage. II - Data/prediction comparison for time-averaged and phase-resolved pressure data	immissions and human annoyance underneath a
Flow unsteadiness effects on boundary layers	[AIAA PAPER 90-2409] p 626 A90-42162	subsequent climbpath p 698 N90-24865
[NASA-CR-186067] p 690 N90-24557	CATHODE RAY TUBES	CLOCKS
BOUNDARY VALUE PROBLEMS	New technology advances for brighter color CRT	Real-time simulation clock
A study of supermanuever aerodynamics	displays p 652 A90-40399	[NASA-CASE-LAR-14056-1] p 689 N90-23713
[AD-A218378] p 631 N90-23349	CAVITIÉS	CLUTTER
Extension-torsion coupling behavior of advanced	Problems of internal acoustics in two and three	Synthetic aperture radar imagery of airports and
composite tilt-rotor blades p 651 N90-25057	dimensional cavities with deformable walls using the	surrounding areas: Denver Stapleton International
BOXES (CONTAINERS)	MSC/Nastran code	Airport
Advanced gearbox technology	[DLC/STR-INT-TN-004] p 699 N90-24876	[NASA-CR-4305] p 637 N90-24257
[NASA-CR-179625] p 666 N90-24274	CENTRIFUGAL COMPRESSORS	COAL
BRAKES (FOR ARRESTING MOTION)	An experimental investigation of rotating stall in a	Criteria for coal tar seal coats on airport pavements.
Accelerators and decelerators for large, hypersonic	centrifugal compressor with vaneless diffuser	Volume 2: Laboratory and field studies
aircraft [AIAA PAPER 90-1986] p 674 A90-40582	p 621 A90-40513 Correlation of radial-to-axial vaneless turns for	[AD-A220167] p 674 N90-24277 COCKPITS
BUBBLES	centrifugal compressors	Taking a new look at cockpit vertical situation displays
	[AIAA PAPER 90-1917] p 656 A90-40556	p 652 A90-40382
Flow visualization via laser-induced reflection from bubble sheets p 680 A90-39784	Characterization of helicopter turboshaft engine noise	Performance of full color active-matrix-LCD in the cockpit
BUFFETING	p 660 A90-41759	environment p 681 A90-40392
An experimental and analytical investigation of the buffet	Computation of flow through a centrifugal impeller with	Polysilicon active-matrix liquid crystal displays for cockpit
excitation parameter p 645 A90-42417	tip leakage	applications p 681 A90-40393
BYPASS RATIO	[AIAA PAPER 90-2021] p 684 A90-41987	Multifunction displays optimized for viewability
Investigation of very high bypass ratio engines for	CERAMIC MATRIX COMPOSITES	p 652 A90-40398
subsonic transports p 659 A90-40945	Glass-ceramic matrix composites for advanced gas	New technology advances for brighter color CRT
Turbofans turn to UHB propulsion p 659 A90-41165	turbines	displays p 652 A90-40399
The promise of advanced materials for a 21st century	[AIAA PAPER 90-2014] p 676 A90-40594	The all glass helicopter cockpit p 653 A90-42447
UBE ultrahigh bypass ratio engine	Composites applications - The future is now	Automatic speech recognition in air-ground data link
[AIAA PAPER 90-2396] p 662 A90-42157	p 678 A90-42372 CERAMICS	p 690 N90-25037 COLLISION AVOIDANCE
Ultra high bypass turbofan technologies for the	Development of impact design methods for ceramic gas	Results of TCAS-2 simulations in reconstructed
twenty-first century	turbine components	dangerous encounters (Jul. 1986 to Jun. 1989)
[AIAA PAPER 90-2397] p 662 A90-42158	[AIAA PAPER 90-2413] p 687 A90-42165	[ETN-90-96474] p 636 N90-23375
•	CERTIFICATION	COLOR
•	Certification testing methodology for fighter hybrid	New technology advances for brighter color CRT
C	structure p 642 A90-40128	displays p 652 A90-40399
	A new noise certification method for 'light propeller	COLOR-COLOR DIAGRAM
C BAND	aircraft' in testing p 635 A90-41728	Performance of full color active-matrix-LCD in the cockpit
Dual cross-polarization planar arrays in the C and X	CHANNEL CAPACITY	environment p 681 A90-40392
bands p 638 A90-40979	Throughput and delay characteristics for a	COMBAT  Proliminary flight evaluation of the SA CCS Parethan
CAMBERED WINGS Strake camber and thickness design procedure for low	slow-frequency hopped aircraft-to-aircraft packet radio network	Preliminary flight evaluation of the SA 365 Panther helicopter in air-to-air combat manoeuvres
anake comber our meanitess design brokedure for low	HELMOIN	mencopies in antional commet marioeuvies

CANARD CONFIGURATIONS

alpha supersonic flow

p 622 A90-40678

[AD-A220525]

p 688 N90-23609

[AIAA PAPER 90-1957]

p 676 A90-40570

Evaluation of speech recognizers for use in advanced Multistep dump combustor design to reduce combustion The problem of supersonic flow past a thin wing of finite combat helicopter crew development p 659 A90-40934 span with fully subsonic leading edges station research and instabilities COMMAND AND CONTROL p 620 A90-39519 Throughput and delay characteristics for a slow-frequency hopped aircraft-to-aircraft packet radio p 650 N90-24265 [NASA-CR-177547] Relationship between velocity circulation around a wing COMBUSTIBLE FLOW profile and vorticity dispersion in a boundary layer network Laser Doppler velocimetry investigation of swirler p 620 A90-39539 p 688 N90-23609 (AD-A2205251 p 682 A90-40929 flowfields An introduction to chaos theory in CFD COMMERCIAL AIRCRAFT p 680 A90-39725 Numerical analysis of the flows in annular slinger [AIAA PAPER 90-1440] Transport aircraft corrosion control Simulation of inviscid blade-row interaction using a p 617 A90-40345 [AIAA PAPER 90-2164] p 685 A90-42052 linearised potential code Requirements for business let aircraft [AIAA PAPER 90-1916] p 621 A90-40555 Direct measurements of skin friction in a scramjet [AIAA PAPER 90-2038] p 644 A90-41991 CFD applications in an aerospace engine test facility combustor Aircraft drawings index p 618 N90-23340 [AIAA PAPER 90-2003] [AIAA PAPER 90-2342] p 626 A90-42132 p 681 A90-40590 AVION: A detailed report on the preliminary design of Computational modeling of inlet hammershock wave COMBUSTION a 79-passenger, high-efficiency, commercial transport On the use of external burning to reduce aerospace eneration aircraft [AIAA PAPER 90-2005] p 621 A90-40592 vehicle transonic drag [NASA-CR-186663] p 649 N90-23395 Application of CFD to pitch/yaw thrust vectoring p 656 A90-40562 [AIAA PAPER 90-1935] High speed civil transport spherical convergent flap nozzles COMBUSTION CHAMBERS [NASA-CR-186661] p 649 N90-23396 [AIAA PAPER 90-2023] p 657 A90-40597 Combustion characteristics of a model can-type The 30th Airlines International Electronics Meeting A numerical investigation of supersonic inlet using p 676 A90-40479 combustor Proceedings implicit TVD scheme Fuel effects on gas turbine combustor dynamics p 637 N90-24261 IETN-90-969731 [AIAA PAPER 90-2135] p 621 A90-40612 p 676 A90-40570 [AIAA PAPER 90-1957] COMMUNICATION EQUIPMENT Transverse fuel-injection model for a scramjet propulsion Hydrocarbon-fueled scramjet combustor investigation AIRNET: A real-time comunications network for p 659 A90-40927 system p 658 A90-40622 [AIAA PAPER 90-2337] aircraft Numerical simulation of the growth of instabilities in [NASA-CR-186140] Development of the jet-swirt high loading combustor p 690 N90-24514 supersonic free shear layers p 623 A90-40941 COMMUNICATION NETWORKS [AIAA PAPER 90-2451] p 658 A90-40633 CFD propels NASP propulsion progress Throughput and delay characteristics for a slow-frequency hopped aircraft-to-aircraft packet radio Multistep dump combustor design to reduce combustion p 683 A90-41163 Viscous-inviscid interaction method for calculating the p 659 A90-40934 instabilities Influence of fuel composition on flame radiation in gas network flow in compressor cascade blade passages and wake turbine combustors p 659 A90-40946 [AD-A2205251 p 688 N90-23609 with separation COMPENSATORY TRACKING Experimental studies of combustor dilution zone aerodynamics. II - Jet development p 659 A90-40947 [AIAA PAPER 90-2125] p 624 A90-42032 Application of optimal tracking methods to aircraft terrain Quasi-3D viscous flow computations in subsonic and following Military engines - Cradle of technology transonic turbomachinery bladings p 660 A90-41758
Some governing parameters of plasma torch igniter/flameholder in a scramjet combustor [AD-A221099] [AIAA PAPER 90-2126] p 641 N90-24264 COMPOSITE MATERIALS Computation of multiple normal shock wave/turbulent Fatigue methodology III; Proceedings of the AHS boundary layer interactions p 661 A90-42017 National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989 [AIAA PAPER 90-2098] [AIAA PAPER 90-2133] p 685 A90-42037 Multiple swirler dome combustor for high temperature Numerical analysis of the flows in annular slinger p 641 A90-39976 rise applications combustors The analysis and testing of composite panels subject [AIAA PAPER 90-2159] p 661 A90-42050 [AIAA PAPER 90-2164] p 675 A90-39991 to muzzle blast effects Modeling gas turbine combustor performance under Numerical modeling of an impinging jet in cross-flow Towards a damage tolerance philosophy for composite transient conditions IAIAA PAPER 90-22461 p 686 A90-42093 [AIAA PAPER 90-2161] p 675 A90-40127 Turbulence model performance in V/STOL flow field p 661 A90-42051 materials and structures Design and manufacturing of composite materials blade Numerical analysis of the flows in annular slinger eimulation p 618 A90-42492 [AIAA PAPER 90-2248] p 625 A90-42094 combustors p 685 A90-42052 Hydraulic accumulators and high pressure bottles in [AIAA PAPER 90-2164] Boundary-layer transition and separation on a turbine composite material p 688 A90-42493 The performance of a combustor pre-diffuser blade in a plane cascade COMPOSITE STRUCTURES incorporating compressor outlet guide vanes [AIAA PAPER 90-2263] p 625 A90-42102 p 661 A90-42053 [AIAA PAPER 90-2165] Optimum design of composite wing structures subjected Numerical simulations of gas turbine combustor flows to displacement constraints p 680 A90-39276 Influences on the uniformity of sprays produced by gas [AIAA PAPER 90-2305] p 686 A90-42116 Finite element analysis of composite panel flutter Investigation of unsteady flow through transonic turbine turbine high shear nozzle/swirler assemblies p 686 A90-42068 p 681 A90-40032 [AIAA PAPER 90-2193] stage. I - Analysis Numerical simulations of gas turbine combustor flows Towards a damage tolerance philosophy for composite p 626 A90-42161 [AIAA PAPER 90-2408] p 686 A90-42116 A modeling technique for STOVL ejector and volume [AIAA PAPER 90-2305] materials and structures p 675 A90-40127 Direct measurements of skin friction in a scramjet Certification testing methodology for fighter hybrid combustor structure p 642 A90-40128 [ÁIAA PAPER 90-2417] p 663 A90-42168 [AIAA PAPER 90-2342] p 626 A90-42132 Mixing characteristics of dilution jets in small gas turbine Advanced materials for landing gear Structure analysis of burning liquid-fueled spray in a combustors p 677 A90-41900 p 664 A90-42217 confined combustor [AIAA PAPER 90-2728] Analysis of composite rotor blades via Saint Venant's [AIAA PAPER 90-2444] p 677 A90-42174 Navier-Stokes analysis of an ejector and mixer-ejector solutions D 688 A90-42491 Engineering design models for ramjet efficiency and lean operating at pressure ratios in the range 2-4 Unique failure behavior of metal/composite aircraft hlowoff [AIAA PAPER 90-2730] p 626 A90-42218 AIAA PAPER 90-2730 J
Calculation of viscous-inviscid strong interaction for ansonic flows over aerofoils p 627 A90-42364 structural components under crash type loads p 663 A90-42176 [AIAA PAPER 90-2453] [NASA-TM-102679] p 690 N90-24660 Radio frequency (RF) heated supersonic flow transonic flows over aerofoils Extension-torsion coupling behavior of advanced laboratory Wind tunnel results and numerical computations for the composite tilt-rotor blades p 651 N90-25057 [AIAA PAPER 90-2469]. p 673 A90-42186 NAE deHavilland series of natural laminar flow airfoils COMPRESSIBLE FLOW Mixing characteristics of dilution jets in small gas turbine p 628 A90-42403 Calculation of three-dimensional jet interaction Application of the KTRAN transonic small disturbance combustors p 664 A90-42217 [AIAA PAPER 90-2728] flowfields code to the complete CF-18 aircraft with stores [AIAA PAPER 90-2099] Introducing the VRT gas turbine combustor p 624 A90-42018 p 629 A90-42416 p 688 N90-23591 COMPRESSOR BLADES [NASA-TM-103176] CFD and transonic helicopter sound Metallized fuel particle size study in a solid fuel ramjet Application of leaned blades to an aeroengine p 696 A90-42433 p 679 N90-24451 p 654 A90-40503 Comparison with experiment of various computational COMBUSTION CHEMISTRY Stall margin improvement in axial-flow compressors by methods of airflow on three helicopter fuselages The influence of swirl on velocity, temperature and p 630 A90-42436 circumferential variation of stationary blade setting species characteristics in a can combustor Rotorcraft computational fluid dynamics - Recent p 664 A90-42177 TAIAA PAPER 90-24541 [AIAA PAPER 90-1912] developments at McDonnell Douglas p 656 A90-40554 COMBUSTION EFFICIENCY Viscous-inviscid interaction method for calculating the p 630 A90-42439 Engineering design models for ramjet efficiency and lean A new Lagrangian method for steady supersonic flow flow in compressor cascade blade passages and wake computation. I - Godunov scheme p 631 A90-42506 with separation [AIAA PAPER 90-2453] p 663 A90-42176 Extension of a three-dimensional viscous wing flow [AIAA PAPER 90-2125] p 624 A90-42032 Metallized fuel particle size study in a solid fuel ramjet Application of neural networks to the F/A-18 engine analysis [AD-A2200791 p 679 N90-24451 [NASA-CR-182023] p 631 N90-23348 condition monitoring system COMBUSTION PHYSICS The computation of turbulent thin shear flows associated p 666 N90-24271 [AD-A219820] Structure analysis of burning liquid-fueled spray in a with flow around multielement aerofoils COMPRESSOR EFFICIENCY p 633 N90-24240 confined combustor Developmental tests on the M 88 engine are on track p 677 A90-42174 [AIAA PAPER 90-24441] Experimental and analytical study of close-coupled ventral nozzles for ASTOVL aircraft p 660 A90-41761 The influence of swirl on velocity, temperature and COMPUTATIONAL FLUID DYNAMICS species characteristics in a can combustor [NASA-TM-103170] p 666 N90-24273 p 664 A90-42177 Calculation of hypersonic forebody/inlet flow fields [AIAA PAPER 90-2454] **COMPUTATIONAL GRIDS** [AIAA PAPER 90-1493] COMBUSTION STABILITY p 619 A90-39049 Application of a new adaptive grid for aerodynamic Boundary layer stability in the case of transonic external Acoustic characteristics of a research step combustor analysis of shock containing single jets p 624 A90-41988 [AIAA PAPER 90-1851] p 655 A90-40530 Fuel effects on gas turbine combustor dynamics p 619 A90-39514 [AIAA PAPER 90-2025]

Perturbations of higher modes in a supersonic jet

p 619 A90-39516

p 686 A90-42116

Numerical simulations of gas turbine combustor flows

[AIAA PAPER 90-2305]

Euler and Navier-Stokes computations for airfoil	A quantitative technique to estimate microburst wind	Digital controller design for the pitch axis of the F-14
geometries using unstructured meshes	shear hazard to aircraft p 692 N90-25040	using an H(infinity) method p 668 A90-40912
p 630 A90-42425 Composite reduced Navier Stokes procedures for flow	CONDENSING  Transonic flow around airfoils with relaxation and energy	Synthesis of optimal multidimensional digital systems for the simulation of the angular motions of a flight vehicle
problems with strong pressure interactions	supply by homogeneous condensation	under random loading p 669 A90-41957
[AD-A219621] p 689 N90-23687	p 620 A90-39782	Propulsion control system designs for advanced Navy
COMPUTER AIDED DESIGN	CONFERENCES	multimission aircraft
Multi-level models for diagnosis of complex electro-mechanical systems p 693 A90-38888	Fatigue methodology III; Proceedings of the AHS	[AIAA PAPER 90-2403] p 663 A90-42160 Design methodology for multivariable helicopter control
electro-mechanical systems p 693 A90-38888  Multilevel optimization of large-scale structures in a	National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989	systems p 669 A90-42461
parallel computing environment p 693 A90-39180	p 641 A90-39976	A highly maneuverable helicopter in-flight simulator -
Development and application of an optimization	Peacetime replacement and crash damage factors for	Aspects of realization
procedure for space and aircraft structures	army aircraft	[AIAA PAPER 88-4607] p 670 A90-42466
p 679 A90-39186	[AD-A218544] p 636 N90-23372	A technique for the tuning of helicopter flight control systems p 670 A90-42467
Design and analysis aid for evaluating aircraft structures p 694 A90-41188	The 30th Airlines International Electronics Meeting	systems p 670 A90-42467 Full Authority Digital Engine Control for the AS 355 N
Applying qualitative knowledge to aircraft engine system	Proceedings [ETN-90-96973] p 637 N90-24261	TM 319 engines p 665 A90-42486
design p 694 A90-41189	FAA/NASA En Route Noise Symposium	CONTROL THEORY
SMAS - An expert system for configuring a research	[NASA-CP-3067] p 696 N90-24853	Prediction of longitudinal pilot induced oscillations using
flight simulator p 694 A90-41191	CONSTRUCTION MATERIALS	the optimal control model
Conceptual design for aerospace vehicles p 651 N90-25043	The promise of advanced materials for a 21st century	[AD-A220593] p 671 N90-23412 Adaptive control of a system with periodic dynamics:
COMPUTER GRAPHICS	UBE ultrahigh bypass ratio engine [AIAA PAPER 90-2396] p 662 A90-42157	Application of an impulse response method to the
Conceptual design for aerospace vehicles	CONTOURS	helicopter vibration problem p 694 N90-23990
p 651 N90-25043	Generation of circumferential velocity contours	CONTROL VALVES
COMPUTER PROGRAMS	associated with pulsed point suction on a rotating disk	Direct drive servovalves: Why and how - The Magnaghi
Modeling gas turbine combustor performance under	p 691 N90-25065	Milano answer p 688 A90-42484
transient conditions [AIAA PAPER 90-2161] p 661 A90-42051	CONTRAROTATING PROPELLERS	CONTROLLABILITY Prediction of longitudinal pilot induced oscillations using
[AIAA PAPER 90-2161] p 661 A90-42051  Trend analysis and diagnostics codes for training	Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937	the optimal control model
purposes	Experimental performance and acoustic investigation of	[AD-A220593] p 671 N90-23412
[AIAA PAPER 90-2394] p 617 A90-42156	modern, counterrotating blade concepts	Static wind-tunnel and radio-controlled flight test
Development and verification of software for flight safety	[NASA-CR-185158] p 649 N90-23393	investigation of a remotely piloted vehicle having a delta
critical strapdown systems p 694 A90-42454	CONTROL SIMULATION	wing planform
The place of knowledge based systems in helicopter	A model for active control of helicopter air resonance	[NASA-TM-4200] p 632 N90-24238 Helicopter controllability
dynamic system condition prognosis p 618 A90-42475	in hover and forward flight p 670 A90-42462 Simulator evaluation of the final approach spacing tool	[AD-A220078] p 672 N90-24275
Continued development and analysis of a new extended	[NASA-TM-102807] p 636 N90-23374	CONTROLLERS
Kalman filter for the Completely Integrated Reference	CONTROL STABILITY	Design of digital self-selecting multivariable controllers
Instrumentation System (CIRIS)	Guaranteed cost control via optimal parametric LQ	for jet engines
[AD-A220106] p 654 N90-23400	design p 693 A90-40810	[AIAA PAPER 90-1875] p 655 A90-40541
STARS: An integrated general-purpose finite element structural, aeroelastic, and aeroservoelastic analysis	Energy based stability analysis of a fuzzy roll controller	Digital controller design for the pitch axis of the F-14 using an H(infinity) method p 668 A90-40912
computer program	design for a flexible aircraft wing p 668 A90-40833 STARS: An integrated general-purpose finite element	An experimental study of fault propagation in a jet-engine
[NASA-TM-101709] p 689 N90-23768	structural, aeroelastic, and aeroservoelastic analysis	controller
IAPSA 2 small-scale system specification	computer program	[NASA-CR-181335] p 665 N90-23401
[NASA-CR-182006] p 695 N90-24103	[NASA-TM-101709] p 689 N90-23768	CONVERGENCE
Extension-torsion coupling behavior of advanced	CONTROL STICKS	Low-density flow effects for hypervelocity vehicles,
composite tilt-rotor blades p 651 N90-25057 Flexural fatigue life prediction of closed hat-section using	Development of the stall warning/stick pusher system	phase 2 [AD-A221034] p 634 N90-24249
materially nonlinear axial fatigue characteristics	for the Boeing/de Havilland Dash 8 Series 300 p 645 A90-42420	CONVERGENT-DIVERGENT NOZZLES
p 691 N90-25062	CONTROL SURFACES	High Mach exhaust system concept scale model test
COMPUTER SYSTEMS DESIGN	Flutter of shaft-supported low aspect-ratio control	results
Development and verification of software for flight safety	surfaces p 667 A90-38912	[AIAA PAPER 90-1905] p 655 A90-40552
critical strapdown systems p 694 A90-42454 COMPUTER SYSTEMS PERFORMANCE	The influence of control-surface compensation	Supersonic rectangular isothermal shrouded jets [AIAA PAPER 90-2028] p 621 A90-40599
IAPSA 2 small-scale system specification	parameters on the hinge moment characteristics p 643 A90-41737	The sensitivity of near-field acoustics to the orientation
[NASA-CR-182006] p 695 N90-24103	Influence of some geometrical and design parameters	of twin two-dimensional supersonic nozzles
COMPUTER TECHNIQUES	on the hinge moment characteristics of rudders	[AIAA PAPER 90-2149] p 625 A90-42045
Measurement of angles and angle characteristics with	p 643 A90-41739	CONVERTIBLE FAN-SHAFT ENGINES
accelerometers and gyroscopes p 653 A90-41730 Computer-aided analysis of three-dimensional multiloop	CONTROL SYSTEMS DESIGN	Precurser convertible engine study [AIAA PAPER 90-2486] p 658 A90-40636
mechanisms p 669 A90-42328	Control system validation in the autonomous helicopter p 667 A90-38908	Convertible engine system for high speed rotorcraft
COMPUTERIZED SIMULATION	Improvement of helicopter handling qualities using	[AIAA PAPER 90-2512] p 658 A90-40643
Dynamic FLIR simulation in flight training research	H(infinity)-optimisation p 667 A90-38965	A hydrodynamic turbo-tan/shaft convertible engine
p 681 A90-40109	Implementation of a transputer-based flight controller	p 665 A90-42487
Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495	p 667 A90-38966	COOLING SYSTEMS
simulation p 620 A90-40495  Numerical simulation of the behaviour of internal	A study on the application of controllability and	The investigation of heat transfer in cooled blades of gas turbines
combustion supercharged engines	observability concepts in the design of flight control systems p 693 A90-39303	[AIAA PAPER 90-2144] · p 685 A90-42043
[AIAA PAPER 90-1873] p 655 A90-40539	Identification of multivariable models of jet engines	CORRIDORS
Simulation of inviscid blade-row interaction using a	[AIAA PAPER 90-1874] p 655 A90-40540	En route noise annoyance laboratory test: Preliminary
linearised potential code	Design of digital self-selecting multivariable controllers	results p 698 N90-24870
[AIAA PAPER 90-1916] p 621 A90-40555	for jet engines	CORROSION PREVENTION
Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687	[AIAA PAPER 90-1875] p 655 A90-40541	Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and
Concept development of automatic guidance for	Analysis of airframe/engine interactions - An integrated control perspective	analysis
rotorcraft obstacle avoidance p 669 A90-41632	[AIAA PAPER 90-1918] p 667 A90-40557	[AD-A218493] p 671 N90-23409
Modeling gas turbine combustor performance under	A preliminary evaluation of an F100 engine parameter	COST ANALYSIS
transient conditions	estimation process using flight data	Peacetime replacement and crash damage factors for
[AIAA PAPER 90-2161] p 661 A90-42051	[AIAA PAPER 90-1921] p 656 A90-40559	army aircraft
Turbulence model performance in V/STOL flow field	Full authority digital electronic engine control system provides needed reliability	[AD-A218544] p 636 N90-23372 Preliminary design of a supersonic Short Takeoff and
simulation	[AIAA PAPER 90-2037] p 658 A90-40606	Vertical Landing (STOVL) fighter aircraft
[AIAA PAPER 90-2248] p 625 A90-42094	Guaranteed cost control via optimal parametric LQ	[NASA-CR-186670] p 649 N90-23394
Active control of tiltrotor blade in-plane loads during maneuvers p 670 A90-42463	design p 693 A90-40810	COST ESTIMATES
Simulator evaluation of the final approach spacing tool	Helicopter control design using feedback linearization	Automated aircraft engine costing using artificial
[NASA-TM-102807] p 636 N90-23374	techniques p 668 A90-40817	intelligence
Introducing the VRT gas turbine combustor	Energy based stability analysis of a fuzzy roll controller	[AIAA PAPER 90-1887] p 660 A90-41981 COST REDUCTION
[NASA-TM-103176] p 688 .N90-23591	design for a flexible aircraft wing p 668 A90-40833 Flight control application of eigenstructure assignment	The promise of advanced materials for a 21st century
Real-time simulation clock		,
		UBE ultrahigh bypass ratio engine
[NASA-CASE-LAR-14056-1] p 689 N90-23713	with optimization of robustness to structured state space uncertainty p 693 A90-40885	[AIAA PAPER 90-2396] p 662 A90-42157
Low-density flow effects for hypervelocity vehicles,	with optimization of robustness to structured state space uncertainty p 693 A90-40885 Ultimate boundedness control of uncertain systems with	(AIAA PAPER 90-2396) p 662 A90-42157 COUNTER ROTATION
	with optimization of robustness to structured state space uncertainty p 693 A90-40885	[AIAA PAPER 90-2396] p 662 A90-42157

**DISPLAY DEVICES** CUMULATIVE DAMAGE p 673 A90-41726 Cryogenic wind tunnels COWLINGS Finite element analysis of structural components using Considerations of reliability design for rotorcraft Toward total quality in industry p 684 A90-41768 viscoplastic models with application to a cowl lip p 680 A90-39977 Design and performance of a small, high speed axial problem The collection of usage data to improve structural compressor [NASA-CR-185189] integrity of operational helicopters p 651 A90-39983 p 690 N90-23769 [AIAA PAPER 90-1911] p 624 A90-41983 CRACK GEOMETRY CYLINDRICAL BODIES Multiple swirter dome combustor for high temperature Subsonic sting interference on the aerodynamic naracteristics of a family of slanted-base Modeling growth of fatigue cracks which originate at rise applications characteristics a family p 691 N90-25060 rivet holes [AIAA PAPER 90-2159] p 661 A90-42050 ogive-cylinders [NASA-CR-4299] CRACK INITIATION On- and off-design performance analysis of hypersonic p 633 N90-24242 Designing rotorcraft dynamic components to reliability detonation wave ramjets [AIAA PAPER 90-2473] p 641 A90-39978 p 664 A90-42188 D CRACK PROPAGATION A novel synthetic method for studying nonlinear flight Designing rotorcraft dynamic components to reliability stability p 645 A90-42355 p 641 A90-39978 requirements Application of 3-D flow analysis to the design of a high ork transonic turbine p 628 A90-42395 Reconstitution of crack growth from fractographic Peacetime replacement and crash damage factors for work transonic turbine observations after flight simulation loading army aircraft Preliminary design and analysis of propellers p 682 A90-40650 p 645 A90-42407 Estimation of fatigue crack growth in patched cracked An experimental study of fault propagation in a jet-engine Flight tests to explore tail rotor limitations in the low p 684 A90-41335 panels controller speed envelope p 647 A90-42498 [NASA-CR-181335] Recent advances in fatigue life analysis methods for p 665 N90-23401 Nonflammable hydraulic power system for tactical DAMAGE ASSESSMENT aerospace applications p 677 A90-41338 aircraft. Volume 1: Aircraft system definition, design and Towards a damage tolerance philosophy for composite The effect on fatigue crack growth under spectrum analysis materials and structures p 675 A90-40127 loading of an imposed placard 'G' limit [AD-A218493] p 671 N90-23409 DAMPERS p 643 A90-41339 DESIGN TO COST Fatique evaluation of C/MH-53E main rotor damper Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary Potential application of automotive fatigue technology threaded joints in rotorcraft design p 681 A90-39987 High temperature powder lubricated dampers for gas and other emissions Automated aircraft engine costing using artificial turbine engines [AERE-R-13303-PT-2] p 678 N90-23523 intelligence [AIAA PAPER 90-2048] p 684 A90-41999 Fatigue crack growth investigation of a Ti-6AI-4V forging under complex loading conditions: NATO/AGARD [AIAA PAPER 90-1887] p 660 A90-41981 DAMPING TESTS The Franco-German helicopter programme HAP, A model for active control of helicopter air resonance PAH-2/HAC supplemental engine disk program p 618 A90-42478 p 670 A90-42462 hover and forward flight DETECTION p 678 N90-23538 [AD-A220239] DATA BASES A comparison of lightning network data with surface Fractographic observations on fatigue crack growth in A comparison of lightning network data with surface weather observations 2024-T3 sheet material under flight-simulation loading weather observations [AD-A220003] p 692 N90-23832 p 689 N90-23760 [AD-A220003] p 692 N90-23832 **DETONATION WAVES** Modeling growth of fatigue cracks which originate at Flow unsteadiness effects on boundary layers p 691 N90-25060 On- and off-design performance analysis of hypersonic p 690 N90-24557 rivet holes [NASA-CR-186067] detonation wave ramjets CRACKING (FRACTURING) **DATA FLOW ANALYSIS** AIAA PAPER 90-2473] p 664 A90-42188 Fatigue evaluation of C/MH-53E main rotor damper The application of an expert maintenance and diagnostic DIFFERENTIAL GEOMETRY p 642 A90-39988 tool to aircraft engines [AIAA PAPER 90-2036] threaded joints Differential-geometrical technique of signal p 657 A90-40605 CRASHES transformation and estimation of position, rate and DATA LINKS Peacetime replacement and crash damage factors for acceleration parameters using supplementary data Applications of Mode S secondary surveillance radar army aircraft p 638 A90-41004 sources [AD-A218544] p 636 N90-23372 to civil air traffic control - Studies, experiments, and policy DIGITAL COMPUTERS of the French Direction de la Navigation Aerienne CRASHWORTHINESS Conceptual design for aerospace vehicles p 639 A90-41056 Operational effects on crashworthy seat attenuators p 651 N90-25043 Automatic speech recognition in air-ground data link p 637 N90-24259 [AD-A221148] DIGITAL ELECTRONICS n 690 N90-25037 CREW WORKSTATIONS High-temperature electronics for aircraft engines [AIAA PAPER 90-2035] p 657 A90-DATA PROCESSING Evaluation of speech recognizers for use in advanced p 657 A90-40604 Real-time simulation clock [NASA-CASE-LAR-14056-1] combat helicopter crew station research and DIGITAL SYSTEMS p 689 N90-23713 development A preliminary evaluation of an F100 engine parameter DATA PROCESSING EQUIPMENT [NASA-CR-177547] p 650 N90-24265 estimation process using flight data Throughput and delay characteristics for a slow-frequency hopped aircraft-to-aircraft packet radio [AIAA PAPER 90-1921] p 656 A90-40559 Full authority digital electronic engine control system provides needed reliability Operational effects on crashworthy seat attenuators network [AD-A221148] ~ p 637 N90-24259 AD-A2205251 p 688 N90-23609 [AIAA PAPER 90-2037] DATA RECORDING Additive evaluation criteria for aircraft noise Digital autopilot for light aircraft p 653 A90-41741 The collection of usage data to improve structural p 698 N90-24867 Synthesis of optimal multidimensional digital systems integrity of operational helicopters
DATA TRANSMISSION p 651 A90-39983 for the simulation of the angular motions of a flight vehicle **CROSS COUPLING** p 669 A90-41957 Analysis of airframe/engine interactions - An integrated under random loading
Digital map reader for helicopters Automatic speech recognition in air-ground data link p 653 A90-42448 control perspective p 690 N90-25037 [AIAA PAPER 90-1918] The Super Puma MKII automatic flight control system p 667 A90-40557 **DECISION MAKING** p 669 A90-42449 CROSS FLOW Aeronautical decisionmaking for air ambulance program The effect of constructive and destructive interference Main characteristics of an integrated flight and display administrators system for AS MKII Super-Puma p 653 A90-42450 on the downstream development of twin jets in a crossflow. [DOT/FAA/DS-88/8] p 635 N90-23368 II - Interference effects of angularly displaced jets DIGITAL TECHNIQUES DECODERS p 684 A90-42020 [AIAA PAPER 90-2107] Design of digital self-selecting multivariable controllers Miniaturization of flight deflection measurement Numerical modeling of an impinging jet in cross-flow for jet engines system [AIAA PAPER 90-2246] p 686 A90-42093 [AIAA PAPER 90-1875] p 655 A90-40541 [NASA-CASE-LAR-13628-1] p 689 N90-23707 Generation of circumferential velocity contours associated with pulsed point suction on a rotating disk Digital control of magnetic bearings supporting a jultimass flexible rotor p 682 A90-40712 DEFLECTION multimass flexible rotor Miniaturization of flight deflection measurement p 691 N90-25065 Onboard digital recording system for flight tests **CROSS POLARIZATION** p 653 A90-41742 [NASA-CASE-LAR-13628-1] p 689 N90-23707 Dual cross-polarization planar arrays in the C and X DEGREES OF FREEDOM
5DOF dynamic loads on a jet vane p 638 A90-40979 Experimental studies of combustor dilution zone aerodynamics. II - Jet development p 659 A90-40947 Mixing characteristics of dilution jets in small gas turbine CROSS SECTIONS [AIAA PAPER 90-2382] p 675 A90-42147 p 618 N90-23340 Aircraft drawings index Helicopter stability and control modeling improvements CRYOGENIC TEMPERATURE combustors [AIAA PAPER 90-2728] and verification on two helicopters p 671 A90-42474 Experimental evaluation of a tuned electromagnetic p 664 A90-42217 DELAMINATING DIRECT LIFT CONTROLS damper for vibration control of cryogenic turbopump Towards a damage tolerance philosophy for composite Advanced material applications for direct lift engines rotors materials and structures p 675 A90-40127 [NASA-TP-3005] p 665 N90-23403 [AIAA PAPER 90-2753] p 664 A90-42226 Development of a finite element based delamination CRYOGENIC WIND TUNNELS DISKS (SHAPES) analysis for laminates subject to extension, bending, and The cryogenic wind tunnel as a testing tool for Coherent vortex structures in the wake of a sphere and

p 679 N90-25049

p 622 A90-40694

p 633 N90-24243

p 658 A90-40633

Flow structure generated by oscillating delta-wing

Development of the jet-swirl high loading combustor

Rotary-Jet thrust augmentor with jet-flapped blades

torsion

DELTA WINGS

DESCRIPTIVE GEOMETRY

[AIAA PAPER 90-2451]

**DESIGN ANALYSIS** 

p 672 A90-40400

p 672 A90-40680

p 673 A90-41726

p 628 A90-42404

p 648 N90-23386

airframe/propulsion systems

Cryogenic wind tunnels

Transonic Cryogenic Tunnel

[NASA-CR-186118]

studies

Sidewall boundary-layer removal and wall adaptation

Wind tunnel wall interference investigations in NAE/NRC

High Reynolds Number 2D Facility and NASA Langley 0.3m

Fighter agility metrics, research, and test

p 623 A90-40749

p 680 A90-39276

p 679 A90-38854

p 652 A90-40381

display,

a circular disk at rest and under forced vibrations

Optimum design of composite wing structures subjected

Flight testing and application of a Peripheral Vision

DISPLACEMENT

DISPLAY DEVICES

to displacement constraints

interpretation of fluid flow datasets

Three-dimensional

Taking a new look at cockpit vertical situation displays	A simple dynamic engine model for use in a real-time	EMERGENCIES
p 652 A90-40382 Performance of full color active-matrix-LCD in the cockpit	aircraft simulation with thrust vectoring [AIAA PAPER 90-2166] p 662 A90-42054	The influence of adjacent seating configurations on egress through a type 3 emergency exit
environment p 681 A90-40392	A comprehensive approach to coupled rotor-fuselage	[AD-A218393] p 636 N90-23371 EMULSIONS
Polysilicon active-matrix liquid crystal displays for cockpit applications p 681 A90-40393	dynamics p 646 A90-42460  Helicopter stability and control modeling improvements	Criteria for coal tar seal coats on airport pavements.
Multifunction displays optimized for viewability p 652 A90-40398	and verification on two helicopters p 671 A90-42474	Volume 2: Laboratory and field studies [AD-A220167] p 674 N90-24277
New technology advances for brighter color CRT	DYNAMIC PRESSURE  Fuel effects on gas turbine combustor dynamics	ENCLOSURES
displays p 652 A90-40399 The all glass helicopter cockpit p 653 A90-42447	[AIAA PAPER 90-1957] p 676 A90-40570	Composite electronic enclosures for engine-mounted environments
Main characteristics of an integrated flight and display	An experimental investigation of turbine rotor wakes for the development of a fiber optic pressure sensor	[AIAA PAPER 90-2030] p 657 A90-40601 ENERGY ABSORPTION
Simulator evaluation of the final approach spacing tool	[AIAA PAPER 90-2411] p 687 A90-42163 DYNAMIC RESPONSE	Operational effects on crashworthy seat attenuators
[NASA-TM-102807] p 636 N90-23374 Automatic speech recognition in air-ground data link	Aeroelastic response characteristics of a rotor executing	[AD-A221148] p 637 N90-24259 ENERGY CONSERVATION
p 690 N90-25037 DISTRIBUTED PROCESSING	arbitrary harmonic blade pitch variations p 646 A90-42464	Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and
Real-time simulation clock	The response of helicopter to dispersed gust	analysis
[NASA-CASE-LAR-14056-1] p 689 N90-23713 DIVERGENCE	p 670 A90-42470  DYNAMIC STRUCTURAL ANALYSIS	[AD-A218493] p 671 N90-23409 ENERGY DISSIPATION
Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915	Non-steady flow loss mechanisms associated with vaneless diffusers
DOPPLER NAVIGATION	Unique failure behavior of metal/composite aircraft	[AIAA PAPER 90-2508] p 682 A90-40641
Modern strapdown system for helicopter p 653 A90-42451	structural components under crash type loads [NASA-TM-102679] p 690 N90-24660	ENGINE AIRFRAME INTEGRATION  Calculation of hypersonic forebody/inlet flow fields
DOPPLER RADAR	[,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	[AIAA PAPER 90-1493] p 619 A90-39049 Analysis of airframe/engine interactions - An integrated
Aviation meteorology - Panel report p 692 A90-39403	E	control perspective
An analytic study of nonsteady two-phase laminar	ECHO SOUNDING	[AIAA PAPER 90-1918] p 667 A90-40557 The challenge of demonstrating the X-30
boundary layer around an airfoil p 691 N90-25051	Ultrasonic regression rate measurement in solid fuel	p 659 A90-41162 3-D Euler calculations for aft-propfan integration
DRAG COEFFICIENTS  Drag measurements on a modified prolate spheroid	ramjets [AIAA PAPER 90-1963] p 656 A90-40573	[AIAA PAPER 90-2147] p 625 A90-42044
using a magnetic suspension and balance system p 672 A90-40684	EDDY VISCOSITY The computation of turbulent thin shear flows associated	Airframe/propulsion integration of supersonic cruise vehicles
DRAG MEASUREMENT	with flow around multielement aerofoils	[AIAA PAPER 90-2151] p 644 A90-42047
Drag measurements on a modified prolate spheroid using a magnetic suspension and balance system	p 633 N90-24240 EGRESS	Direct lift STOVL engine integration [AIAA PAPER 90-2274] p 644 A90-42103
p 672 A90-40684 DRAG REDUCTION	The influence of adjacent seating configurations on egress through a type 3 emergency exit	Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective
On the use of external burning to reduce aerospace	[AD-A218393] p 636 N90-23371	[AIAA PAPER 90-2278] p 644 A90-42105
vehicle transonic drag [AIAA PAPER 90-1935] p 656 A90-40562	EJECTORS  Navier-Stokes analysis of an ejector and mixer-ejector	ENGINE CONTROL Identification of multivariable models of jet engines
Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690	operating at pressure ratios in the range 2-4 [AIAA PAPER 90-2730] p 626 A90-42218	[AIAA PAPER 90-1874] p 655 A90-40540 Design of digital self-selecting multivariable controllers
Effect of detailed surface geometry on riblet drag	Rotary-Jet thrust augmentor with jet-flapped blades	for jet engines
reduction performance p 622 A90-40693  DRAWINGS	p 633 N90-24243 ELASTOMERS	[AIAA PAPER 90-1875] p 655 A90-40541 A preliminary evaluation of an F100 engine parameter
Aircraft drawings index p 618 N90-23340 DROP TESTS	Equilibrium swelling of elastomeric materials in solvent environments	estimation process using flight data [AIAA PAPER 90-1921] p 656 A90-40559
Preliminary characterization of parachute wake	[DE90-010164] p 678 N90-24430	Composite electronic enclosures for engine-mounted
recontact p 622 A90-40681 DROPS (LIQUIDS)	ELECTRIC EQUIPMENT TESTS  A captive store flight vibration simulation project	environments [AIAA PAPER 90-2030] p 657 A90-40601
The effects of toughening stresses on liquid impact induced fracture p 692 A90-41315	p 672 A90-40476 ELECTRICAL FAULTS	Lightweight fuel pump and metering component for advanced gas turbine engine control
DUCTED BODIES	An experimental study of fault propagation in a jet-engine	[AIAA PAPER 90-2032] p 657 A90-40602
Computational modeling of inlet hammershock wave generation	controller [NASA-CR-181335] p 665 N90-23401	Fiber-optic turbine inlet temperature measurement system (FOTITMS)
[AIAA PAPER 90-200\$] p 621 A90-40592  DUCTED FANS	ELECTRO-OPTICS  Redesign of an electro-optical shroud in	[AIAA PAPER 90-2033] p 657 A90-40603 High-temperature electronics for aircraft engines
Recent propeller development and studies conducted	graphite/epoxy p 676 A90-40215	[AIAA PAPER 90-2035] p 657 A90-40604
at ONERA [ONERA, TP NO. 1990-16] p 683 A90-41201	EXPERIMENTAL EVALUATION OF A TUNED Electromagnetic	Full authority digital electronic engine control system provides needed reliability
DUCTED FLOW  Directivity of the noise radiation emitted from the inlet	damper for vibration control of cryogenic turbopump rotors	[AIAA PAPER 90-2037] p 658 A90-40606 Development of high temperature actuation systems for
duct of a turboshaft helicopter engine	[NASA-TP-3005] p 665 N90-23403	advanced aircraft engines
[ONERA, TP NO. 1990-26] p 695 A90-41205 Interaction between a high-level steady acoustic field	ELECTROMECHANICAL DEVICES  Multi-level models for diagnosis of complex	[AIAA PAPER 90-2031] p 660 A90-41990 Propulsion control system designs for advanced Navy
and a ducted turbulent flow [ONERA, TP NO. 1990-27] p 695 A90-41206	electro-mechanical systems p 693 A90-38888 ELECTRON OPTICS	multimission aircraft [AIAA PAPER 90-2403] p 663 A90-42160
Analysis of internal flow in a ventral nozzle for STOVL	Failure analysis handbook	UH-60A helicopter stability augmentation study
aircraft [NASA-TM-103123] p 666 N90-23404	[AD-A219747] p 689 N90-23752 ELECTRONIC CONTROL	p 670 A90-42471 Full Authority Digital Engine Control for the AS 355 N
DUCTS Experimental and analytical study of close-coupled	Composite electronic enclosures for engine-mounted environments	TM 319 engines p 665 A90-42486 ENGINE COOLANTS
ventral nozzles for ASTOVL aircraft	[AIAA PAPER 90-2030] p 657 A90-40601	Gas turbine engine brush seal applications
[NASA-TM-103170] p 666 N90-24273 <b>DUMP COMBUSTORS</b>	High-temperature electronics for aircraft engines [AIAA PAPER 90-2035] p 657 A90-40604	[AIAA PAPER 90-2142] p 685 A90-42041 ENGINE DESIGN
Multistep dump combustor design to reduce combustion instabilities p 659 A90-40934	Full authority digital electronic engine control system provides needed reliability	Linear dynamics of supersonic ramjet p 655 A90-40519
DURABILITY	[AIAA PAPER 90-2037] p 658 A90-40606	Acoustic characteristics of a research step combustor
Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591	ELECTRONIC EQUIPMENT The EH101 electronic instrument system	Lightweight fuel pump and metering component for
DYNAMIC CONTROL  A technique for the tuning of helicopter flight control	p 652 A90-40462 ELEVATION	advanced gas turbine engine control [AIAA PAPER 90-2032] p 657 A90-40602
systems p 670 A90-42467 The place of knowledge based systems in helicopter	Position computation without elevation information for	Convertible engine system for high speed rotorcraft
dynamic system condition prognosis	computed centerline operations [DOT/FAA/CT-TN89/42] p 640 N90-23379	[AIAA PAPER 90-2512] p 658 A90-40643 Rationale for determining information associated with
p 618 A90-42475 DYNAMIC LOADS	Noise measurements of turboprop airplanes at different overflight elevations p 697 N90-24860	aircraft gas turbine engines that is of historical importance .
Gearbox system design for ultra-high bypass engines	EMBEDDED COMPUTER SYSTEMS	[AIAA PAPER 90-2754] p 617 A90-40648
[AIAA PAPER 90-2152] p 685 A90-42048 <b>DYNAMIC MODELS</b>	The Super Puma MKII automatic flight control system p 669 A90-42449	Transverse fuel-injection model for a scramjet propulsion system p 659 A90-40927
Linear dynamics of supersonic ramjet p 655 A90-40519	Main characteristics of an integrated flight and display system for AS MKII Super-Puma p 653 A90-42450	Multistep dump combustor design to reduce combustion instabilities p 659 A90-40934
p 000 7,00 400 10	-, p 000 1100-12400	p 000 7100-40004

Investigation of very high bypass ratio engines for **ENGINE TESTS** EVACUATING (TRANSPORTATION) p 659 A90-40945 CFD applications in an aerospace engine test facility The influence of adjacent seating configurations on subsonic transports [AIAA PAPER 90-2003] p 681 A90-40590 Aircraft engine technology gets a second wind egress through a type 3 emergency exit Adjusting turbine engine transient performance for the [AD-A218393] · p 636 N90-23371 p 659 A90-41166 effects of environmental variances
[AIAA PAPER 90-2501] EVALUATION Applying qualitative knowledge to aircraft engine system p 658 A90-40639 The evaluation of flight recorders p 653 A90-41729 p 694 A90-41189 Developmental tests on the M 88 engine are on track EXHAUST DIFFUSERS Starter systems and auxiliary power units p 660 A90-41761 The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes p 660 A90-41760 Gas turbine engine brush seal applications Design and analysis of a large-plug inlet ADP nacelle [AIAA PAPER 90-2142] p 685 A90-42041 [AIAA PAPER 90-2165] p 661 A90-42053 and pylon --- Advanced Ducted Prop [AIAA PAPER 90-2015] Multiple swirler dome combustor for high temperature EXHAUST EMISSION p 673 A90-41986 rise applications Characterization of helicopter turboshaft engine noise Development of high temperature actuation systems for [AIAA PAPER 90-2159] p 661 A90-42050 p 660 A90-41759 advanced aircraft engines **ENTHALPY** p 660 A90-41990 **EXHAUST FLOW SIMULATION** [AIAA PAPER 90-2031] Radio frequency (RF) heated supersonic flow Analysis of internal flow in a ventral nozzle for STOVL Evaluation of brush seals for limited-life engines laboratory aircraft [AIAA PAPER 90-2140] p 685 A90-42040 [AIAA PAPER 90-2469] p 673 A90-42186 [NASA-TM-103123] High enthalpy hypersonic wind tunnel F4: General description and associated instrumentation p 666 N90-23404 Gas turbine engine brush seal applications EXHAUST NOZZLES [AIAA PAPER 90-2142] p 685 A90-42041 High Mach exhaust system concept scale model test p 673 N90-24228 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 **ENVIRONMENT POLLUTION** [AIAA PAPER 90-1905] p 655 A90-40552 Proposed definition of the term en route in en route The development of a probabilistic turbine rotor design Flight test results of the F-15 SMTD thrust aircraft noise p 696 N90-24854 exhaust vectoring/thrust reversing nozzle En route noise of two turboprop aircraft [AIAA PAPER 90-2176] p 662 A90-42060 STOL/Maneuvering Technology Demonstrator
[AIAA PAPER 90-1906] p 660 p 697 N90-24859 The promise of advanced materials for a 21st century [DLR-MITT-89-18] p 660 A90-41982 UBE -- ultrahigh bypass ratio engine The effect of noise-abatement profiles on noise On and off-design performance prediction of single spool turbojets using gasdynamics immissions and human annoyance underneath a p 662 A90-42157 [AIAA PAPER 90-2396] subsequent climbpath p 698 N90-24865 Ultra high bypass turbofan technologies for the [AIAA PAPER 90-2393] p 662 A90-42155 Problems related to aircraft noise in Switzerland twenty-first century Experimental and analytical study of close-coupled p 698 N90-24871 [AIAA PAPER 90-2397] p 662 A90-42158 ventral nozzles for ASTOVL aircraft **ENVIRONMENT SIMULATION** Component arrangement studies for an 8000 shp p 666 N90-24273 [NASA-TM-103170] Adjusting turbine engine transient performance for the turboshaft high technology core EXHAUST SYSTEMS effects of environmental variances [AIAA PAPER 90-2398] p 663 A90-42159 High Mach exhaust system concept scale model test p 658 A90-40639 [AIAA PAPER 90-2501] Development of impact design methods for ceramic gas requite turbine components **ENVIRONMENTAL TESTS** [AIAA PAPER 90-1905] p 655 A90-40552 p 687 A90-42165 Adjusting turbine engine transient performance for the [AIAA PAPER 90-2413] EXPERT SYSTEMS effects of environmental variances Engineering design models for ramjet efficiency and lean diagnosis Multi-level models of [AIAA PAPER 90-2501] p 658 A90-40639 blowoff
[AIAA PAPER 90-2453] p 693 A90-38888 electro-mechanical systems **EQUATIONS OF MOTION** p 663 A90-42176 The application of an expert maintenance and diagnostic CFE738 - A case for joint engine development Kane's methods in rotorblade dynamics tool to aircraft engines p 646 A90-42458 [AIAA PAPER 90-2522] p 664 A90-42197 [AIAA PAPER 90-2036] p 657 A90-40605 **EROSIVE BURNING** Turbine configuration impact on advanced IHPTET engine system mission capabilities Inverse heat transfer studies and the effects of propellant aluminum on TVC jet vane heating and erosion [AIAA PAPER 90-1860] p 655 A90-40533 Concept demonstration of the use of interactive fault diagnosis and isolation for TF30 engines p 664 A90-42221 [AIAA PAPER 90-2739] p 617 A90-41177 Advanced material applications for direct lift engines p 664 A90-42226 [AIAA PAPER 90-2753] Jet Engine Technical Advisor (JETA) **ERROR ANALYSIS** p 693 A90-41184 Co-development of CT7-6 engines - A continued tradition Concept demonstration of the use of interactive fault p 665 A90-42485 diagnosis and isolation for TF30 engines Design and analysis aid for evaluating aircraft in technology and reliability Contribution of engine improvement on next future p 617 A90-41177 structures p 694 A90-41188 p 665 A90-42488 Applying qualitative knowledge to aircraft engine system rotorcraft **ERROR SIGNALS ENGINE FAILURE** MLS - A total system approach design p 694 A90-41189 p 640 A90-41710 Concept demonstration of the use of interactive fault SMAS - An expert system for configuring a research ight simulator p 694 A90-41191 **ESCAPE SYSTEMS** diagnosis and isolation for TF30 engines flight simulator Forward canopy feasibility and Thru-The-Canopy (TTC) p 617 A90-41177 The place of knowledge based systems in helicopter eiection system study Inclement weather induced aircraft engine power loss [AD-A220360] p 637 N90-24258 dynamic system condition prognosis [AIAA PAPER 90-2169] p 662 A90-42055 p 618 A90-42475 **ESTIMATES** Trend analysis and diagnostics codes for training **EXTERNAL STORE SEPARATION** A quantitative technique to estimate microburst wind Aerodynamics of store separation p 629 A90-42418 shear hazard to aircraft p 692 N90-25040 p 617 A90-42156 [AIAA PAPER 90-2394] Helicopter store separation - Predictive techniques and **ETHYLENE** Application of neural networks to the F/A-18 engine Nonflammable hydraulic power system for tactical fliaht testina p 647 A90-42495 condition monitoring system **EXTERNAL STORES** aircraft. Volume 1: Aircraft system definition, design and [AD-A219820] p 666 N90-24271 A captive store flight vibration simulation project analysis **ENGINE INLETS** p 672 A90-40476 Application of the KTRAN transonic small disturbance (AD-A2184931 p 671 N90-23409 CFD applications in an aerospace engine test facility **EULER EQUATIONS OF MOTION** [AIAA PAPER 90-2003] p 681 A90-40590 code to the complete CF-18 aircraft with stores 3-D Euler calculations for aft-propfan integration Finite element analysis of structural components using viscoplastic models with application to a cowl lip p 629 A90-42416 [AIAA PAPER 90-2147] p 625 A90-42044 Measurements of aerodynamic forces on aircraft Modelling of boundary layer and trailing edge thickness problem external stores in the NAE trisonic blowdown effects for the Euler equations ns using surface p 629 A90-42412 p 690 N90-23769 (NASA-CR-185189) wind-tunnel D 629 A90-42419 ENGINE MONITORING INSTRUMENTS Finite volume solutions of two-dimensional Euler Application of neural networks to the F/A-18 engine condition monitoring system equations on adapted structured meshes n 666 N90-24271 p 629 A90-42413 [AD-A219820] **ENGINE NOISE** of F-14 AIRCRAFT generation two-dimensional Automated Directivity of the noise radiation emitted from the inlet non-overlapping structured grids for multiple element Digital controller design for the pitch axis of the F-14 using an H(infinity) method F-15 AIRCRAFT p 629 A90-42422 duct of a turboshaft helicopter engine airfoils with Euler solutions p 668 A90-40912 [ONERA, TP NO. 1990-26] p 695 A90-41205 Euler and Navier-Stokes computations for airfoil A/F32T-9 large turbo fan engine enclosed noise suppressor system (T-9 NSS), exterior far-field and interior Full authority digital electronic engine control system geometries using unstructured meshes provides needed reliability p 630 A90-42425 noise, McConnell AFB, Kansas [AIAA PAPER 90-2037] p 658 A90-40606 A study of the influence of a helicopter rotor blade on [AD-A220535] p 665 N90-23402 Multiple model adaptive controller for the STOL F-15 the following blades using Euler equations with sensor/actuator failures p 668 A90-40878 Flight test results of the F-15 SMTD thrust Noise measurements of turboprop airplanes at different p 630 A90-42435 overflight elevations p 697 N90-24860 Euler code predicted separation at the airfoil trailing vectoring/thrust reversing exhaust **ENGINE PARTS** nozzle edge Component arrangement studies for an 8000 shp

STOL/Maneuvering Technology Demonstrator [AIAA PAPER 90-1906] p 660 p 660 A90-41982 F-16 AIRCRAFT

Flight control application of eigenstructure assignment with optimization of robustness to structured state space p 693 A90-40885

F-17 AIRCRAFT

p 632 N90-23364

p 631 A90-42506

p 637 N90-24260

An experimental investigation of support strut interference on a three-percent fighter model at high angles p 631 N90-23353 [AD-A219793]

p 663 A90-42159

p 687 A90-42165

p 664 A90-42197

turboshaft high technology core

Development of impact design methods for ceramic gas

CFE738 - A case for joint engine development [AIAA PAPER 90-2522] p 664 A9

Starter systems and auxiliary power units

[AIAA PAPER 90-2398]

[AIAA PAPER 90-2413]

turbine components

**ENGINE STARTERS** 

[FFA-TN-1989-30]

**EUROPEAN AIRBUS** 

**EULER-LAGRANGE EQUATION** 

A new Lagrangian method for steady supersonic flow computation. I - Godunov scheme p 631 A90-42506

The Airbus . . . a challenge launched twenty years ago p 699 A90-41769

Aerodynamic development perspective for traffic

5 to tipopart	CILOR distance to the second	A short of the Asset of the Ass
F-18 AIRCRAFT A simple dynamic engine model for use in a real-time	SH-2F airframe fatigue test program p 642 A90-39989	A study of the technology required for advanced vertical take-off aircraft
aircraft simulation with thrust vectoring	Certification plan for an all-composite main rotor	[ETN-90-96786] p 650 N90-24268
[AIAA PAPER 90-2166] p 662 A90-42054	flexbeam p 642 A90-39992	FILAMENT WINDING
Fighter agility metrics, research, and test	Characterisation of fatigue of aluminium alloys by	Aircraft applications of advanced composite fiber/metal
[NASA-CR-186118] p 648 N90-23386 Application of neural networks to the F/A-18 engine	acoustic emission. Part 2: Discrimination between primary	pressure vessels [AIAA PAPER 90-2344] p 386 A90-42133
condition monitoring system	and other emissions · [AERE-R-13303-PT-2] p 678 N90-23523	FINITE DIFFERENCE THEORY
[AD-A219820] p 666 N90-24271	Fatigue crack growth investigation of a Ti-6Al-4V forging	CFD and transonic helicopter sound
FAIL-SAFE SYSTEMS  Towards a damage tolerance philosophy for composite	under complex loading conditions: NATO/AGARD	p 696 A90-42433 FINITE ELEMENT METHOD
materials and structures p 675 A90-40127	supplemental engine disk program	Finite element analysis of composite panel flutter
FAILURE ANALYSIS	[AD-A220239] p 678 N90-23538	p 681 A90-40032
Application of fracture mechanics to microscale	FAULT TOLERANCE An experimental study of fault propagation in a jet-engine	Simulation of inviscid blade-row interaction using a
phenomena in electronic assemblies p 684 A90-41334	controller	linearised potential code [AIAA PAPER 90-1916] p 621 A90-40555
Initiation of spalling in aircraft gas turbine bearings	[NASA-CR-181335] p 665 N90-23401	Planet gear sleeve spinning analysis
[AIAA PAPER 90-2291] p 686 A90-42110	FEASIBILITY ANALYSIS	[AIAA PAPER 90-2154] p 681 A90-40613
A 'new' philosophy of structural reliability, fail safe versus	Forward canopy feasibility and Thru-The-Canopy (TTC) ejection system study	Nonlinear finite-element analysis to predict fan-blade
sate life p 688 A90-42490 Failure analysis handbook	[AD-A220360] p 637 N90-24258	damage due to soft-body impact p 683 A90-40939
[AD-A219747] p 689 N90-23752	FEEDBACK CONTROL	Finite-element analysis of large spur and helical gear systems p 683 A90-40940
Development of a finite element based delamination	Improvement of helicopter handling qualities using	An improvement on upwinding technique used in the
analysis for laminates subject to extension, bending, and	H(infinity)-optimisation p 667 A90-38965	Galerkin finite element method for the computation of
torsion p 679 N90-25049 FAILURE MODES	Analysis of airframe/engine interactions - An integrated control perspective	inviscid transonic flow with shock waves
The modular HUM system Health and Usage	[AIAA PAPER 90-1918] p 667 A90-40557	ρ 627 A90-42361 Finite element simulation of unsteady two-dimensional
Monitoring instruments for rotary wing aircraft failure	Guaranteed cost control via optimal parametric LQ	incompressible viscous flows p 629 A90-42423
detection p 618 A90-42476	design p 693 A90-40810	Correlation/validation of finite element code analyses
Failure analysis handbook [AD-A219747] p 689 N90-23752	Helicopter control design using feedback linearization	for vibration assessment of avionic equipment
Unique failure behavior of metal/composite aircraft	techniques p 668 A90-40817 Ultimate boundedness control of uncertain systems with	[AD-A220393] p 654 N90-23398
structural components under crash type loads	application to roll coupled aircraft maneuver	STARS: An integrated general-purpose finite element
[NASA-TM-102679] p 690 N90-24660	p 668 A90-40886	structural, aeroelastic, and aeroservoelastic analysis computer program
Development of a finite element based delamination analysis for laminates subject to extension, bending, and	Helicopter Airborne Laser Positioning System (HALPS)	[NASA-TM-101709] p 689 N90-23768
torsion p 679 N90-25049	[NASA-TM-102814] p 654 N90-23399	Finite element analysis of structural components using
FAN BLADES	Adaptive control of a system with periodic dynamics: Application of an impulse response method to the	viscoplastic models with application to a cowl lip
Nonlinear finite-element analysis to predict fan-blade damage due to soft-body impact p 683 A90-40939	helicopter vibration problem p 694 N90-23990	problem [NASA-CR-185189] p 690 N90-23769
Metal matrix composite fan blade development	FIBER COMPOSITES	Short time Force and moment measurement System
[AIAA PAPER 90-2178] p 677 A90-42062	Glass-ceramic matrix composites for advanced gas	for shock tubes (SFS) for measuring times less than 10
FAR FIELDS	turbines [AIAA PAPER 90-2014] p 676 A90-40594	- ms p 674 N90-24233
Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the	[AIAA PAPER 90-2014] p 676 A90-40594 Metal matrix composite fan blade development	Rotary-Jet thrust augmentor with jet-flapped blades
spatial network method p 638 . A90-39855	[AIAA PAPER 90-2178] p 677 A90-42062	p 633 N90-24243 Development of a finite element based delamination
FAST FOURIER TRANSFORMATIONS	Aircraft applications of advanced composite fiber/metal	analysis for laminates subject to extension, bending, and
Discrete Fourier transform with high resolution for low	pressure vessels	torsion . p 679 N90-25049
frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975	[AIAA PAPER 90-2344] p 686 A90-42133 Composites applications - The future is now	Extension-torsion coupling behavior of advanced
FATIGUE (MATERIALS)	p 678 A90-42372	composite tilt-rotor blades p 651 N90-25057
Fatigue methodology III; Proceedings of the AHS	Eight years of flight operations with composite	FINITE VOLUME METHOD  Three dimensional transonic and supersonic flow
National Technical Specialists' Meeting on Advanced	rotorblades p 635 A90-42481	prediction in axi-vectored nozzles using a finite volume
Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989 p 641 A90-39976	Analysis of composite rotor blades via Saint Venant's solutions p 688 A90-42491	method
Estimation of fatigue crack growth in patched cracked	FIBER OPTICS	[AIAA PAPER 90-2026] p 624 A90-41989
panels p 684 A90-41335	Reduced insertion loss of X-band RF fiber optic links	Modeling supersonic combustion using a fully-implicit numerical method
Fatigue crack growth investigation of a Ti-6AI-4V forging under complex loading conditions: NATO/AGARD	p 695 A90-41240	[AIAA PAPER 90-2307] p 677 A90-42117
supplemental engine disk program	An experimental investigation of turbine rotor wakes for the development of a fiber optic pressure sensor	Finite volume solutions of two-dimensional Euler
[AD-A220239] p 678 N90-23538	[AIAA PAPER 90-2411] p 687 A90-42163	equations on adapted structured meshes
Failure analysis handbook	FIBER ORIENTATION	p 629 A90-42413
[AD-A219747] p 689 N90-23752 Modeling growth of fatigue cracks which originate at	EH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489	A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed
rivet holes p 691 N90-25060	FIELD OF VIEW	[DLC-EST-TN-030] p 632 N90-23359
FATIGUE LIFE	An image analysis method for vehicle stabilization	FINS
Considerations of reliability design for rotorcraft p 680 A90-39977	p 668 A90-40914	Calculation of the aeroelastic blade stabilization with
Retirement lives of rolling element bearings	FIGHTER AIRCRAFT  Certification testing methodology for fighter hybrid	linearized process [MITT-87-01] p 666 N90-24272
p 680 A90-39980	structure p 642 A90-40128	FIRES
The collection of usage data to improve structural	YF-23A previews design features of future fighters	Fire hazards of aerosol cans in aircraft cargo
integrity of operational helicopters p 651 A90-39983 Usage monitoring of military helicopters	p 643 A90-40344	compartments
p 651 A90-39984	Multifunction displays optimized for viewability p 652 A90-40398	[DOT/FAA/CT-89/32] p 636 N90-23369
Potential application of automotive fatigue technology	New technology advances for brighter color CRT	FIXED WINGS  Extension of a three-dimensional viscous wing flow
in rotorcraft design p 681 A90-39987	displays ρ 652 A90-40399	analysis
Fatigue evaluation of C/MH-53E main rotor damper	Experimental windtunnel studies for EFA	[NASA-CR-182023] p 631 N90-23348
threaded joints p 642 A90-39988  The influence of material quality on airframe structural	p 672 A90-41113 Exploration of concepts for multi-role fighters	FLAME HOLDERS
durability p 676 A90-41336	[AIAA PAPER 90-2276] p 644 A90-42104	Engineering design models for ramjet efficiency and lean blowoff
Recent advances in fatigue life analysis methods for	Integrated air vehicle/propulsion technology for a	[AIAA PAPER 90-2453] p 663 A90-42176
aerospace applications p 677 A90-41338	multirole fighter - A MCAIR perspective	FLAME PROPAGATION
The effect on fatigue crack growth under spectrum	[AIAA PAPER 90-2278] p 644 A90-42105 Propulsion control system designs for advanced Navy	Development of the jet-swirl high loading combustor
loading of an imposed placard 'G' limit p 643 A90-41339	multimission aircraft	[AIAA PAPER 90-2451] p 658 A90-40633
Flexural fatigue life prediction of closed hat-section using	[AIAA PAPER 90-2403] p 663 A90-42160	FLAME SPECTROSCOPY Influence of fuel composition on flame radiation in gas
materially nonlinear axial fatigue characteristics	A remote tip-driven fan powered supersonic fighter concept	turbine combustors p 659 A90-40946
p 691 N90-25062	[AIAA PAPER 90-2415] p 663 A90-42167	FLAME STABILITY
FATIGUE TESTS	Preliminary design of a supersonic Short Takeoff and	On the use of external burning to reduce aerospace
Stress concentration factors - Comparison of theory with fatigue test data p 680 A90-39979	Vertical Landing (STOVL) fighter aircraft	vehicle transonic drag [AIAA PAPER 90-1935] p 656 A90-40562
Improvements to the fatigue substantiation of the H-60	[NASA-CR-186670] p 649 N90-23394 Throughput and delay characteristics for a	[AIAA PAPER 90-1935] p 656 A90-40562 FLAMEOUT
composite tail rotor blade p 642 A90-39985	slow-frequency hopped aircraft-to-aircraft packet radio	Application of neural networks to the F/A-18 engine

[AD-A219820]

p 688 N90-23609

condition monitoring system

p 666 N90-24271

network [AD-A220525]

Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987

Pr Assaanu imi	FLIQUE MANAGEMENT OVOTENO	ELIQUE TEST INCERNINGUES
FLAMMABILITY  Financial and computational flammability limits in a	FLIGHT MANAGEMENT SYSTEMS The 30th Airlines International Electronics Meeting	FLIGHT TEST INSTRUMENTS
Experimental and computational flammability limits in a		Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference
solid fuel ramjet [AIAA PAPER 90-1964] p 676 A90-40574	Proceedings [ETN-90-96973] p 637 N90-24261	Instrumentation System (CIRIS)
[AIAA PAPER 90-1964] p 676 A90-40574  FLAMMABLE GASES	FLIGHT MECHANICS	[AD-A220106] p 654 N90-23400
	Helicopter store separation - Predictive techniques and	FLIGHT TEST VEHICLES
Fire hazards of aerosol cans in aircraft cargo	flight testing p 647 A90-42495	Initial flight test of half-scale unmanned air vehicle
compartments [DOT/FAA/CT-89/32] p 636 N90-23369	FLIGHT PATHS	[AD-A219584] p 648 N90-23388
• • • • • • • • • • • • • • • • • • • •	Differential-geometrical technique of signal	
FLAPS (CONTROL SURFACES)	transformation and estimation of position, rate and	FLIGHT TESTS
Application of CFD to pitch/yaw thrust vectoring	acceleration parameters using supplementary data	Rotating system load monitoring using minimum fixed
spherical convergent flap nozzles	sources p 638 A90-41004	system instrumentation p 651 A90-39982
[AIAA PAPER 90-2023] p 657 A90-40597	MLS - A total system approach p 640 A90-41710	Improvements to the fatigue substantiation of the H-60
FLAT PLATES	Analytical evaluation of helicopter true air speed and	composite tail rotor blade p 642 A90-39985
Wave structure of artificial perturbations in a supersonic	associated flight tests p 647 A90-42499	SH-2F airframe fatigue test program
boundary layer on a plate p 619 A90-39518	Prediction of longitudinal pilot induced oscillations using	p 642 A90-39989
Supersonic flutter of shear deformable laminated	the optimal control model	Flight testing and application of a Peripheral Vision
composite flat panels p 683 A90-41104	[AD-A220593] p 671 N90-23412	Display p 652 A90-40381
Electrical analog circuit for heat transfer measurements	Application of optimal tracking methods to aircraft terrain	A captive store flight vibration simulation project
on a flat plate simulating turbine vane heat transfer in	following	p 672 A90-40476
turbulent flow	[AD-A221099] p 641 N90-24264	Demonstration of MLS advanced approach techniques
[AIAA PAPER 90-2412] p 687 A90-42164	When propfans cruise, will LDN 65 fly	p 640 A90-41711
FLEXIBLE BODIES	p 697 N90-24864	Onboard digital recording system for flight tests
Certification plan for an all-composite main rotor	An aircraft noise study in Norway p 698 N90-24872	p 653 A90-41742
flexbeam p 642 A90-39992	FLIGHT PLANS	Developmental tests on the M 88 engine are on track
Digital control of magnetic bearings supporting a	Air traffic control Russian book	p 660 A90-41761
multimass flexible rotor p 682 A90-40712	p 638 A90-39581	Flight test results of the F-15 SMTD thrust
FLEXIBLE WINGS	· · · · · · · · · · · · · · · · · · ·	vectoring/thrust reversing exhaust nozzle
Energy based stability analysis of a fuzzy roll controller	FLIGHT RECORDERS	STOL/Maneuvering Technology Demonstrator
design for a flexible aircraft wing p 668 A90-40833	The evaluation of flight recorders p 653 A90-41729	[AIAA PAPER 90-1906] p 660 A90-41982
FLEXING	Onboard digital recording system for flight tests	Influence of ground effect on helicopter takeoff and
Flexural fatigue life prediction of closed hat-section using	p 653 A90-41742	landing performance p 645 A90-42278
materially nonlinear axial fatigue characteristics	FLIGHT SAFETY	EH101 development progress p 646 A90-42442
p 691 N90-25062	Flight safety performance of the microwave landing	The modular HUM system Health and Usage
FLIGHT CHARACTERISTICS	system p 639. A90-41705	Monitoring instruments for rotary wing aircraft failure
The cryogenic wind tunnel as a testing tool for	ILS - A safe bet for your future landings	detection p 618 A90-42476
airframe/propulsion systems p 672 A90-40400	p 639 A90-41707	New systems for helicopter and aircraft vibration
The response of helicopter to dispersed gust	Inclement weather induced aircraft engine power loss	monitoring p 653 A90-42477
p 670 A90-42470	[AIAA PAPER 90-2169] p 662 A90-42055	The Franco-German helicopter programme HAP,
Development of a least squares time response	Main characteristics of an integrated flight and display	PAH-2/HAC p 618 A90-42478
lower-order equivalent systems technique	system for AS MKII Super-Puma p 653 A90-42450	Preliminary flight evaluation of the SA 365 Panther
[AD-A220527] p 648 N90-23389	System concept and performance criteria of modern	helicopter in air-to-air combat manoeuvres
Estimating short-period dynamics using an extended	helicopter navigation p 640 A90-42452	p 647 A90-42494
Kalman filter	Development and verification of software for flight safety	Helicopter store separation - Predictive techniques and
[NASA-TM-101722] p 648 N90-23392	critical strapdown systems p 694 A90-42454	flight testing p 647 A90-42495
Static wind-tunnel and radio-controlled flight test	Aeronautical decisionmaking for air ambulance program	Flight tests to explore tail rotor limitations in the low
investigation of a remotely piloted vehicle having a delta	administrators	speed envelope p 647 A90-42498
wing planform	[DOT/FAA/DS-88/8] p 635 N90-23368	Analytical evaluation of helicopter true air speed and
[NASA-TM-4200] p 632 N90-24238	Results of TCAS-2 simulations in reconstructed	associated flight tests p 647 A90-42499
FLIGHT CONDITIONS		An evaluation of the accuracy of a microwave landing
Inclement weather induced aircraft engine power loss	dangerous encounters (Jul. 1986 to Jun. 1989) [ETN-90-96474] p 636 N90-23375	system area navigation system at Miami/Tamiami Florida
[AIAA PAPER 90-2169] p 662 A90-42055	· · · · · · · · · · · · · · · · · · ·	Airport
Analytical evaluation of helicopter true air speed and	FLIGHT SIMULATION	[DOT/FAA/CT-TN89/40] p 640 N90-23377
associated flight tests p 647 A90-42499	Reconstitution of crack growth from fractographic	MLS mathematical model validation study using airborne
FLIGHT CONTROL	observations after flight simulation loading p 682 A90-40650	MLS data from Midway Airport engineering flight tests,
Implementation of a transputer-based flight controller	· · · · · · · · · · · · · · · · · · ·	August 1988
p 667 A90-38966	The application of concentric vortex simulation to	[DOT/FAA/CT-TN90/2] p 640 N90-23378
A study on the application of controllability and	calculating the aerodynamic characteristics of bodies of	Fighter agility metrics, research, and test [NASA-CR-186118] p 648 N90-23386
observability concepts in the design of flight control	revolution at high angles of attack p 627 A90-42357	[NASA-CR-186118] p 648 N90-23386 Preliminary airworthiness evaluation of the RC-12K
systems p 693 A90-39303	Preliminary flight evaluation of the SA 365 Panther	[AD-A219545] p 648 N90-23387
Flight control application of eigenstructure assignment with optimization of robustness to structured state space	helicopter in air-to-air combat manoeuvres	Initial flight test of half-scale unmanned air vehicle
uncertainty p 693 A90-40885	p 647 A90-42494	[AD-A219584] p 648 N90-23388
Ultimate boundedness control of uncertain systems with	Results of TCAS-2 simulations in reconstructed	Development of a least squares time response
application to roll coupled aircraft maneuver	dangerous encounters (Jul. 1986 to Jun. 1989)	lower-order equivalent systems technique
p 668 A90-40886	[ETN-90-96474] p 636 N90-23375	[AD-A220527] p 648 N90-23389
Digital controller design for the pitch axis of the F-14	Fighter agility metrics, research, and test	Prediction of longitudinal pilot induced oscillations using
using an H(infinity) method p 668 A90-40912	[NASA-CR-186118] p 648 N90-23386	the optimal control model
MLS - A total system approach p 640 A90-41710	Estimating short-period dynamics using an extended	[AD-A220593] p 671 N90-23412
Expanding the B-1B flight envelope	Kalman filter	Static wind-tunnel and radio-controlled flight test
p 644 A90-41899	[NASA-TM-101722] p 648 N90-23392	investigation of a remotely piloted vehicle having a delta
Propulsion system-flight control integration-flight	Real-time simulation clock	wing planform
evaluation and technology transition	[NASA-CASE-LAR-14056-1] p 689 N90-23713	[NASA-TM-4200] p 632 N90-24238
[AIAA PAPER 90-2280] p 644 A90-42106	Fractographic observations on fatigue crack growth in	Helicopter controllability
Main characteristics of an integrated flight and display	2024-T3 sheet material under flight-simulation loading	[AD-A220078] p 672 N90-24275
system for AS MKII Super-Puma p 653 A90-42450	[LR-592] p 689 N90-23760	En route noise of turboprop aircraft and their
Modern strapdown system for helicopter	IAPSA 2 small-scale system specification	acceptability: Report of tests p 697 N90-24858
p 653 A90-42451	[NASA-CR-182006] p 695 N90-24103	FLIGHT TRAINING
A technique for the tuning of helicopter flight control	Helicopter controllability	Dynamic FLIR simulation in flight training research
systems p 670 A90-42467	[AD-A220078] p 672 N90-24275	p 681 A90-40109
Use of smart actuators for the tail rotor collective pitch	FLIGHT SIMULATORS	FLIGHT VEHICLES
control p 688 A90-42483	SMAS - An expert system for configuring a research	Analysis of aeroelastic divergence for the slender flight
Direct drive servovalves: Why and how - The Magnaghi	flight simulator p 694 A90-41191	vehicles p 680 A90-39298
Milano answer p 688 A90-42484	ATTHES - A helicopter in-flight simulator for ACT	An image analysis method for vehicle stabilization
Prediction of longitudinal pilot induced oscillations using	testing p 643 A90-41727	p 668 A90-40914
the optimal control model	A highly maneuverable helicopter in-flight simulator -	Synthesis of optimal multidimensional digital systems
(AD-A220593) p 671 N90-23412	A THORE THE POST OF THE POST O	for the simulation of the angular motions of a flight vehicle

Aspects of realization
[AIAA PAPER 88-4607]

FLIGHT STABILITY TESTS

stability

Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374

A novel synthetic method for studying nonlinear flight

for the simulation of the angular motions of a flight vehicle under random loading p 669 A90-41957

FLIR DETECTORS Dynamic FLIR simulation in flight training research p 681 A90-40109

FLOW CHARACTERISTICS

The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets
[AIAA PAPER 90-2107] p 684 A90-42020

A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040

Miniaturization of flight deflection measurement

p 689 N90-23707

system [NASA-CASE-LAR-13628-1]

Expanding the B-1B flight envelope

FLIGHT ENVELOPES

p 670 A90-42466

FLOW DEFLECTION

Experimental and analytical study of close-coupled ventral nozzles for ASTOVL aircraft

[NASA-TM-103170] p 666 N90-24273

FLOW DISTORTION

Perturbations of higher modes in a supersonic jet p 619 A90-39516 Wave structure of artificial perturbations in a supersonic

p 619 A90-39518 boundary layer on a plate Calculation of stability derivatives for slender bodies p 620 A90-40181 using boundary element method FLOW DISTRIBUTION

Calculation of hypersonic forebody/inlet flow fields [AIAA PAPER 90-1493] p 619 A90-39049 Confined let thrust vector control nozzle studies

p 657 A90-40598 [AIAA PAPER 90-2027] A numerical investigation of supersonic inlet using implicit TVD scheme

[AIAA PAPER 90-2135] p 621 A90-40612 Flow structure generated by oscillating delta-wing p 622 A90-40694 seaments

Symmetry assessment of an air-blast atomizer spray p 682 A90-40930 Calculation of three-dimensional jet interaction

p 624 A90-42018

[AIAA PAPER 90-2099] The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets

[AIAA PAPER 90-2107] p 684 A90-42020 Model of a labyrinth seal with flow

p 687 A90-42334 The flow over a wing/nacelle combination in the presence of a propeller slipstream p 629 A90-42415

Extension of a three-dimensional viscous wing flow anatvsis

[NASA-CR-182023] p 631 N90-23348 Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability

[AD-A219651] p 678 N90-23571 Composite reduced Navier Stokes procedures for flow

problems with strong pressure interactions [AD-A219621] p 689 N90-23687 The interaction of a supersonic streamwise vortex and a normal shock wave n 633 N90-24241

Unsteady potential flow past a propeller blade section p 634 N90-24246 [NASA-CR-4307] Low-density flow effects for hypervelocity vehicles.

phase 2 p 634 N90-24249 [AD-A221034]

Experimental and analytical study of close-coupled ventral nozzles for ASTOVL aircraft [NASA-TM-103170] p 666 N90-24273

FLOW EQUATIONS

Calculation of the complete transonic unsteady small

disturbance equation by ADI method p 627 A90-42353

FLOW GEOMETRY

Navier-Stokes solutions for vortical flows over a tangent-ogive cylinder p 620 A90-39780 Generation of circumferential velocity contours associated with pulsed point suction on a rotating disk p 691 N90-25065

FLOW MEASUREMENT

Three-dimensional measurement, display, interpretation of fluid flow datasets p 679 A90-38854 Laser Doppler velocimetry investigation of swirler p 682 A90-40929 flowfields

FLOW STABILITY

Numerical simulation of the growth of instabilities in p 623 A90-40941 supersonic free shear layers Generation of circumferential velocity contours associated with pulsed point suction on a rotating disk p 691 N90-25065

FLOW THEORY

Mathematical modeling of plane parallel separated flows past bodies - Russian book p 619 A90-39475 Perturbations of higher modes in a supersonic jet

p 619 A90-39516

FLOW VELOCITY

Supersonic rectangular isothermal shrouded jets [AIAA PAPER 90-2028] p 621 A90-40599 Measurements of turbulent dual-jet interaction

[AIAA PAPER 90-2105] p 624 A90-42019

FLOW VISUALIZATION

Three-dimensional measurement, display, interpretation of fluid flow datasets p 679 A90-38854 Flow visualization via laser-induced reflection from bubble sheets p 680 A90-39784

Flow visualization studies of the Mach number effects on dynamic stall of an oscillating airfoil p 622 A90-40683

Flow structure generated by oscillating delta-wing p 622 A90-40694 seaments A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41119

Ground evaluation of seeding an in-flight wingtip vortex using infrared imaging flow visualization technique

p 635 N90-25035 **FLOWMETERS** 

Lightweight fuel pump and metering component for advanced gas turbine engine control

[AIAA PAPER 90-2032] p 657 A90-40602 FLUID FILMS Analysis of thermal gradient effects in oil ring seals

FLUID MANAGEMENT

Lightweight fuel pump and metering component for dvanced gas turbine engine control

p 657 A90-40602 [AIAA PAPER 90-2032]

ELUID MECHANICS

An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model p 634 N90-24250 [AD-A221220]

**FLUTTER ANALYSIS** 

Flutter of shaft-supported low aspect-ratio control p 667 A90-38912 surfaces Aeroelastic analysis of a low aspect ratio wing

p 619 A90-38915

On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-561 p 672 N90-24276

**FOKKER AIRCRAFT** 

Activities report in aerospace and aerodynamics p 699 N90-24224 FTN-90-967741

FORCED VIBRATION

Coherent vortex structures in the wake of a sphere and a circular disk at rest and under forced vibration

p 623 A90-40749

p 682 A90-40716

**FOREBODIES** 

Strake camber and thickness design procedure for lov alpha supersonic flow p 622 A90-40678

Actuated forebody strakes [NASA-CASE-LAR-13983-1] p 648 'N90-23390 FORECASTING

IFR aircraft handled forecast by air route traffic control enter: Fiscal years 1990 to 2005

(AD-A220312) p 641 N90-24263

FRACTOGRAPHY

Reconstitution of crack growth from fractographic observations after flight simulation loading

p 682 A90-40650 Failure analysis handbook

p 689 N90-23752 [AD-A219747] Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simulation loading fLR-5921 p 689 N90-23760

FRACTURE MECHANICS

Application of fracture mechanics to microscale phenomena in electronic assemblies

p 684 A90-41334 Estimation of fatigue crack growth in patched cracked p 684 A90-41335 panels The influence of material quality on airframe structural

p 676 A90-41336 Recent advances in fatigue life analysis methods for

aerospace applications p 677 A90-41338 Fracture control via DRM-Algorithm

p 694 A90-41343 Failure analysis handbook

[AD-A219747] p 689 N90-23752

FRACTURE STRENGTH

The effects of toughening stresses on liquid impact induced fracture p 692 A90-41315 FREE FLOW

Numerical simulation of the growth of instabilities in p 623 A90-40941 supersonic free shear layers

Measurements of turbulent dual-iet interaction [AIAA PAPER 90-2105] p 624 A90-42019

The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets p 684 A90-42020 [AIAA PAPER 90-2107]

FREE JETS

Supersonic rectangular isothermal shrouded iets [AIAA PAPER 90-2028] p 621 A90-40599

FREQUENCY HOPPING Throughput and delay characteristics for slow-frequency hopped aircraft-to-aircraft packet radio

network [AD-A220525] p 688 N90-23609

FRICTION MEASUREMENT

Direct measurements of skin friction in a scramjet combustor

[AIAA PAPER 90-2342] p 626 A90-42132

**FUEL COMBUSTION** 

Ultrasonic regression rate measurement in solid fuel ramiets

[AIAA PAPER 90-1963] p 656 A90-40573 Hydrocarbon-fueled scramjet combustor investigation [AIAA PAPER 90-2337] p 658 A90-40622

Influence of fuel composition on flame radiation in gas p 659 A90-40946 turbine combustors

**FUEL CONSUMPTION** 

Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 FUEL INJECTION

Transverse fuel-injection model for a scramjet propulsion p 659 A90-40927 Military engines - Cradle of technology

p 660 A90-41758 Further validation of a semi-analytical approach for fuel injectors of different concepts (ÁIAA PAPER 90-2190) p 686 A90-42067

FUEL PUMPS Lightweight fuel pump and metering component for advanced gas turbine engine control

[AIAA PAPER 90-2032] p 657 A90-40602

FUEL SPRAYS Further validation of a semi-analytical approach for fuel

injectors of different concepts [AIAA PAPER 90-2190] p 686 A90-42067 Structure analysis of burning liquid-fueled spray in a confined combustor

[AIAA PAPER 90-2444] p 677 A90-42174 Introducing the VRT gas turbine combustor p 688 N90-23591 [NASA-TM-103176]

**FUEL TANKS** Aircraft applications of advanced composite fiber/metal

pressure vessels [AIAA PAPER 90-2344] p 686 A90-42133

**FUEL TESTS** Fuel effects on gas turbine combustor dynamics [AIAA PAPER 90-1957] p 676 A90p 676 A90-40570

**FUEL-AIR RATIO** Fuel effects on gas turbine combustor dynamics

[AIAA PAPER 90-1957] p 676 A90-40570 FUSELAGES

Fuselage boundary-layer effects on sound propagation nd scattering p 695 A90-39781 and scattering Comparison with experiment of various computational methods of airflow on three helicopter fuselages

p 630 A90-42436 Experimental study of the flow around an helicopter fuselage - Comparison with three-dimensional boundary layer calculations p 630 A90-42438

Helicopter ground and air resonance dynamics p 646 A90-42457 A comprehensive approach to coupled rotor-fuselage p 646 A90-42460 dynamics

Feasibility study for a microwave-powered ozone sniffer aircraft

[NASA-CR-186660] p 650 N90-23397

FUZZY SYSTEMS

Energy based stability analysis of a fuzzy roll controller design for a flexible aircraft wing p 668 A90-40833

G

GAS DYNAMICS

On and off-design performance prediction of single spool turbojets using gasdynamics

[AIAA PAPER 90-2393] p 662 A90-42155 GAS PRESSURE Tests for integrating measurement of gas pressures in

flight propellers [ETN-90-96498] p 634 N90-24253

**GÀS TURBINE ENGINES** 

Combustion characteristics of a model can-type combustor p 676 A90-40479 Application of leaned blades to an aeroengine

p 654 A90-40503 Partial similarity and a real-time model of twin-spool gas

turbine p 654 A90-40512 Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530 Numerical simulation of the behaviour of internal

combustion supercharged engines [AIAA PAPER 90-1873] p 655 A90-40539 Fuel effects on gas turbine combustor dynamics [AIAA PAPER 90-1957] p 676 A90p 676 A90-40570

Glass-ceramic matrix composites for advanced gas turbines [AIAA PAPER 90-2014]

Lightweight fuel pump and metering component for advanced gas turbine engine control [AIAA PAPER 90-2032] p 657 A90-40602

Fiber-optic turbine inlet temperature measurement ystem (FOTITMS) [AIAA PAPER 90-2033] p 657 A90-40603

Development of the jet-swirt high loading combustor [AIAA PAPER 90-2451] p 658 A90-40633 Rationale for determining information associated with

aircraft gas turbine engines that is of historical importance

Laser Doppler velocimetry investigation of swirler	GLASS	HARDWARE
flowfields p 682 A90-40929	Glass-ceramic matrix composites for advanced gas	IAPSA 2 small-scale system specification
Design and performance of a small, high speed axial	turbines	[NASA-CR-182006] p 695 N90-24103
compressor [AIAA PAPER 90-1911] p 624 A90-41983	[AIAA PAPER 90-2014] p 676 A90-40594 The all glass helicopter cockpit p 653 A90-42447	HARMONIC MOTION
High temperature solid lubricant requirements for	GLOBAL POSITIONING SYSTEM	Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations
advanced high performance gas turbine engines	Continued development and analysis of a new extended	p 646 A90-42464
[AIAA PAPER 90-2042] p 661 A90-41993	Kalman filter for the Completely Integrated Reference	HARMONIC OSCILLATION
High temperature powder lubricated dampers for gas	Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400	An interactive boundary-layer method for unsteady airfoil
turbine engines	GOALS ·	flows. Part 1: Quasi-steady-state model
[AIAA PAPER 90-2048] p 684 A90-41999	Langley aerospace test highlights, 1989	[AD-A221220] p 634 N90-24250 HEAD-UP DISPLAYS
Viscous flow analysis for advanced inlet particle separators	[NASA-TM-102631] p 699 N90-24221	Dynamic FLIR simulation in flight training research
[AIAA PAPER 90-2136] p 661 A90-42038	GOVERNMENTS	p 681 A90-40109
Evaluation of brush seals for limited-life engines	The influence of adjacent seating configurations on egress through a type 3 emergency exit	Holographic combiner design to obtain uniform symbol
[AIAA PAPER 90-2140] p 685 A90-42040	[AD-A218393] p 636 N90-23371	brightness at head-up display video camera
Gas turbine engine brush seal applications	GRAPHITE-EPOXY COMPOSITES	p 652 A90-40394
[AIAA PAPER 90-2142] p 685 A90-42041	The analysis and testing of composite panels subject	HEAT TRANSFER
The investigation of heat transfer in cooled blades of	to muzzle blast effects p 675 A90-39991	Inverse heat transfer studies and the effects of propellant aluminum on TVC jet vane heating and erosion
gas turbines [AIAA PAPER 90-2144] p 685 A90-42043	Certification testing methodology for fighter hybrid structure p 642 A90-40128	[AIAA PAPER 90-1860] p 655 A90-40533
Modeling gas turbine combustor performance under	impact damage and residual strength analysis of	The investigation of heat transfer in cooled blades of
transient conditions	composite panels with bonded stiffeners for primary	gas turbines
[AIAA PAPER 90-2161] p 661 A90-42051	aircraft structures p 642 A90-40130	[AIAA PAPER 90-2144] p 685 A90-42043
The development of a probabilistic turbine rotor design	Redesign of an electro-optical shroud in	Radio frequency (RF) heated supersonic flow
system	graphite/epoxy p 676 A90-40215 GRID GENERATION (MATHEMATICS)	laboratory
[AIAA PAPER 90-2176] p 662 A90-42060	An introduction to chaos theory in CFD	[AIAA PAPER 90-2469] p 673 A90-42186 HEAT TRANSFER COEFFICIENTS
Influences on the uniformity of sprays produced by gas turbine high shear nozzle/swirler assemblies	[AIAA PAPER 90-1440] p 680 A90-39725	Electrical analog circuit for heat transfer measurements
[AIAA PAPER 90-2193] p 686 A90-42068	Investigation of unsteady flow through transonic turbine	on a flat plate simulating turbine vane heat transfer in
Direct lift STOVL engine integration	stage. I - Analysis	turbulent flow
[AIAA PAPER 90-2274] p 644 A90-42103	[AIAA PAPER 90-2408] p 626 A90-42161	[AIAA PAPER 90-2412] p 687 A90-42164
Initiation of spalling in aircraft gas turbine bearings	GROUND BASED CONTROL  IFR aircraft handled forecast by air route traffic control	HELICAL WINDINGS
[AIAA PAPER 90-2291] p 686 A90-42110	center: Fiscal years 1990 to 2005	Finite-element analysis of large spur and helical gear systems p 683 A90-40940
Numerical simulations of gas turbine combustor flows	[AD-A220312] p 641 N90-24263	HELICOPTER CONTROL
[AIAA PAPER 90-2305] p 686 A90-42116	GROUND EFFECT (AERODYNAMICS)	Control system validation in the autonomous
Component arrangement studies for an 8000 shp	Influence of ground effect on helicopter takeoff and	helicopter p 667 A90-38908
turboshaft high technology core [AIAA PAPER 90-2398] p 663 A90-42159	landing performance p 645 A90-42278 Influence of ground effect on helicopter takeoff and	Improvement of helicopter handling qualities using
An experimental investigation of turbine rotor wakes for	landing performance p 646 A90-42468	H(infinity)-optimisation p 667 A90-38965 Helicopter control design using feedback linearization
the development of a fiber optic pressure sensor	Aerodynamic performance of a 0.27-scale model of an	techniques p 668 A90-40817
[AIAA PAPER 90-2411] p 687 A90-42163	AH-64 helicopter with baseline and alternate rotor blade	ATTHES - A helicopter in-flight simulator for ACT
Electrical analog circuit for heat transfer measurements	sets	testing p 643 A90-41727
on a flat plate simulating turbine vane heat transfer in	[NASA-TM-4201] p 632 N90-24237 GROUND RESONANCE	Active control of helicopter cabin noise
turbulent flow	Experimental study of the effects of nonlinearities on	p 645 A90-42434 Modern strapdown system for helicopter
[AIAA PAPER 90-2412] p 687 A90-42164	ground resonance p 643 A90-40172	p 653 A90-42451
Development of impact design methods for ceramic gas	Helicopter ground and air resonance dynamics	Design methodology for multivariable helicopter control
turbine components		
turbine components [AIAA PAPER 90-2413] p 687 A90-42165	p 646 A90-42457	systems p 669 A90-42461
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options	p 646 A90-42457  GROUND TESTS	systems p 669 A90-42461 A model for active control of helicopter air resonance
[AIAA PAPÉR 90-2413] p 687 A90-42165	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590	systems p 669 A90-42461 A model for active control of helicopter air resonator in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166  JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPÉR 90-2419] p 663 A90-42169	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442	systems p 669 A90-42461 A model for active control of helicopter air resonator in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166  JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPÉR 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-42741  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS)	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AlAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPÉR 90-2419] p 663 A90-42169 The influence of swirt on velocity, temperature and species characteristics in a can combustor [AIAA PAPÉR 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPÉR 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD	P 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-42161  EH101 development progress p 646 A90-42424  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters and control of hingeless rotor helicopters tability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight Analytical evaluation of helicopter true air speed and
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AlAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42494 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters and control of hingeless rotor helicopters tability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight Analytical evaluation of helicopter true air speed and
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591  GAS TURBINES	GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 p 640 A90-42422 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirt on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42424  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-4249 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters stability and control of mingeless rotor helicopters and verification on two helicopters p 671 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591  GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LP4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42473 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters stability and control of mingeless rotor helicopters and verification on two helicopters p 671 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591  GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LP4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42494 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirt on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-4095 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42424  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DDT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42473 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42499 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter voltration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987 Characterization of helicopter turboshaft engine noise
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirt on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-4095 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42473 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42499 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275  HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 687 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42177 Eatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters at bility and control of hingeless rotor helicopters and verification on two helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42497 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275  HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirt on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages p 630 A90-42436 Improving tilt rotor aircraft performance with
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 660 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-424467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-38965 Potential application of automotive fatigue technology in rotorcatt design p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft p 646 A90-42435
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40495 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 The modular HUM system Health and Usage	gROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988 H-60 HELICOPTER Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingeless rotor helicopters and control of hingeless rotor helicopters and control of hingeless rotor helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42473 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42497 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275  HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages Improving tilt rotor aircraft performance with variable-diameter rotors p 653 A90-42447
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 660 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-2399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988  H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-424467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-38965 Potential application of automotive fatigue technology in rotorcatt design p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft p 646 A90-42435
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-8AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40495 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [MASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 The modular HUM system — Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-4276	GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LP4] p 696 N90-24856 GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42473 Aeroelastic effects on stability and control of hingless rotor helicopters stability and control of hingless rotor helicopters stability and control of mingless rotor helicopters stability and control modeling improvements and verification on two helicopters p 671 A90-42473 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275  HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-3997 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft performance with variable-diameter rotors p 646 A90-42445 The all glass helicopter cockpit p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460 The Place of knowledge based systems in helicopter
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40945 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-40940 Gearbox system design for rotary wing aircraft failure detection p 618 A90-4276 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274	GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988 H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 HALOGENATION	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingless rotor helicopters p 647 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter turboshaft engine noise p 650 A90-42436 Improving tilt rotor aircraft performance with variable-diameter rotors p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460 The place of knowledge based systems in helicopter dynamic system condition prognosis
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPÉR 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPÉR 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPÉR 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flamer radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPÉR 90-2177] p 686 A90-42061 Advanced gearbox technology (NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-42048 The modular HUM system Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-42476 Advanced gearbox technology (NASA-CR-179625) p 666 N90-24274 GEERRAL AVIATION AIRCRAFT	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988  H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986  HALOGENATION  Nonflammable hydraulic power system for tactical	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-424467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft p 646 A90-42445 The all glass helicopter cockpit p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460 The place of knowledge based systems in helicopter dynamic system condition prognosis
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 The modular HUM system — Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-42476 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GENERAL AVIATION AIRCRAFT GE'S CF34 engine for business and regional jets	GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988 H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 HALOGENATION	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters stability and control of hingeless rotor helicopters and verification on two helicopters p 671 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter obration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275  HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft performance with variable-diameter rotors p 646 A90-42440 The all glass helicopter cockpit p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42440 The place of knowledge based systems in helicopter dynamic system condition prognosis
[AIAA PAPÉR 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPÉR 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPÉR 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPÉR 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPÉR 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flamer radiation in gas turbine combustors p 659 A90-40946 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPÉR 90-2177] p 686 A90-42061 Advanced gearbox technology (NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-42048 The modular HUM system Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-42476 Advanced gearbox technology (NASA-CR-179625) p 666 N90-24274 GEERRAL AVIATION AIRCRAFT	gROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H-53 HELICOPTER Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988 H-60 HELICOPTER Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 HALOGENATION Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and analysis [AD-A218493] p 671 N90-23409	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-424467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopter stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft p 646 A90-42445 The all glass helicopter cockpit p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460 The place of knowledge based systems in helicopter dynamic system condition prognosis
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A220239] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40495 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-40940 Gearbox system design for ultra-high bypass engines [AIAA PAPER 90-2152] p 685 A90-42048 The modular HUM system — Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-4274 GENERAL AVIATION AIRCRAFT GE'S CF34 engine for business and regional jets [AIAA PAPER 90-2041] p 661 A90-41992 GEOMETRY Euler and Navier-Stokes computations for airfoil	p 646 A90-42457  GROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590  Developmental tests on the M 88 engine are on track p 660 A90-41761  EH101 development progress p 646 A90-42442  Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399  En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856  GUIDANCE SENSORS  System concept and performance criteria of modern helicopter navigation p 640 A90-42452  GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470  The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H  H-53 HELICOPTER  Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988  H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  H-60 HELICOPTER  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  H-60 HELICOPTER  Indicate programs p 642 A90-39986  HALOGENATION  Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and analysis  [AD-A218493] p 671 N90-23409  HANDBOOKS	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters stability and control of hingeless rotor helicopters and verification on two helicopters p 671 A90-42473 Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and stains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter obration problem p 694 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages  Improving tilt rotor aircraft performance with variable-diameter rotors p 646 A90-42446 The all glass helicopter cockpit p 653 A90-42447 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42447 The place of knowledge based systems in helicopter dynamic system condition prognosis  P 618 A90-42475 FeH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489
[AIAA PAPER 90-2413] p 687 A90-42165 Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90-42166 JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 Mixing characteristics of dilution jets in small gas turbine combustors [AIAA PAPER 90-2728] p 664 A90-42217 Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program [AD-A22029] p 678 N90-23538 Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 N90-23591 GAS TURBINES Supercomputer applications in gas turbine flowfield simulation p 620 A90-40945 Bonded airfoil attachments - A path to rotor structural efficiency [AIAA PAPER 90-2177] p 686 A90-42061 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS Finite-element analysis of large spur and helical gear systems p 683 A90-42048 The modular HUM system Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-42476 Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 GEARS The modular HUM system Health and Usage Monitoring instruments for rotary wing aircraft failure detection p 618 A90-42476 GENERAL AVIATION AIRCRAFT GE'S CF34 engine for business and regional jets [AIAA PAPER 90-2041] p 661 A90-41992	gROUND TESTS  CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590 Developmental tests on the M 88 engine are on track p 660 A90-41761 EH101 development progress p 646 A90-42442 Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856 GUIDANCE SENSORS System concept and performance criteria of modern helicopter navigation p 640 A90-42452 GUIDE VANES  The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053 GUST LOADS  The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472  H-53 HELICOPTER Fatigue evaluation of C/MH-53E main rotor damper threaded joints p 642 A90-39988 H-60 HELICOPTER Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 HALOGENATION Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and analysis [AD-A218493] p 671 N90-23409	systems p 669 A90-42461 A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462 A technique for the tuning of helicopter flight control systems p 670 A90-42467 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Helicopters stability and control modelling improvements and verification on two helicopters p 671 A90-42474 Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 684 N90-23990 Helicopter controllability [AD-A220078] p 672 N90-24275 HELICOPTER DESIGN Improvement of helicopter handling qualities using P 667 A90-38965 Potential application of automotive fatigue technology in rotorcraft design p 681 A90-39987 Characterization of helicopter turboshaft engine noise p 660 A90-41759 Comparison with experiment of various computational methods of airflow on three helicopter fuselages    P 630 A90-42436   P 646 A90-42445   P 648 A90-42446   P 648 A90-42460   P 648

Flight tests to explore tail rotor limitations in the low	Low speed testing of a laminar flow airfoil in an adaptive	HYDROGEN
speed envelope p 647 A90-42498	wall wind tunnel	On the use of external burning to reduce aerospace
HELICOPTER ENGINES Precurser convertible engine study	[FFA-TN-1989-08] p 632 N90-23363 HIGH SPEED	vehicle transonic drag [AIAA PAPER 90-1935] p 656 A90-40562
[AIAA PAPER 90-2486] p 658 A90-40636	High speed civil transport	The role of hydrogen/air chemistry in nozzle
Directivity of the noise radiation emitted from the inlet	[NASA-CR-186661] p 649 N90-23396	performance for a hypersonic propulsion system
duct of a turboshaft helicopter engine	HIGH TEMPERATURE	[AIAA PAPER 90-2492] p 658 A90-40637
[ONERA, TP NO. 1990-26] p 695 A90-41205 Full Authority Digital Engine Control for the AS 355 N	High-temperature electronics for aircraft engines	HYDROGEN FUELS Hydrogen in future energy and propulsion technology
TM 319 engines p 665 A90-42486	[AIAA PAPER 90-2035] p 657 A90-40604	p 692 A90-41736
Contribution of engine improvement on next future	High temperature powder lubricated dampers for gas turbine engines	Some governing parameters of plasma torch
rotorcraft p 665 A90-42488	[AIAA PAPER 90-2048] p 684 A90-41999	igniter/flameholder in a scramjet combustor
HELICOPTER PERFORMANCE	Multiple swirter dome combustor for high temperature	[AIAA PAPER 90-2098] p 661 A90-42017
Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278	rise applications	HYDROGEN OXYGEN ENGINES  Modeling supersonic combustion using a fully-implicit
EH101 development progress p 646 A90-42442	[AIAA PAPER 90-2159] p 661 A90-42050	numerical method
Improving tilt rotor aircraft performance with	HIGH TEMPERATURE ENVIRONMENTS	[AIAA PAPER 90-2307] p 677 A90-42117
variable-diameter rotors p 646 A90-42445	Development of high temperature actuation systems for advanced aircraft engines	HYDROGEN-BASED ENERGY
Digital map reader for helicopters p 653 A90-42448	[AIAA PAPER 90-2031] p 660 A90-41990	Hydrogen in future energy and propulsion technology p 692 A90-41736
System concept and performance criteria of modern helicopter navigation p 640 A90-42452	HIGH TEMPERATURE LUBRICANTS	HYPERSONIC AIRCRAFT
A highly maneuverable helicopter in-flight simulator -	High temperature solid lubricant requirements for	Accelerators and decelerators for large, hypersonic
Aspects of realization	advanced high performance gas turbine engines	aircraft
[AIAA PAPER 88-4607] p 670 A90-42466	[AIAA PAPER 90-2042] p 661 A90-41993	[AIAA PAPER 90-1986] p 674 A90-40582
Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468	HIGHLY MANEUVERABLE AIRCRAFT A highly maneuverable helicopter in-flight simulator -	HYPERSONIC COMBUSTION  Transverse fuel-injection model for a scramjet propulsion
Analytical study of dynamic response of helicopter in	Aspects of realization	system p 659 A90-40927
autorotative flight p 670 A90-42469	[AIAA PAPER 88-4607] p 670 A90-42466	HYPERSONIC FLOW
The response of helicopter to dispersed gust	HOLES (MECHANICS)	Calculation of hypersonic forebody/inlet flow fields
p 670 A90-42470 Eight years of flight operations with composite	Modeling growth of fatigue cracks which originate at	[AIAA PAPER 90-1493] p 619 A90-39049 HYPERSONIC INLETS
rotorblades p 635 A90-42481	rivet holes p 691 N90-25060 HOLOGRAPHY	Finite element analysis of structural components using
Preliminary flight evaluation of the SA 365 Panther	Holographic combiner design to obtain uniform symbol	viscoplastic models with application to a cowl lip
helicopter in air-to-air combat manoeuvres	brightness at head-up display video camera	problem
p 647 A90-42494	p 652 A90-40394	[NASA-CR-185189] p 690 N90-23769 HYPERSONIC NOZZLES
Aeronautical decisionmaking for air ambulance program administrators	HOT-WIRE FLOWMETERS	The role of hydrogen/air chemistry in nozzle
[DOT/FAA/DS-88/8] p 635 N90-23368	Vorticity distribution of vortex street in the wake of a circular cylinder p 623 · A90-41751	performance for a hypersonic propulsion system
Aerodynamic performance of a 0.27-scale model of an	circular cylinder p 623 · A90-41751  HOTSHOT WIND TUNNELS	[AIAA PAPER 90-2492] p 658 A90-40637
AH-64 helicopter with baseline and alternate rotor blade	High enthalpy hypersonic wind tunnet F4: General	HYPERSONIC TEST APPARATUS
sets [NASA-TM-4201] p 632 N90-24237	description and associated instrumentation	Test and Measurement Technique in Hypersonics [ILR-MITT-225(1989)] p 618 N90-24225
Helicopter controllability	p 673 N90-24228	The gun tunnel of the Brunswick Institute for Fluid
[AD-A220078] p 672 N90-24275	HOVERING	Mechanics: Current development status
HELICOPTER TAIL ROTORS	Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738	p 673 N90-24227
Flight tests to explore tail rotor limitations in the low speed envelope p 647 A90-42498	A review of tilt rotor download research	HYPERSONIC VEHICLES  The role of hydrogen/air chemistry in nozzle
HELICOPTERS	p 630 A90-42437	performance for a hypersonic propulsion system
The EH101 electronic instrument system	Influence of ground effect on helicopter takeoff and	[AIAA PAPER 90-2492] p 658 A90-40637
p 652 A90-40462	landing performance p 646 A90-42468	On- and off-design performance analysis of hypersonic
Obstacle warning system for helicopters	HOVERING STABILITY	detonation wave ramjets
p 653 A90-41114 Wind-tunnel measurement of noise emitted by helicopter	UH-60A helicopter stability augmentation study p 670 A90-42471	[AIAA PAPER 90-2473] p 664 A90-42188 Hypersonic (T-D) 'pinch' and aerospaceplane
rotors at high speed	HUBS	propulsion
[ONERA, TP NO. 1990-28] p 695 A90-41207	Vortex theory for the screw propeller with a hub	[AIAA PAPER 90-2474] p 675 A90-42189
Experimental study of the flow around an helicopter	p 620 A90-39538	Low-density flow effects for hypervelocity vehicles,
fuselage - Comparison with three-dimensional boundary layer calculations p 630 A90-42438	EH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489	phase 2 [AD-A221034] p 634 N90-24249
Computation of viscous aerodynamic characteristics of	unidirectional tension bands p 618 A90-42489 HUMAN FACTORS ENGINEERING	HYPERSONIC WIND TUNNELS
2-D airfoils for helicopter applications	Evaluation of speech recognizers for use in advanced	The University of Toronto-Ryerson Polytechnical
p 631 A90-42440	combat helicopter crew station research and	Institute hypersonic gun tunnel p 673 A90-42432
Helicopter ground and air resonance dynamics p 646 A90-42457	development	Infrared thermography at hypersonic channel H2K p 674 N90-24235
Helicopter Airborne Laser Positioning System (HALPS)	[NASA-CR-177547] p 650 N90-24265 HUMAN PERFORMANCE	HYPERSONICS
[NASA-TM-102814] p 654 N90-23399	Aeronautical decisionmaking for air ambulance program	Test and Measurement Technique in Hypersonics
- Adaptive control of a system with periodic dynamics:	administrators	[ILR-MITT-225(1989)] p 618 N90-24225
Application of an impulse response method to the	[DOT/FAA/DS-88/8] p 635 N90-23368	High enthalpy hypersonic wind tunnel F4: General
helicopter vibration problem p 694 N90-23990 Operational effects on crashworthy seat attenuators	HUMAN REACTIONS  Human response research update	description and associated instrumentation p 673 N90-24228
[AD-A221148] p 637 N90-24259	p 699 N90-24873	HYPERVELOCITY
Evaluation of speech recognizers for use in advanced	HYDRAULIC CONTROL	Hypervelocity, minimum-radii, coordinated turns
combat helicopter crew station research and	Hydraulic accumulators and high pressure bottles in	p 667 A90-40691
development [NASA-CR-177547] p 650 N90-24265	composite material p 688 A90-42493	•
HPLC analysis of helicopter rotor blade materials	HYDRAULIC EQUIPMENT  Hydraulic accumulators and high pressure bottles in	
[AD-A221121] p 650 N90-24270	composite material p 688 A90-42493	
Helicopter controllability	Nonflammable hydraulic power system for tactical	IGNITERS Some governing parameters of plasma torch
[AD-A220078] p 672 N90-24275	aircraft. Volume 1: Aircraft system definition, design and	igniter/flameholder in a scramjet combustor
Extension-torsion coupling behavior of advanced composite tilt-rotor blades p 651 N90-25057	analysis (AD-A218493) p 671 N90-23409	[AIAA PAPER 90-2098] p 661 A90-42017
HERMES MANNED SPACEPLANE	HYDROCARBON COMBUSTION	ILLUMINATION
Aerodynamic work for Hermes spaceplane	Combustion characteristics of a model can-type	Flow visualization via laser-induced reflection from
p 675 A90-41115	combustor p 676 A90-40479	bubble sheets p 680 A90-39784 IMAGE ANALYSIS
HIGH ALTITUDE  NASA/USRA high attitude reconnaissance aircraft	HYDROCARBON FUELS  Experimental and computational flammability limits in a	An image analysis method for vehicle stabilization
[NASA-CR-186685] p 650 N90-24266	solid fuel ramjet	p 668 A90-40914
HIGH PRESSURE	(AIAA PAPER 90-1964) p 676 A90-40574	IMAGING TECHNIQUES
Nonflammable hydraulic power system for tactical	Hydrocarbon-fueled scramjet combustor investigation	Ground evaluation of seeding an in-flight wingtip vortex
aircraft. Volume 1: Aircraft system definition, design and analysis	[AIAA PAPER 90-2337] p 658 A90-40622	using infrared imaging flow visualization technique p 635 N90-25035
[AD-A218493] p 671 N90-23409	HYDROCARBONS Fire hazards of aerosol cans in aircraft cargo	IMPACT DAMAGE
HIGH REYNOLDS NUMBER	compartments	Impact damage and residual strength analysis of
Coherent vortex structures in the wake of a sphere and	[DOT/FAA/CT-89/32] p 636 N90-23369	composite panels with bonded stiffeners for primary
a circular disk at rest and under forced vibrations p 623 A90-40749	Some 1-(diorganooxyphosphonyl)methyl-2,4- and -2,6-dinitro-benzenes	aircraft structures p 642 A90-40130  Nonlinear finite-element analysis to predict fan-blade
P 020 1,00-40140	- 2.0 - 3.110 0 - DE1 (2016)	INVIBURED BUILD-CICKER ANALYSIS TO DIGUED 130-DISOR

-2,6-dinitro-benzenes [NASA-CASE-ARC-11425-3]

p 678 N90-23475

p 673 A90-41726

Nonlinear finite-element analysis to predict fan-blade lamage due to soft-body impact p 683 A90-40939

damage due to soft-body impact

Cryogenic wind tunnels

bevelopment of impact design methods for coramic gas	Coloulation of humanosis foreholds flow fields	Concept demonstration of the use of interestive fault
turbine components	Calculation of hypersonic forebody/inlet flow fields	Concept demonstration of the use of interactive fault
[AIAA PAPER 90-2413] p 687 A90-42165	[AIAA PAPER 90-1493] p 619 A90-39049	diagnosis and isolation for TF30 engines
Unique failure behavior of metal/composite aircraft	The influence of the inlet Mach number on the boundary	p 617 A90-41177
structural components under crash type loads	layer development on turbomachinery blade surfaces	INTERFERENCE DRAG
[NASA-TM-102679] p 690 N90-24660	p 621 A90-40504	Subsonic sting interference on the aerodynamic
MPACT PREDICTION	Computational modeling of inlet hammershock wave	characteristics of a family of slanted-base
The analysis and testing of composite panels subject	generation	ogive-cylinders
to muzzle blast effects p 675 A90-39991	[AIAA PAPER 90-2005] p 621 A90-40592	(NASA-CR-4299) p 633 N90-24242
MPACT RESISTANCE	A numerical investigation of supersonic inlet using	INVISCID FLOW
Development of impact design methods for ceramic gas	implicit TVD scheme	Simulation of inviscid blade-row interaction using a
turbine components	[AIAA PAPER 90-2135] p 621 A90-40612	linearised potential code
[AIAA PAPER 90-2413] p 687 A90-42165	Directivity of the noise radiation emitted from the inlet	[AIAA PAPER 90-1916] p 621 A90-40555
	duct of a turboshaft helicopter engine	Viscous-inviscid interaction method for calculating the
MPACT TESTS	[ONERA, TP NO. 1990-26] p 695 A90-41205	flow in compressor cascade blade passages and wake
The effects of toughening stresses on liquid impact	Mixing characteristics of dilution jets in small gas turbine	with separation
induced fracture p 692 A90-41315	combustors	
MPELLERS	[AIAA PAPER 90-2728] p 664 A90-42217	[AIAA PAPER 90-2125] p 624 A90-42032
Computation of flow through a centrifugal impeller with	INLET NOZZLES	Inviscid and viscous flows in transonic and supersonic
tip leakage	Radio frequency (RF) heated supersonic flow	cascades using an implicit upwind relaxation algorithm
[AIAA PAPER 90-2021] p 684 A90-41987	laboratory	[AIAA PAPER 90-2128] p 625 A90-42034
MPROVEMENT	[AIAA PAPER 90-2469] p 673 A90-42186	Calculation of viscous-inviscid strong interaction for
Aviation security: Corrective actions underway, but better	INLET PRESSURE	transonic flows over aerofoils p 627 A90-42364
inspection guidance still needed. Report to the	Experimental investigation of terminal shock sensors in	ISOENERGETIC PROCESSES
Chairwoman, Government Activities and Transportation	mixed-compression inlets	The interaction of a supersonic streamwise vortex and
Subcommittee, Committee on Government Operations,		a normal shock wave p 633 N90-24241
House of Representatives	[AIAA PAPER 90-1931] p 681 A90-40560	a normal shock wave p 000 1450-24241
	INLET TEMPERATURE	
	Fiber-optic turbine inlet temperature measurement	J
Transonic wing charge improvements by passive shock	system (FOTITMS)	<b>U</b>
boundary layer interference control: Development status	[AIAA PAPER 90-2033] p 657 A90-40603	
and prospects	INOCULATION	JET AIRCRAFT
[ETN-90-96463] p 650 N90-24267	Ground evaluation of seeding an in-flight wingtip vortex	Requirements for business jet aircraft
MPULSES	using infrared imaging flow visualization technique	[AIAA PAPER 90-2038] p 644 A90-41991
Adaptive control of a system with periodic dynamics:	p 635 N90-25035	GE's CF34 engine for business and regional jets
Application of an impulse response method to the	INSERTION LOSS	[AIAA PAPER 90-2041] p 661 A90-41992
helicopter vibration problem p 694 N90-23990	Reduced insertion loss of X-band RF fiber optic links	Throughput and delay characteristics for a
N-FLIGHT MONITORING	p 695 A90-41240	slow-frequency hopped aircraft-to-aircraft packet radio
The Super Puma MKII automatic flight control system		network
p 669 A90-42449	INSPECTION	
F	Aviation security: Corrective actions underway, but better	[AD-A220525] p 688 N90-23609
A highly maneuverable helicopter in-flight simulator -	inspection guidance still needed. Report to the	Forward canopy feasibility and Thru-The-Canopy (TTC)
Aspects of realization	Chairwoman, Government Activities and Transportation	ejection system study
[AIAA PAPER 88-4607] p 670 A90-42466	Subcommittee, Committee on Government Operations,	[AD-A220360] p 637 N90-24258
The modular HUM system Health and Usage	House of Representatives	JET AIRCRAFT NOISE
Monitoring instruments for rotary wing aircraft failure	[GAO/RCED-88-160] p 635 N90-23367	En route noise annoyance laboratory test: Preliminary
detection p 618 A90-42476	Modeling growth of fatigue cracks which originate at	results p 698 N90-24870
New systems for helicopter and aircraft vibration	rivet holes p 691 N90-25060	JET ENGINE FUELS
monitoring p 653 A90-42477	INSTRUMENT APPROACH	Three-dimensional analysis on flow and temperature
Estimation of rotor blade incidence and blade		distributions for aircraft fuel thermal stability
deformation from the measurement of pressures and	Demonstration of MLS advanced approach techniques	[AD-A219651] p 678 N90-23571
strains in flight p 647 A90-42497	p 640 A90-41711	JET ENGINES
NCOMPRESSIBLE FLOW	Microwave landing system - A pilot's point of view	A preliminary evaluation of an F100 engine parameter
Navier-Stokes solutions for vortical flows over a	p 640 A90-41712	estimation process using flight data
tangent-ogive cylinder p 620 A90-39780	INSTRUMENT ERRORS	[AIAA PAPER 90-1921] p 656 A90-40559
	MLS - A total system approach p 640 A90-41710	
Viscous flow around a propeller-shaft configuration with	INSTRUMENT FLIGHT RULES	Nonlinear finite-element analysis to predict fan-blade
infinite-pitch rectangular blades p 683 A90-40938	IFR aircraft handled forecast by air route traffic control	damage due to soft-body impact p 683 A90-40939
Flow induced forced response of an incompressible		Jet Engine Technical Advisor (JETA)
radial cascade including profile and incidence effects	center: Fiscal years 1990 to 2005	p 693 A90-41184
[AIAA PAPER 90-2352] p 626 A90-42136	[AD-A220312] p 641 N90-24263	JFS190 turbine engine performance optimized using
NDEXES (DOCUMENTATION)	INSTRUMENT LANDING SYSTEMS	Taguchi methods
Aircraft drawings index p 618 N90-23340	ILS - Past and present p 639 A90-41706	[AIAA PAPER 90-2419] p 663 A90-42169
NDUSTRIES	ILS - A safe bet for your future landings	A/F32T-9 large turbo fan engine enclosed noise
Langley aerospace test highlights, 1989	p 639 A90-41707	suppressor system (T-9 NSS), exterior far-field and interior
[NASA-TM-102631] p 699 N90-24221	Applications of slotted cable antennas in the instrument	noise, McConnell AFB, Kansas
NERTIA	landing system p 639 A90-41708	[AD-A220535] p 665 N90-23402
The influence of the inertia coupling on the stability and		JET EXHAUST
control of the helicopter and the response of helicopter	MLS - Keeping pace with the future	The cryogenic wind tunnel as a testing tool for
gust p 671 A90-42472	p 640 A90-41709	airframe/propulsion systems p 672 A90-40400
NERTIAL NAVIGATION	Microwave landing system - A pilot's point of view	JET FLAPS
Measurement of angles and angle characteristics with	p 640 A90-41712	Rotary-Jet thrust augmentor with jet-flapped blades
accelerometers and gyroscopes p 653 A90-41730	An evaluation of the accuracy of a microwave landing	p 633 N90-24243
Modern strapdown system for helicopter	system area navigation system at Miami/Tamiami Florida	JET FLOW
p 653 A90-42451	Airport	
	[DOT/FAA/CT-TN89/40] p 640 N90-23377	Confined jet thrust vector control nozzle studies
System concept and performance criteria of modern	INTEGRATED ENERGY SYSTEMS	[AIAA PAPER 90-2027] p 657 A90-40598
helicopter navigation p 640 A90-42452		Development of the jet-swirl high loading combustor
Continued development and analysis of a new extended	Aircraft engine technology gets a second wind	[AIAA PAPER 90-2451] p 658 A90-40633
Kalman filter for the Completely Integrated Reference	p 659 A90-41166	Measurements of turbulent dual-jet interaction
Instrumentation System (CIRIS)	INTERACTIONAL AERODYNAMICS	[AIAA PAPER 90-2105] p 624 A90-42019
[AD-A220106] p 654 N90-23400	Boundary layer stability in the case of transonic external	JET IMPINGEMENT
NFLATING	flow p 619 A90-39514	Inverse heat transfer studies and the effects of propellant
Wind tunnel tests of a 20-gore disk-gap-band	A visualization study of the interaction of a free vortex	aluminum on TVC jet vane heating and erosion
parachute	with the wake behind an airfoil p 623 A90-41119	[AIAA PAPER 90-1860] p 655 A90-40533
[AD-A221326] p 634 N90-24251	Interaction between a high-level steady acoustic field	Numerical modeling of an impinging jet in cross-flow
NFORMATION DISSEMINATION		[AIAA PAPER 90-2246] p 686 A90-42093
Conceptual design for aerospace vehicles	and a ducted turbulent flow	JET MIXING FLOW
p 651 N90-25043	[ONERA, TP NO. 1990-27] p 695 A90-41206	Experimental studies of combustor dilution zone
NFORMATION MANAGEMENT	Measurements of turbulent dual-jet interaction	aerodynamics. II - Jet development p 659 A90-40947
	[AIAA PAPER 90-2105] p 624 A90-42019	
Automatic speech recognition in air-ground data link	Computation of multiple normal shock wave/turbulent	
p 690 N90-25037	boundary layer interactions	flowfields
NFRARED IMAGERY	[AIAA PAPER 90-2133] p 685 A90-42037	[AIAA PAPER 90-2099] p 624 A90-42018
Dynamic FLIR simulation in flight training research	Numerical analysis of viscous-inviscid interaction in	Mixing characteristics of dilution jets in small gas turbine
p 681 A90-40109		combustors .
Infrared thermography at hypersonic channel H2K	transonic flow p 627 A90-42363	[AIAA PAPER 90-2728] p 664 A90-42217
p 674 N90-24235	Calculation of viscous-inviscid strong interaction for	JET NOZZLES
Ground evaluation of seeding an in-flight wingtip vortex	transonic flows over aerofoils p 627 A90-42364	The sensitivity of near-field acoustics to the orientation
using infrared imaging flow visualization technique	Higher-order boundary-layer approximations in	of twin two-dimensional supersonic nozzles
p 635 N90-25035	interactive airfoil calculations p 628 A90-42402	[AIAA PAPER 90-2149] p 625 A90-42045

		`•
JET THRUST	Impact damage and residual strength analysis of	LINEAR QUADRATIC REGULATOR
Confined jet thrust vector control nozzle studies	composite panels with bonded stiffeners for primary	Guaranteed cost control via optimal parametric LQ
[AIAA PAPER 90-2027] p 657 A90-40598	aircraft structures p 642 A90-40130	design p 693 A90-40810
JET VANES	Supersonic flutter of shear deformable laminated	LINEARIZATION
Inverse heat transfer studies and the effects of propellant	composite flat panels p 683 A90-41104	Helicopter control design using feedback linearization
aluminum on TVC jet vane heating and erosion	Development of a finite element based delamination	techniques p 668 A90-40817
[AIAA PAPER 90-1860] p 655 A90-40533	analysis for laminates subject to extension, bending, and	LIQUEFIED NATURAL GAS
5DOF dynamic loads on a jet vane	torsion p 679 N90-25049	Experimental turbofan using liquid hydrogen and liquid natural gas as fuel
[AIAA PAPER 90-2382] p 675 A90-42147	LANDING GEAR	[AIAA PAPER 90-2421] p 663 A90-42170
JETTISONING Aerodynamics of store separation p 629 A90-42418	Advanced materials for landing gear	LIQUID ATOMIZATION
JOURNAL BEARINGS	ρ 677 A90-41900	Further validation of a semi-analytical approach for fuel
Planet gear sleeve spinning analysis	LANDING SPEED	injectors of different concepts
[AIAA PAPER 90-2154] p 681 A90-40613	Accelerators and decelerators for large, hypersonic	[AIAA PAPER 90-2190] p 686 A90-42067
Analysis of thermal gradient effects in oil ring seals	aircraft	LIQUID CHROMATOGRAPHY
p 682 A90-40716	[AIAA PAPER 90-1986] p 674 A90-40582	HPLC analysis of helicopter rotor blade materials
JP-4 JET FUEL	LASER APPLICATIONS	[AD-A221121] p 650 N90-24270
Equilibrium swelling of elastomeric materials in solvent	Flow visualization via laser-induced reflection from	LIQUID CRYSTALS
environments	bubble sheets p 680 A90-39784	Performance of full color active-matrix-LCD in the cockpit
[DE90-010164] p 678 N90-24430	LASER DOPPLER VELOCIMETERS	environment p 681 A90-40392
	Laser Doppler velocimetry investigation of swirler	Polysilicon active-matrix liquid crystal displays for cockpit
K	flowfields p 682 A90-40929	applications p 681 A90-40393
• • • • • • • • • • • • • • • • • • • •	Three-component LDA measurements in an axial-flow	LIQUID FUELS
K-EPSILON TURBULENCE MODEL	compressor p 683 A90-40943	Influence of fuel composition on flame radiation in gas
Numerical modeling of an impinging jet in cross-flow	LATERAL CONTROL	turbine combustors p 659 A90-40946
[AIAA PAPER 90-2246] p 686 A90-42093	Energy based stability analysis of a fuzzy roll controller	Structure analysis of burning liquid-fueled spray in a
Turbulence model performance in V/STOL flow field	design for a flexible aircraft wing p 668 A90-40833	confined combustor [AIAA PAPER 90-2444] p 677 A90-42174
simulation	Ultimate boundedness control of uncertain systems with	[AIAA PAPER 90-2444] p 677 A90-42174 LIQUID HYDROGEN
[AIAA PAPER 90-2248] p 625 A90-42094	application to roll coupled aircraft maneuver p 668 A90-40886	Hydrogen in future energy and propulsion technology
The computation of turbulent thin shear flows associated		p 692 A90-41736
with flow around multielement aerofoils	An image analysis method for vehicle stabilization p 668 A90-40914	Experimental turbofan using liquid hydrogen and liquid
p 633 N90-24240	Fighter agility metrics, research, and test	natural gas as fuel
KALMAN FILTERS	[NASA-CR-186118] p 648 N90-23386	[AIAA PAPER 90-2421] p 663 A90-42170
A proposed Kalman filter algorithm for estimation of	Lateral-directional stability and control characteristics of	LIQUID PROPELLANT ROCKET ENGINES
unmeasured output variables for an F100 turbofan	the Quiet Short-Haul Research Aircraft (QSRA)	The SEPR 844 reusable liquid rocket engine for Mirage
engine	[NASA-TM-102250] p 671 N90-23413	combat aircraft
[AIAA PAPER 90-1920] p 656 A90-40558	LATERAL STABILITY	[AIAA PAPER 90-1835] p 655 A90-40526
Multiple model adaptive controller for the STOL F-15 with sensor/actuator failures p 668 A90-40878	Lateral-directional stability and control characteristics of	LOAD DISTRIBUTION (FORCES)
with sensor/actuator failures p 668 A90-40878 Estimating short-period dynamics using an extended	the Quiet Short-Haul Research Aircraft (QSRA)	Rotating system load monitoring using minimum fixed
Kalman filter	[NASA-TM-102250] p 671 N90-23413	system instrumentation p 651 A90-39982
[NASA-TM-101722] p 648 N90-23392	LEADING EDGES	Finite-element analysis of large spur and helical gear
KNOWLEDGE BASES (ARTIFICIAL INTELLIGENCE)	The problem of supersonic flow past a thin wing of finite	systems p 683 A90-40940
Control system validation in the autonomous	span with fully subsonic leading edges	The effect on fatigue crack growth under spectrum loading of an imposed placard 'G' limit
helicopter p 667 A90-38908	p 620 A90-39519 LEAKAGE	p 643 A90-41339
Applying qualitative knowledge to aircraft engine system	Computation of flow through a centrifugal impeller with	LOADING RATE
design p 694 A90-41189	tip leakage	Reconstitution of crack growth from fractographic
Automated aircraft engine costing using artificial	[AIAA PAPER 90-2021] p 684 A90-41987	observations after flight simulation loading
intelligence	Evaluation of brush seals for limited-life engines	p 682 A90-40650
[AIAA PAPER 90-1887] p 660 A90-41981	[AIAA PAPER 90-2140] p 685 A90-42040	LOADS (FORCES)
The place of knowledge based systems in helicopter	LEAST SQUARES METHOD	Unique failure behavior of metal/composite aircraft
dynamic system condition prognosis	Identification of multivariable models of jet engines	structural components under crash type loads
p 618 A90-42475 KNOWLEDGE REPRESENTATION	[AIAA PAPER 90-1874] p 655 A90-40540	[NASA-TM-102679] p 690 N90-24660
SMAS - An expert system for configuring a research	Development of a least squares time response	LOCAL AREA NETWORKS
flight simulator p 694 A90-41191	lower-order equivalent systems technique	AIRNET: A real-time comunications network for
KUTTA-JOUKOWSKI CONDITION	[AD-A220527] p 648 N90-23389	aircraft
Euler code predicted separation at the airfoil trailing	Adaptive control of a system with periodic dynamics:	[NASA-CR-186140] p 690 N90-24514 LOGISTICS
edge	Application of an impulse response method to the	Peacetime replacement and crash damage factors for
[FFA-TN-1989-30] p 632 N90-23364	helicopter vibration problem p 694 N90-23990 Application of optimal tracking methods to aircraft terrain	army aircraft
	following	[AD-A218544] p 636 N90-23372
1	[AD-A221099] p 641 N90-24264	LONGITUDINAL CONTROL
<b>-</b>	LIFE (DURABILITY)	Digital controller design for the pitch axis of the F-14
LABYRINTH SEALS	A 'new' philosophy of structural reliability, fail safe versus	using an H(infinity) method p 668 A90-40912
Evaluation of brush seals for limited-life engines	safe life p 688 A90-42490	Feasibility study for a microwave-powered ozone sniffer
[AIAA PAPER 90-2140] p 685 A90-42040	LIFE CYCLE COSTS	aircraft
Model of a labyrinth seal with flow	Eight years of flight operations with composite	[NASA-CR-186660] p 650 N90-23397
p 687 A90-42334	rotorblades p 635 A90-42481	LONGITUDINAL STABILITY
LAMINAR BOUNDARY LAYER	Preliminary design of a supersonic Short Takeoff and	Large receiver aircraft - The performance and
An analytic study of nonsteady two-phase laminar	Vertical Landing (STOVL) fighter aircraft	longitudinal stability and control during air to air
boundary layer around an airfoil p 691 N90-25051	[NASA-CR-186670] p 649 N90-23394	refuelling p 669 A90-41767
LAMINAR FLOW	Lift recognics of a rectangular wine undersoing a cton	LOW ASPECT RATIO
Wind tunnel results and numerical computations for the	Lift response of a rectangular wing undergoing a step change in forward speed p 620 A90-39801	Flutter of shaft-supported low aspect-ratio control
NAE deHavilland series of natural laminar flow airfoils		surfaces p 667 A90-38912
p 628 A90-42403	Unsteady notantial flow nast a propeller blade section	
Dradiction of agraduamic parformance of sidelle in term	Unsteady potential flow past a propeller blade section [NASA-CR-4307] p 634 N90-24246	LOW ASPECT RATIO WINGS
Prediction of aerodynamic performance of airfoils in low  Reynolds number flows		Aeroelastic analysis of a low aspect ratio wing
Reynolds number flows	[NASA-CR-4307] p 634 N90-24246	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360	[NASA-CR-4307] p 634 N90-24246 LIFT FANS	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive	[NASA-CR-4307] p 634 N90-24246 LIFT FANS A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW Low-density flow effects for hypervelocity vehicles,
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel	[NASA-CR-4307] p 634 N90-24246 LIFT FANS A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167 LIGHT AIRCRAFT	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Los speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller'	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2  [AD-A221034] p 634 N90-24249
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2  [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Los speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2  [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741  On simplified analytical flutter clearance procedures for	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER
Reynolds number flows [DLC-EST-Th-O31] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741  On simplified analytical flutter clearance procedures for light aircraft	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2  [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  Composite reduced Navier Stokes procedures for flow	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 63 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276  LIGHT SCATTERING	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low Reynolds number flows
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 635 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276  LIGHT SCATTERING  Nondestructive measurement of residual stresses in	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low Reynolds number flows  [DLC-EST-TN-031] p 632 N90-23360
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions [AD-A219621] p 689 N90-23687  LAMINAR MIXING Investigation of supersonic mixing layers	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 63 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276  LIGHT SCATTERING	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360  LOW SPEED WIND TUNNELS
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions [AD-A219621] p 689 N90-23687  LAMINAR MIXING	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven lan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276  LIGHT SCATTERING  Nondestructive measurement of residual stresses in aircraft transparencies	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360  LOW SPEED WIND TUNNELS  Vorticity distribution of vortex street in the wake of a
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360 Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  LAMINAR FLOW AIRFOILS Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363  Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions [AD-A219621] p 689 N90-23687  LAMINAR MIXING Investigation of supersonic mixing layers	[NASA-CR-4307] p 634 N90-24246  LIFT FANS  A remote tip-driven fan powered supersonic fighter concept [AIAA PAPER 90-2415] p 663 A90-42167  LIGHT AIRCRAFT  A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728  Digital autopilot for light aircraft p 653 A90-41741  On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276  LIGHT SCATTERING  Nondestructive measurement of residual stresses in aircraft transparencies [AD-A218680] p 689 N90-23762	Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915  LOW DENSITY FLOW  Low-density flow effects for hypervelocity vehicles, phase 2 [AD-A221034] p 634 N90-24249  LOW LEVEL TURBULENCE  Wind shear at Pantelleria airport p 692 A90-39702  LOW REYNOLDS NUMBER  Prediction of aerodynamic performance of airfoils in low Reynolds number flows  [DLC-EST-TN-031] p 632 N90-23360  LOW SPEED WIND TUNNELS  Vorticity distribution of vortex street in the wake of a circular cylinder p 623 A90-41751

NASA PROGRAMS

SUBJECT INDEX LUBRICANT TESTS High temperature solid lubricant requirements for advanced high performance gas turbine engines [AIAA PAPER 90-2042] p 661 A90-41993 LUBRICATION SYSTEMS High temperature solid lubricant requirements for advanced high performance gas turbine engines [AIAA PAPER 90-2042] p 661 A90-41993 Evaluation of solid lubricant powder delivery system for turbine bearing lubrication [AIAA PAPER 90-2046] p 684 A90-41997 M MACH NUMBER Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing p 619 A90-39465 The influence of the inlet Mach number on the boundary layer development on turbomachinery blade surfaces p 621 A90-40504 High Mach exhaust system concept scale model test results [AIAA PAPER 90-1905] p 655 A90-40552 Flow visualization studies of the Mach number effects on dynamic stall of an oscillating airfoil p 622 A90-40683 The gun tunnel of the Brunswick Institute for Fluid Mechanics: Current development status p 673 N90-24227 Calculation of the aeroelastic blade stabilization with linearized process [MITT-87-01] p 666 N90-24272 MAGNETIC BEARINGS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 MAGNETIC SUSPENSION Drag measurements on a modified prolate spheroid using a magnetic suspension and balance system wind tunnel testing MAINTENANCE TRAINING

The six component magnetic suspension system for p 673 A90-41725

Trend analysis and diagnostics codes for training

DUMOSAS [AIAA PAPER 90-2394] p 617 A90-42156 MAN-COMPUTER INTERFACE

SMAS - An expert system for configuring a research ght simulator p 694 A90-41191 flight simulator MARKET RESEARCH Euromant - The European aviation research and

p 617 A90-41112 technology program MARS ATMOSPHERE

Preliminary design of a long-endurance Mars aircraft [AIAA PAPER 90-2000] p 674 A90-40587 MASS FLOW RATE

Ultrasonic regression rate measurement in solid fuel ramjets [AIAA PAPER 90-1963] p 656 A90-40573

MATCHING Development of a least squares time response

lower-order equivalent systems technique p 648 N90-23389 [AD-A220527]

MATHEMATICAL MODELS

Mathematical modeling of plane parallel separated flows p 619 A90-39475 past bodies -- Russian book p 619 A90-39475 Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 A modeling technique for STOVL ejector and volume dynamics

[AIAA PAPER 90-2417] p 663 A90-42168 Euler and Navier-Stokes computations for airfoil geometries using unstructured meshes

p 630 A90-42425 A model for active control of helicopter air resonance in hover and forward flight p 670 , A90-42462 A study of supermanuever aerodynamics

[AD-A218378] p 631 N90-23349 A computer code for the prediction of aerodynamic

characteristics of lifting airfoils at transonic speed p 632 N90-23359 [DLC-EST-TN-030]

MLS mathematical model validation study using airborne MLS data from Midway Airport engineering flight tests, August 1988

[DOT/FAA/CT-TN90/2] p 640 N90-23378 The computation of turbulent thin shear flows associated with flow around multielement aerofoils

p 633 N90-24240 Sound propagation elements in evaluation of en route noise of advanced turbofan aircraft p 697 N90-24861 A quantitative technique to estimate microburst wind

p 692 N90-25040 shear hazard to aircraft Development of a finite element based delamination analysis for laminates subject to extension, bending, and p 679 N90-25049 torsion

Extension-torsion coupling behavior of advanced p 651 N90-25057 composite tilt-rotor blades MCDONNELL DOUGLAS AIRCRAFT

Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439

MEASURING INSTRUMENTS

MEDICAL SERVICES

Ultrasonic regression rate measurement in solid fuel ramiets

AIAA PAPER 90-1963] p 656 A90-40573 MECHANICAL PROPERTIES

Composites applications - The future is now p 678 A90-42372

Aeronautical decisionmaking for air ambulance program administrators

(DOT/FAA/DS-88/8) p 635 N90-23368 MESSAGE PROCESSING

AIRNET: A real-time comunications network for aircraft p 690 N90-24514

[NASA-CR-186140] METAL FATIGUE

Reconstitution of crack growth from fractographic observations after flight simulation loading

Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary and other emissions

[AFRF-R-13303-PT-2] p 678 N90-23523 MÈTAL FUELS

Metallized fuel particle size study in a solid fuel ramjet p 679 N90-24451 [AD-A2200791

METAL MATRIX COMPOSITES

Advanced materials for landing gear

p 677 A90-41900 Metal matrix composites structural design experience p 677 A90-42059 [AIAA PAPER 90-2175] Metal matrix composite fan blade development [AIAA PAPER 90-2178] p 677 A90

p 677 A90-42062 Composites applications - The future is now

p 678 A90-42372 **METEOROLOGICAL PARAMETERS** 

Microwave landing system - A pilot's point of view p 640 A90-41712

METEOROLOGICAL RADAR Design of new Polish primary radars AVIA DM/CM p 638 A90-41035

METEOROLOGICAL SERVICES Wind shear at Pantelleria airport p 692 A90-39702

METHYL COMPOUNDS Some 1-(diorganooxyphosphonyl)methyl-2,4- and

-2,6-dinitro-benzenes [NASA-CASE-ARC-11425-3] p 678 N90-23475 MICROBURSTS (METEOROLOGY)

Synthetic aperture radar imagery of airports and surrounding areas: Denver Stapleton International

Airport [NASA-CR-4305] p 637 N90-24257 A quantitative technique to estimate microburst wind

p 692 N90-25040 shear hazard to aircraft MICROMECHANICS Application of fracture mechanics to microscale

phenomena in electronic assemblies p 684 A90-41334

MICROPROCESSORS An experimental study of fault propagation in a jet-engine

controller [NASA-CR-181335] p 665 N90-23401

MICROSTRIP ANTENNAS Dual cross-polarization planar arrays in the C and X p 638 A90-40979 MICROWAVE LANDING SYSTEMS

Flight safety performance of the microwave landing p 639 A90-41705

MLS - Keeping pace with the future p 640 A90-41709 MLS - A total system approach p 640 A90-41710

Demonstration of MLS advanced approach techniques p 640 A90-41711 Microwave landing system - A pilot's point of view

p 640 A90-41712 An evaluation of the accuracy of a microwave landing

system area navigation system at Miami/Tamiami Florida (DOT/FAA/CT-TN89/40) p 640 N90-23377

MLS mathematical model validation study using airborne MLS data from Midway Airport engineering flight tests,

[DOT/FAA/CT-TN90/2] p 640 N90-23378 Position computation without elevation information for computed centerline operations

[DOT/FAA/CT-TN89/42] p 640 N90-23379

MICROWAVE TRANSMISSION

Reduced insertion loss of X-band RF fiber optic links p 695 A90-41240 **MILITARY AIR FACILITIES** 

A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832

MILITARY AIRCRAFT

Aircraft drawings index

Military engines - Cradle of technology p 660 A90-41758 p 618 N90-23340

MILITARY HELICOPTERS The Franco-German helicopter programme HAP, PAH-2/HAC p 618 A90-42478

Preliminary flight evaluation of the SA 365 Panther helicopter in air-to-air combat manoeuvres

p 647 A90-42494 Helicopter store separation - Predictive techniques and ight testing p 647 A90-42495 FH101 vibration control p 647 A90-42496

MILITARY TECHNOLOGY Exploration of concepts for multi-role fighters

[AIAA PAPER 90-2276] p 644 A90-42104 MINIATURIZATION

Miniaturization of flight deflection measurement system [NASA-CASE-LAR-13628-1]

p 689 N90-23707 MINOR CIRCLE TURNING FLIGHT

Hypervelocity, minimum-radii, coordinated turns p 667 A90-40691

**MIRAGE 3 AIRCRAFT** The SEPR 844 reusable liquid rocket engine for Mirage combat aircraft

[AIAA PAPER 90-1835] p 655 A90-40526

MIXERS Navier-Stokes analysis of an ejector and mixer-ejector

operating at pressure ratios in the range 2-4 AIAA PAPER 90-27301 p 626 A90-42218 MIXING LAYERS (FLUIDS)

Investigation of supersonic mixing layers

p 623 A90-40926

MODAL RESPONSE A comprehensive approach to coupled rotor-fuselage

MODEL REFERENCE ADAPTIVE CONTROL Multiple model adaptive controller for the STOL F-15

th sensor/actuator failures p 668 A90-40878 MODELS

An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack

[AD-A219793] p 631 N90-23353 New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel

[AD-A2209331 p 674 N90-24278 Unique failure behavior of metal/composite aircraft

structural components under crash type loads p 690 N90-24660 INASA-TM-1026791

MOMENT DISTRIBUTION

The influence of control-surface compensation parameters on the hinge moment characteristics

p 643 A90-41737

MONTE CARLO METHOD Low-density flow effects for hypervelocity vehicles,

AD-A2210341 p 634 N90-24249 MOVING TARGET INDICATORS

The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 MULTIGRID METHODS

Automated generation of two-dimensional non-overlapping structured grids for multiple element airfoils with Euler solutions p 629 A90-42422 **MULTIPHASE FLOW** 

Review of mixed flow and radial turbine options [AIAA PAPER 90-2414] p 687 A90 p 687 A90-42166 MULTIPLEXING

Automatic speech recognition in air-ground data link p 690 N90-25037 MULTISTAGE ROCKET VEHICLES

Hypersonic (T-D) 'pinch' and aerospaceplane [AIAA PAPER 90-2474] p 675 A90-42189

NAP-OF-THE-EARTH NAVIGATION

Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 p 669 A90-41632 NASA PROGRAMS

FAA/NASA En Route Noise Symposium p 696 N90-24853 [NASA-CP-3067] p 696 N90-24853 En route noise: NASA propfan test aircraft (corrected

data - simplified procedure) IDOT-TSC-FA953-LR41 p 696 N90-24856 En route noise: NASA propfan test aircraft (calculated

[DOT-TSC-FA953-LR5] p 697 N90-24857

NATIONAL AEROSPACE PLANE PROGRAM CFD propels NASP propulsion progress	En route noise annoyance laboratory test: Preliminary results p 698 N90-24870	Estimating short-period dynamics using an extended Kalman filter
p 683 A90-41163	Human response research update	[NASA-TM-101722] p 648 N90-23392
NATURAL GAS Experimental turbofan using liquid hydrogen and liquid	p 699 N90-24873	NONLINEARITY  A time-marching method for calculating unsteady
natural gas as fuel	NOISE POLLUTION	airloads on three-dimentional wings. Part 2: Full-potential
[AIAA PAPER 90-2421] p 663 A90-42170 NAVIER-STOKES EQUATION	Fuselage boundary-layer effects on sound propagation and scattering p 695 A90-39781	formulation [DLR-FB-89-59] p 635 N90-24255
Numerical solution of the problem of supersonic flow	A/F32T-9 large turbo fan engine enclosed noise	Flexural fatigue life prediction of closed hat-section using
of a viscous gas past a concave conical wing	suppressor system (T-9 NSS), exterior far-field and interior noise, McConnell AFB, Kansas	materially nonlinear axial fatigue characteristics
p 619 A90-39465	[AD-A220535] p 665 N90-23402	p 691 N90-25062
Navier-Stokes solutions for vortical flows over a	Activities report in aerospace and aerodynamics	NORMAL SHOCK WAVES
tangent-ogive cylinder p 620 A90-39780	[ETN-90-96774] p 699 N90-24224	Experimental investigation of terminal shock sensors in
A numerical investigation of supersonic inlet using implicit TVD scheme	FAA/NASA En Route Noise Symposium	mixed-compression inlets [AIAA PAPER 90-1931] p 681 A90-40560
[AIAA PAPER 90-2135] p 621 A90-40612	[NASA-CP-3067] p 696 N90-24853	Computation of multiple normal shock wave/turbulent
Calculation of three-dimensional jet interaction	. Sound propagation elements in evaluation of en route	boundary layer interactions
flowfields	noise of advanced turbofan aircraft p 697 N90-24861	[AIAA PAPER 90-2133] p 685 A90-42037
[AIAA PAPER 90-2099] p 624 A90-42018	Preliminary thoughts on an acoustic metric for the	The interaction of a supersonic streamwise vortex and
Application of 3-D Navier-Stokes computation to bowed	wilderness aircraft overflight study p 697 N90-24862	a normal shock wave p 633 N90-24241
stacking turbine vane design	NOISE PREDICTION	NORWAY
[AIAA PAPER 90-2129] p 625 A90-42035	En route noise annoyance laboratory test: Preliminary	An aircraft noise study in Norway p 698 N90-24872
Navier-Stokes analysis of an ejector and mixer-ejector operating at pressure ratios in the range 2-4	results p 698 N90-24870	NOSE CONES  Comments on 'Effect of nose bluntness and cone angle
[AIAA PAPER 90-2730] p 626 A90-42218	NOISE PREDICTION (AIRCRAFT)  Acoustics of ultralight airplanes p 643 A90-40685	on slender-vehicle transition' p 620 A90-39814
Euler and Navier-Stokes computations for airfoil	Characterization of helicopter turboshaft engine noise	NOWCASTING
geometries using unstructured meshes	p 660 A90-41759	Wind shear at Pantelleria airport p 692 A90-39702
p 630 A90-42425	NOISE PROPAGATION	NOZZLE DESIGN
A study of supermanuever aerodynamics	Characterization of helicopter turboshaft engine noise	Computation of vectoring nozzle performance
[AD-A218378] p 631 N90-23349	p 660 A90-41759	[AIAA PAPER 90-2752] p 627 A90-42225
Composite reduced Navier Stokes procedures for flow	En route noise: NASA propfan test aircraft (corrected	NOZZLE EFFICIENCY
problems with strong pressure interactions [AD-A219621] p 689 N90-23687	data - simplified procedure)  [DOT-TSC-FA953-LR4] p 696 N90-24856	The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system
The interaction of a supersonic streamwise vortex and	[DOT-TSC-FA953-LR4] p 696 N90-24856 En route noise: NASA propfan test aircraft (calculated	[AIAA PAPER 90-2492] p 658 A90-40637
a normal shock wave p 633 N90-24241	source noise	Experimental and analytical study of close-coupled
Low-density flow effects for hypervelocity vehicles,	[DOT-TSC-FA953-LR5] p 697 N90-24857	ventral nozzles for ASTOVL aircraft
phase 2	NOISE REDUCTION	[NASA-TM-103170] p 666 N90-24273
[AD-A221034] p 634 N90-24249	Experiments on the active control of the transmission	NOZZLE FLOW
Experimental and analytical study of close-coupled	of sound through a clamped rectangular plate	Application of CFD to pitch/yaw thrust vectoring
ventral nozzles for ASTOVL aircraft [NASA-TM-103170] p 666 N90-24273	p 695 A90-41109 Wind-tunnel measurement of noise emitted by helicopter	spherical convergent flap nozzles [AIAA PAPER 90-2023] p 657 A90-40597
NAVIGATION AIDS	rotors at high speed	The role of hydrogen/air chemistry in nozzle
Continued development and analysis of a new extended	[ONERA, TP NO. 1990-28] p 695 A90-41207	performance for a hypersonic propulsion system
Kalman filter for the Completely Integrated Reference	Twin jet screech suppression concepts tested for 4.7	[AIAA PAPER 90-2492] p 658 A90-40637
Instrumentation System (CIRIS)	percent axisymmetric and two-dimensional nozzle	Influences on the uniformity of sprays produced by gas
[AD-A220106] p 654 N90-23400	configurations	turbine high shear nozzle/swirter assemblies
NEAR FIELDS  The sensitivity of near-field acoustics to the orientation	[AIAA PAPER 90-2150] p 696 A90-42046	[AIAA PAPER 90-2193] p 686 A90-42068
of twin two-dimensional supersonic nozzles	Active control of helicopter cabin noise p 645 A90-42434	<ul> <li>Analysis of internal flow in a ventral nozzle for STOVL aircraft</li> </ul>
[AIAA PAPER 90-2149] p 625 A90-42045	A/F32T-9 large turbo fan engine enclosed noise	[NASA-TM-103123] p 666 N90-23404
NEAR WAKES	suppressor system (T-9 NSS), exterior far-field and interior	NOZZLE GEOMETRY
Investigation of the near wake of a propfan	noise, McConnell AFB, Kansas	Confined jet thrust vector control nozzle studies
p 622 A90-40686	[AD-A220535] - p 665 N90-23402	[AIAA PAPÉR 90-2027] p 657 A90-40598
NEURAL NETS	The effect of noise-abatement profiles on noise	Three dimensional transonic and supersonic flow
Neural networks for adaptive shape tracking p 638 A90-39959	immissions and human annoyance underneath a	prediction in axi-vectored nozzles using a finite volume
Application of neural networks to the F/A-18 engine	subsequent climbpath p 698 N90-24865 Problems of internal acoustics in two and three	method
condition monitoring system	dimensional cavities with deformable walls using the	[AIAA PAPER 90-2026] p 624 A90-41989
[AD-A219820] p 666 N90-24271	MSC/Nastran code	Twin jet screech suppression concepts tested for 4.7 percent axisymmetric and two-dimensional nozzle
NEWTON-RAPHSON METHOD	[DLC/STR-INT-TN-004] p 699 N90-24876	configurations
A technique for the tuning of helicopter flight control	NOISE TOLERANCE	[AIAA PAPER 90-2150] p 696 A90-42046
systems p 670 A90-42467	FAA/NASA En Route Noise Symposium	NUMERICAL ANALYSIS
NITRATION Some 1-(diorganooxyphosphonyl)methyl-2,4- and	[NASA-CP-3067] p 696 N90-24853	Numerical analysis of viscous-inviscid interaction in
-2,6-dinitro-benzenes	Proposed definition of the term en route in en route aircraft noise p 696 N90-24854	transonic flow p 627 A90-42363
[NASA-CASE-ARC-11425-3] p 678 N90-23475	aircraft noise p 696 N90-24854  The effect of noise-abatement profiles on noise	Analysis of internal flow in a ventral nozzle for STOVL
NOISE INTENSITY	immissions and human annoyance underneath a	aircraft
Summary of sonic boom rise times observed during FAA	subsequent climbpath p 698 N90-24865	[NASA-TM-103123] p 666 N90-23404
community response studies over a 6-month period in the	Additive evaluation criteria for aircraft noise	NUMERICAL CONTROL
Oklahoma City area	p 698 N90-24867	Implementation of a transputer-based flight controller p 667 A90-38966
[NASA-CR-4277] p 696 N90-24852 Sound propagation elements in evaluation of en route	Social survey findings on en route noise annoyance	Digital control of magnetic bearings supporting a
noise of advanced turbofan aircraft p 697 N90-24861	issues p 698 N90-24868 Problems related to aircraft noise in Switzerland	multimass flexible rotor p 682 A90-40712
Additive evaluation criteria for aircraft noise	p 698 N90-24871	Fracture control via DRM-Algorithm .
p 698 N90-24867	Human response research update	p 694 A90-41343
En route noise annoyance laboratory test: Preliminary	p 699 N90-24873	Digital autopilot for light aircraft p 653 A90-41741
results p 698 N90-24870	NONDESTRUCTIVE TESTS	Use of smart actuators for the tail rotor collective pitch
An aircraft noise study in Norway p 698 N90-24872	Nondestructive measurement of residual stresses in	control p 688 A90-42483
NOISE MEASUREMENT Wind-tunnel measurement of noise emitted by helicopter	aircraft transparencies	Full Authority Digital Engine Control for the AS 355 N
rotors at high speed	[AD-A218680] p 689 N90-23762	TM 319 engines p 665 A90-42486
[ONERA, TP NO. 1990-28] p 695 A90-41207	NONEQUILIBRIUM FLOW  Transonic flow around airfoils with relaxation and energy	NUMERICAL FLOW VISUALIZATION
Noise-source measurements by thin-film pressure	supply by homogeneous condensation	Supercomputer applications in gas turbine flowfield
transducers in a subsonic turbofan model	- p 620 A90-39782	simulation p 620 A90-40495
[ONERA, TP NO. 1990-36] p 659 A90-41212	NONLINEAR PROGRAMMING	Numerical solution of 3-D hybrid problems in
PTA en route noise measurements .	Design methodology for multivariable helicopter control	turbomachinery p 621 A90-40501
p 696 N90-24855	systems p 669 A90-42461	Prediction of aerodynamic performance of airfoils in low
En route noise: NASA propfan test aircraft (corrected data - simplified procedure)	NONLINEAR SYSTEMS	Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360
[DOT-TSC-FA953-LR4] p 696 N90-24856	An introduction to chaos theory in CFD [AIAA PAPER 90-1440] p 680 A90-39725	[DEC-EG1-111-001] p 032 1/30-23300
En route noise of two turboprop aircraft	Experimental study of the effects of nonlinearities on	_
[DLR-MITT-89-18] p 697 N90-24859	ground resonance p 643 A90-40172	0
Noise measurements of turboprop airplanes at different	Helicopter control design using feedback finearization	
overflight elevations p 697 N90-24860	techniques p 668 A90-40817	O RING SEALS
Preliminary thoughts on an acoustic metric for the wilderness aircraft overflight study p 697 N90-24862	Nonlinear finite-element analysis to predict fan-blade	Analysis of thermal gradient effects in oil ring seals
	damage due to soft-body impact p 683 A90-40939	p 682 A90-40716

OBLIQUE WINGS  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689
OBSERVABILITY (SYSTEMS)
A study on the application of controllability and observability concepts in the design of flight control
systems p 693 A90-39303  OBSTACLE AVOIDANCE
Obstacle warning system for helicopters p 653 A90-41114
Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632
OCCURRENCES Additive evaluation criteria for aircraft noise p 698 N90-24867
OGIVES
Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders
[NASA-CR-4299] p 633 N90-24242
OH-58 HELICOPTER  The collection of usage data to improve structural integrity of operational helicopters p 651 A90-39983
OPTICAL FIBERS
Fiber-optic turbine inlet temperature measurement system (FOTITMS)
[ÁIAA PAPER 90-2033] p 657 A90-40603 Tests for integrating measurement of gas pressures in
flight propellers
[ETN-90-96498] p 634 N90-24253 OPTICAL FILTERS
New technology advances for brighter color CRT
displays p 652 A90-40399 OPTICAL GYROSCOPES
Measurement of angles and angle characteristics with
accelerometers and gyroscopes p 653 A90-41730  OPTIMAL CONTROL
Design methodology for multivariable helicopter control
systems p 669 A90-42461 Analytical study of dynamic response of helicopter in
autorotative flight p 670 A90-42469 Prediction of longitudinal pilot induced oscillations using
the optimal control model
[AD-A220593] p 671 N90-23412 OPTIMIZATION
Improvement of helicopter handling qualities using
H(infinity)-optimisation p 667 A90-38965 Multilevel optimization of large-scale structures in a
parallel computing environment p 693 A90-39180
Development and application of an optimization procedure for space and aircraft structures
p 679 A90-39186 Boundary-element shape optimization system for aircraft
structural components p 680 A90-39786
Synthesis of optimal multidimensional digital systems for the simulation of the angular motions of a flight vehicle
under random loading p 669 A90-41957
evaluation and technology transition
[AIAA PAPER 90-2280] p 644 A90-42106
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 ORGANIC MATERIALS
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 DRGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 DRGANIC MATERIALS HPLC analysis of helicopter rotor blade materials
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 DRGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbrine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  P 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow DUTLET FLOW The performance of a combustor incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  DUTLET FLOW The performance of a combustor incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aicraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-18666] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186665] p 650 N90-23397  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  OZONOPHERE
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-186660] p 650 N90-23397  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-23266
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  OZONOSPHERE  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-14277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266 OZONOSPHERE NASA/USRA high altitude reconnaissance aircraft
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aicraft [NASA-CR-18660] p 650 N90-2397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  OZONOSPHERE NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow p 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-24266  OZONOSPHERE NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  OZONOSPHERE NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  PP-I-N JUNCTIONS Performance of full color active-matrix-LCD in the cockpit
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-4277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-2397 NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  P P-I-N JUNCTIONS Performance of full color active-matrix-LCD in the cockpit environment p 681 A90-40392
[AIAA PAPER 90-2280] p 644 A90-42106 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  ORGANIC MATERIALS HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270  OSCILLATING FLOW Model of a labyrinth seal with flow  P 687 A90-42334  OUTLET FLOW The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053  OVERPRESSURE Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area [NASA-CR-1277] p 696 N90-24852  OZONE Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-2397  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  OZONOSPHERE  NASA/USRA high altitude reconnaissance aircraft [NASA-CR-186685] p 650 N90-24266  PP  P-I-N JUNCTIONS Performance of full color active-matrix-LCD in the cockpit environment p 681 A90-40392

	PLATE THEORY
PANEL METHOD (FLUID DYNAMICS) Counter-rotating propellant analysis using a frequency	On and off-design performance prediction of single spool turbojets using gasdynamics
domain panel method p 623 A90-40937 A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized	[AIAA PAPER 90-2393] p 662 A90-42155 A modeling technique for STOVL ejector and volume dynamics
formulation [DLR-FB-89-58] p 634 N90-24254 A time-marching method for calculating unsteady	[ÁIAA PAPER 90-2417] p 663 A90-42168 Helicopter store separation - Predictive techniques and
airloads on three-dimentional wings. Part 2: Full-potential formulation	flight testing p 647 A90-42495 Prediction of aerodynamic performance of airfoils in low Reynolds number flows
[DLR-FB-89-59] p 635 N90-24255  PANELS  The analysis and testing of composite panels subject	[DLC-EST-TN-031] p 632 N90-23360 Correlation/validation of finite element code analyses for vibration assessment of avionic equipment
to muzzle blast effects p 675 A90-39991  Damage tolerance of carbon fibre reinforced plastic sandwich panels p 675 A90-40047	[AD-A220393] p 654 N90-23398 Application of neural networks to the F/A-18 engine condition monitoring system
Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104	[AD-A219820] p 666 N90-24271 PERFORMANCE TESTS
Estimation of fatigue crack growth in patched cracked panels p 684 A90-41335 PARACHUTE FABRICS	High Mach exhaust system concept scale model test results [AIAA PAPER 90-1905] p 655 A90-40552
Wind tunnel tests of a 20-gore disk-gap-band parachute [AD-A221326] p 634 N90-24251	Reverse flow in multistage axial compressors p 623 A90-40942 Operational effects on crashworthy seat attenuators
PARACHUTES Preliminary characterization of parachute wake	[AD-A221148] p 637 N90-24259 Human response research update
recontact p 622 A90-40681  Wind tunnel tests of a 20-gore disk-gap-band parachute	p 699 N90-24873 PERIPHERAL VISION Flight testing and application of a Peripheral Vision
[AD-A221326] p 634 N90-24251  PARALLEL COMPUTERS  Multilevel optimization of large-scale structures in a	Display p 652 A90-40381 PERSONAL COMPUTERS Digital control of magnetic bearings supporting a
parallel computing environment p 693 A90-39180  PARALLEL FLOW  Mathematical modeling of plane parallel separated flows	multimass flexible rotor p 682 A90-40712 PHOSPHORUS Some 1-(diorganooxyphosphonyl)methyl-2,4- and
past bodies Russian book p 619 A90-39475 Measurements of turbulent dual-jet interaction	-2,6-dinitro-benzenes [NASA-CASE-ARC-11425-3] p 678 N90-23475
[AIAA PAPER 90-2105] p 624 A90-42019 The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.	PHOTOELASTIC ANALYSIS  Stress concentration factors - Comparison of theory with fatigue test data p 680 A90-39979
II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020 PARALLEL PROCESSING (COMPUTERS)	PHOTOELASTICITY  Nondestructive measurement of residual stresses in aircraft transparencies
Implementation of a transputer-based flight controller p 667 A90-38966 PARAMETER IDENTIFICATION	[AD-A218680] p 689 N90-23762 PILOT INDUCED OSCILLATION
Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166	Prediction of longitudinal pilot induced oscillations using the optimal control model
Differential-geometrical technique of signal transformation and estimation of position, rate and	[AD-A220593] p 671 N90-23412 PILOT PERFORMANCE Multifunction displays optimized for viewability
acceleration parameters using supplementary data sources p 638 A90-41004 Design methodology for multivariable helicopter control	p 652 A90-40398 ATTHeS - A helicopter in-flight simulator for ACT testing p 643 A90-41727
systems p 669 A90-42461 Estimating short-period dynamics using an extended Kalman filter	Fighter agility metrics, research, and test [NASA-CR-186118] p 648 N90-23386 Helicopter controllability
[NASA-TM-101722] p 648 N90-23392 PARTICLE SIZE DISTRIBUTION	[AD-A220078] p 672 N90-24275 PILOT SELECTION
Metallized fuel particle size study in a solid fuel ramjet [AD-A220079] p 679 N90-24451 PARTICLE TRAJECTORIES	Aeronautical decisionmaking for air ambulance program administrators  [DOT/FAA/DS-88/8] p 635 N90-23368
Viscous flow analysis for advanced inlet particle separators	PILOT TRAINING Aviation meteorology - Panel report
[AIAA PAPER 90-2136] p 661 A90-42038  PASSENGER AIRCRAFT  AVION: A detailed report on the preliminary design of	p 692 A90-39403 Aeronautical decisionmaking for air ambulance program administrators
a 79-passenger, high-efficiency, commercial transport aircraft	[DOT/FAA/DS-88/8] p 635 N90-23368 PILOTLESS AIRCRAFT
[NASA-CR-186663] p 649 N90-23395  PASSENGERS  The influence of adjacent seating configurations on	Initial flight test of half-scale unmanned air vehicle [AD-A219584] p 648 N90-23388 PITCH (INCLINATION)
egress through a type 3 emergency exit [AD-A218393] p 636 N90-23371 High speed civil transport	Digital controller design for the pitch axis of the F-14 using an H(infinity) method p 668 A90-40912  The influence of control-surface compensation
[NAŚA-CR-186661] p 649 N90-23396 PATTERN RECOGNITION	parameters on the hinge moment characteristics p 643 A90-41737
Neural networks for adaptive shape tracking p 638 A90-39959 PAVEMENTS	Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations p 646 A90-42464
Criteria for coal tar seal coats on airport pavements.  Volume 2: Laboratory and field studies  [AD-A220167] p 674 N90-24277	Agusta methodology for pitch link loads prediction in preliminary design phase p 646 A90-42465 Use of smart actuators for the tail rotor collective pitch
PAYLOADS Feasibility study for a microwave-powered ozone sniffer	control p 688 A90-42483 PLANE STRESS
aircraft [NASA-CR-186660] p 650 N90-23397 PEACETIME	Active control of tiltrotor blade in-plane loads during maneuvers p 670 A90-42463 PLASMA TORCHES
Peacetime replacement and crash damage factors for army aircraft	Some governing parameters of plasma torch igniter/flameholder in a scramjet combustor
[AD-A218544] p 636 N90-23372 PENDULUMS  Measurement of angles and angle characteristics with	[AIAA PAPER 90-2098] p 661 A90-42017 PLASTIC AIRCRAFT STRUCTURES
accelerometers and gyroscopes p 653 A90-41730 PERFORMANCE PREDICTION	thermoplastics p 676 A90-41111 PLATE THEORY
Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986	Supersonic flutter of shear deformable laminated composite flat panels p 683 A90-41104

POLICIES	Noise-source measurements by thin-film pressure	When propfans cruise, will LDN 65 fly
Social survey findings on en route noise annoyance issues p 698 N90-24868	transducers in a subsonic turbofan model [ONERA, TP NO. 1990-36] p 659 A90-41212	p 697 N90-24864 PROPELLER NOISE
POLYMERIZATION	An experimental investigation of turbine rotor wakes for	Recent propeller development and studies conducted
Some 1-(diorganooxyphosphonyl)methyl-2,4- and	the development of a fiber optic pressure sensor	at ONERA
-2,6-dinitro-benzenes (NASA-CASE-ARC-11425-3) p 678 N90-23475	[AIAA PAPER 90-2411] p 687 A90-42163	[ONERA, TP NO. 1990-16] p 683 A90-41201 En route noise of turboprop aircraft and their
POSITION (LOCATION)	Tests for integrating measurement of gas pressures in flight propellers	acceptability: Report of tests p 697 N90-24858
Differential-geometrical technique of signal	[ETN-90-96498] p 634 N90-24253	En route noise of two turboprop aircraft
transformation and estimation of position, rate and	PRESSURE VESSEL DESIGN	[DLR-MITT-89-18] p 697 N90-24859
acceleration parameters using supplementary data sources p 638 A90-41004	Aircraft applications of advanced composite fiber/metal pressure vessels	When propfans cruise, will LDN 65 fly p 697 N90-24864
Position computation without elevation information for	[AIAA PAPER 90-2344] p 686 A90-42133	PROPELLER SLIPSTREAMS
computed centerline operations [DOT/FAA/CT-TN89/42] p 640 N90-23379	PRESSURE VESSELS	Vortex theory for the screw propeller with a hub p 620 A90-39538
POSITION ERRORS	Hydraulic accumulators and high pressure bottles in composite material p 688 A90-42493	The flow over a wing/nacelle combination in the
Helicopter Airborne Laser Positioning System (HALPS)	PRESSURIZING	presence of a propeller slipstream p 629 A90-42415
[NASA-TM-102814] p 654 N90-23399 <b>POSITIONING</b>	Starter systems and auxiliary power units	PROPELLERS  Tests for integrating measurement of gas pressures in
Helicopter Airborne Laser Positioning System (HALPS)	PRINTED CIRCUITS	flight propellers
[NASA-TM-102814] p 654 N90-23399	Correlation/validation of finite element code analyses	[ETN-90-96498] p 634 N90-24253
POTENTIAL FLOW Simulation of inviscid blade-row interaction using a	for vibration assessment of avionic equipment	FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853
linearised potential code	[AD-A220393] p 654 N90-23398 PRIORITIES	En route noise of turboprop aircraft and their
[AIAA PAPER 90-1916] p 621 A90-40555	Social survey findings on en route noise annoyance	acceptability: Report of tests p 697 N90-24858
Comparison of high-angle-of-attack slender-body theory and exact solutions for potential flow over an ellipsoid	issues p 698 N90-24868	PROPULSION SYSTEM CONFIGURATIONS Precurser convertible engine study
p 622 A90-40692	PROBABILITY THEORY  The development of a probabilistic turbine rotor design	[AIAA PAPER 90-2486] p 658 A90-40636
Unsteady potential flow past a propeller blade section	system	CFD propels NASP propulsion progress
[NASA-CR-4307] p 634 N90-24246 <b>POWER EFFICIENCY</b>	[AIAA PAPER 90-2176] p 662 A90-42060	p 683 A90-41163 Turbofans turn to UHB propulsion p 659 A90-41165
Review of mixed flow and radial turbine options	PROCEDURES  En route noise: NASA propfan test aircraft (corrected	Integrated air vehicle/propulsion technology for a
[AIAA PAPER 90-2414] p 687 A90-42166	data - simplified procedure)	multirole fighter - A MCAIR perspective
POWER LOSS Inclement weather induced aircraft engine power loss	[DOT-TSC-FA953-LR4] p 696 N90-24856	[AIAA PAPER 90-2278] p 644 A90-42105
[AIAA PAPER 90-2169] p 662 A90-42055	PRODUCT DEVELOPMENT  Toward total quality in industry p 684 A90-41768	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport
PREDICTION ANALYSIS TECHNIQUES	The Airbus a challenge launched twenty years ago	aircraft
A computer code for the prediction of aerodynamic	p 699 A90-41769	[NASA-CR-186663] p 649 N90-23395
characteristics of lifting airfoils at transonic speed [DLC-EST-TN-030] p 632 N90-23359	PROLATE SPHEROIDS  Drag measurements on a modified prolate spheroid	Analysis of internal flow in a ventral nozzle for STOVL aircraft
Low-density flow effects for hypervelocity vehicles,	using a magnetic suspension and balance system	[NASA-TM-103123] p 666 N90-23404
phase 2	p 672 A90-40684	Advanced gearbox technology
[AD-A221034] p 634 N90-24249 Flexural fatigue life prediction of closed hat-section using	PROP-FAN TECHNOLOGY Investigation of the near wake of a propfan	[NASA-CR-179625] p 666 N90-24274 PROPULSION SYSTEM PERFORMANCE
materially nonlinear axial fatigue characteristics	p 622 A90-40686	The cryogenic wind tunnel as a testing tool for
p 691 N90-25062	Experimental performance and acoustic investigation of	airframe/propulsion systems p 672 A90-40400
PREDICTIONS The interestion of a supermonic atransmutes warter and	modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393	A preliminary evaluation of an F100 engine parameter estimation process using flight data
The interaction of a supersonic streamwise vortex and a normal shock wave p 633 N90-24241	Advanced gearbox technology	[AIAA PAPER 90-1921] p 656 A90-40559
PREDICTOR-CORRECTOR METHODS	[NASA-CR-179625] p 666 N90-24274	Preliminary design of a long-endurance Mars aircraft
Fracture control via DRM-Algorithm	En route noise: NASA propfan test aircraft (corrected data - simplified procedure)	[AIAA PAPER 90-2000] p 674 A90-40587 Precurser convertible engine study
p 694 A90-41343 PRESSURE DISTRIBUTION	[DOT-TSC-FA953-LR4] p 696 N90-24856	[AIAA PAPER 90-2486] p 658 A90-40636
Investigation of unsteady flow through a transonic turbine	En route noise: NASA propfan test aircraft (calculated	Investigation of very high bypass ratio engines for
stage. II - Data/prediction comparison for time-averaged	source noise [DOT-TSC-FA953-LR5] p 697 N90-24857	subsonic transports p 659 A90-40945
and phase-resolved pressure data [AIAA PAPER 90-2409] p 626 A90-42162	En route noise of turboprop aircraft and their	CFD propels NASP propulsion progress p 683 A90-41163
Unsteady potential flow past a propeller blade section	acceptability: Report of tests p 697 N90-24858	Turbofans turn to UHB propulsion p 659 A90-41165
[NASA-CR-4307] p 634 N90-24246	En route noise of two turboprop aircraft [DLR-MITT-89-18] p 697 N90-24859	Aircraft engine technology gets a second wind
New transonic test sections for the NAE 5 ft x 5 ft trisonic	Noise measurements of turboprop airplanes at different	p 659 A90-41166
wind tunnel [AD-A220933] p 674 N90-24278	overflight elevations p 697 N90-24860	Development of a heavy fuel engine for an unmanned air vehicle
PRESSURE DROP	When propfans cruise, will LDN 65 fly p 697 N90-24864	[AIAA PAPER 90-2170] p 662 A90-42056
Interaction between a high-level steady acoustic field	En route noise annoyance laboratory test: Preliminary	Propulsion system-flight control integration-flight
and a ducted turbulent flow	results p 698 N90-24870	evaluation and technology transition
[ONERA, TP NO. 1990-27] p 695 A90-41206 PRESSURE MEASUREMENT	PROPELLANT GRAINS  Metallized fuel particle size study in a solid fuel ramjet	[AIAA PAPER 90-2280] p 644 A90-42106 JFS190 turbine engine performance optimized using
Noise-source measurements by thin-film pressure	[AD-A220079] p 679 N90-24451	Taguchi methods
transducers in a subsonic turbofan model	PROPELLER BLADES	[AIAA PAPER 90-2419] p 663 A90-42169
[ONERA, TP NO. 1990-36] p 659 A90-41212 Estimation of rotor blade incidence and blade	Viscous flow around a propeller-shaft configuration with infinite-pitch rectangular blades p 683 A90-40938	On- and off-design performance analysis of hypersonic detonation wave ramiets
deformation from the measurement of pressures and	Nonlinear unsteady airfoil response studies	[AIAA PAPER 90-2473] p 664 A90-42188
strains in flight p 647 A90-42497	p 628 A90-42406	A hydrodynamic turbo-fan/shaft convertible engine
PRESSURE OSCILLATIONS	Preliminary design and analysis of propellers p 645 A90-42407	p 665 A90-42487
Computational modeling of inlet hammershock wave generation	Unsteady potential flow past a propeller blade section	PROPULSIVE EFFICIENCY  AVION: A detailed report on the preliminary design of
[AIAA PAPER 90-2005] p 621 A90-40592	[NASA-CR-4307] p 634 N90-24246	a 79-passenger, high-efficiency, commercial transport
Multistep dump combustor design to reduce combustion	PROPELLER EFFICIENCY  Experimental performance and acoustic investigation of	aircraft
instabilities p 659 A90-40934	modern, counterrotating blade concepts	[NASA-CR-186663] p 649 N90-23395 PROTECTION
An experimental investigation of turbine rotor wakes for the development of a fiber optic pressure sensor	[NASA-CR-185158] p 649 N90-23393	Forward canopy feasibility and Thru-The-Canopy (TTC)
[AIAA PAPER 90-2411] p 687 A90-42163	PROPELLER FANS Recent propeller development and studies conducted	ejection system study
PRESSURE RATIO	at ONERA	[AD-A220360] p 637 N90-24258
Navier-Stokes analysis of an ejector and mixer-ejector operating at pressure ratios in the range 2-4	[ONERA, TP NO. 1990-16] p 683 A90-41201	PROTECTIVE COATINGS  Criteria for coal tar seal coats on airport pavements.
[AIAA PAPER 90-2730] p 626 A90-42218	En route noise: NASA propfan test aircraft (corrected data - simplified procedure)	Volume 2: Laboratory and field studies
PRESSURE REDUCTION	[DOT-TSC-FA953-LR4] p 696 N90-24856	[AD-A220167] p 674 N90-24277
Correlation of radial-to-axial vaneless turns for centrifugal compressors	En route noise: NASA propfan test aircraft (calculated	PROTOTYPES  Jet Engine Technical Advisor (JETA)
[AIAA PAPER 90-1917] p 656 A90-40556	source noise [DOT-TSC-FA953-LR5] p 697 N90-24857	p 693 A90-41184
PRESSURE SENSORS	En route noise of two turboprop aircraft	An evaluation of the accuracy of a microwave landing
Experimental investigation of terminal shock sensors in mixed-compression inlets	[DLR-MITT-89-18] p 697 N90-24859 Noise measurements of turboprop airplanes at different	system area navigation system at Miami/Tamiami Florida Airport
[AIAA PAPER 90-1931] p 681 A90-40560	overflight elevations p 697 N90-24860	[DOT/FAA/CT-TN89/40] p 640 N90-23377

PULSE DOPPLER RADAR

Use of pulse radars for helicopters detection - Design p 683 A90-41073 constraints

Q

QUALITY CONTROL

p 684 A90-41768 Toward total quality in industry HPLC analysis of helicopter rotor blade materials p 650 N90-24270 (AD-A2211211

R

RACKS (GEARS)

Planet gear sleeve spinning analysis

(AIAA PAPER 90-2154) p 681 A90-40613

RADAR ABSORBERS

Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the p 638 A90-39855 spatial network method

RADAR BEACONS

Performances and new surveillance possibilities in SSR Mode S p 639 A90-41036

RADAR DETECTION

Use of pulse radars for helicopters detection - Design constraints p 683 A90-41073

RADAR EQUIPMENT

The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034

RADAR IMAGERY

Synthetic aperture radar imagery of airports and surrounding areas: Denver Stapleton International

INASA-CR-43051

p 637 N90-24257

RADAR SCANNING

The GE solid state air defence/ATC radar

p 639 A90-41062

RADAR SCATTERING

Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the p 638 A90-39855 spatial network method

**RADIAL FLOW** 

Flow induced forced response of an incompressible radial cascade including profile and incidence effects p 626 A90-42136 [AIAA PAPER 90-2352]

Review of mixed flow and radial turbine options p 687 A90-42166 [AIAA PAPER 90-2414]

RADIATION MEASURING INSTRUMENTS

UV spectroradiometric output of an F404 turbojet aircraft

p 652 A90-40195 engine

**RADIO COMMUNICATION** 

Automatic speech recognition in air-ground data link p 690 N90-25037

RADIO FREQUENCY HEATING

Radio frequency (RF) heated supersonic flow laboratory

[AIAA PAPER 90-2469]

**RADIOISOTOPE BATTERIES** Preliminary design of a long-endurance Mars aircraft

p 673 A90-42186

[AIAA PAPER 90-2000] p 674 A90-40587 RAIN

An analytic study of nonsteady two-phase laminar p 691 N90-25051 boundary layer around an airfoil RAMJET ENGINES

Linear dynamics of supersonic ramjet

p 655 A90-40519 Ultrasonic regression rate measurement in solid fuel

[AIAA PAPER 90-1963] p 656 A90-40573 Experimental and computational flammability limits in a

solid fuel ramjet p 676 A90-40574 [AIAA PAPER 90-1964]

Engineering design models for ramjet efficiency and lean hlowaff

[AIAA PAPER 90-2453] p 663 A90-42176 On- and off-design performance analysis of hypersonic

detonation wave ramjets (AIAA PAPER 90-2473) p 664 A90-42188 Hypersonic (T-D) 'pinch' and aerospaceplane

[AIAA PAPER 90-2474] p 675 A90-42189 Metallized fuel particle size study in a solid fuel ramjet p 679 N90-24451

RASTER SCANNING

p 653 A90-42447 The all glass helicopter cockpit RAY TRACING

PTA en route noise measurements

p 696 N90-24855

**RAYLEIGH-RITZ METHOD** 

Flutter of shaft-supported low aspect-ratio control p 667 A90-38912 REACTION KINETICS

On the use of external burning to reduce aerospace vehicle transonic drag

[AIAA PAPER 90-1935] p 656 A90-40562 REAL GASES

High enthalpy hypersonic wind tunnel F4: General description and associated instrumentation

p 673 N90-24228

**REAL TIME OPERATION** Implementation of a transputer-based flight controller p 667 A90-38966

Partial similarity and a real-time model of twin-spool gas p 654 A90-40512

ATTHeS - A helicopter in-flight simulator for ACT testing p 643 A90-41727 Development and verification of software for flight safety p 694 A90-42454 critical strapdown systems A comparison of lightning network data with surface

veather observations [AD-A220003] p 692 N90-23832 AIRNET: A real-time comunications network for

aircraft [NASA-CR-186140]

p 690 N90-24514

RECEIVERS

Miniaturization of flight deflection measurement svstem p 689 N90-23707

[NASA-CASE-LAR-13628-1] RECIRCULATIVE FLUID FLOW

Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions [AD-A219621] p 689 N90-23687

RECTANGULAR PLATES

Experiments on the active control of the transmission of sound through a clamped rectangular plate p 695 A90-41109

RECTANGULAR WINGS Lift response of a rectangular wing undergoing a step change in forward speed р 620 🛚 А90-39801 REGULATIONS

Problems related to aircraft noise in Switzerland

p 698 N90-24871

RELAXATION METHOD (MATHEMATICS) Inviscid and viscous flows in transonic and supersonic

cascades using an implicit upwind relaxation algorithm
[AIAA PAPER 90-2128] p 625 A90-42034 RÈLIABILITY

IAPSA 2 small-scale system specification [NASA-CR-182006] p 695

p 695 N90-24103

RELIABILITY ANALYSIS

Considerations of reliability design for rotorcraft p 680 A90-39977

Designing rotorcraft dynamic components to reliability p 641 A90-39978 Application of fracture mechanics to microscale phenomena in electronic assemblies p 684 A90-41334

Correlation/validation of finite element code analyses for vibration assessment of avionic equipment

AD-A2203931 p 654 N90-23398

RELIABILITY ENGINEERING

Fatigue methodology III; Proceedings of the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989 p 641 A90-39976

Full authority digital electronic engine control system provides needed reliability

[AIAA PAPER 90-2037] p 658 A90-40606 Toward total quality in industry p 684 A90-41768 Co-development of CT7-6 engines - A continued tradition in technology and reliability p 665 A90-42485 RELIEF MAPS

Digital map reader for helicopters p 653 A90-42448 REMOTELY PILOTED VEHICLES

Preliminary design of a long-endurance Mars aircraft [AIAA PAPER 90-2000] p 674 A90-40587

Development of a heavy fuel engine for an unmanned [AIAA PAPER 90-2170] p 662 A90-42056

Initial flight test of half-scale unmanned air vehicle (AD-A2195841 p 648 N90-23388

Static wind-tunnel and radio-controlled flight test investigation of a remotely piloted vehicle having a delta wing planform

INASA-TM-42001 p 632 N90-24238 REQUIREMENTS

A study of the technology required for advanced vertical take-off aircraft p 650 N90-24268 [ETN-90-96786]

RESEARCH AIRCRAFT

Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA) p 671 N90-23413 [NASA-TM-102250]

RESEARCH AND DEVELOPMENT

Technological preparations of civil aircraft programs

p 617 A90-41110

Euromart - The European aviation research and p 617 A90-41112 technology program The development of a probabilistic turbine rotor design

system [AIAA PAPER 90-2176] p 662 A90-42060

Langley aerospace test highlights, 1989 [NASA-TM-102631] p 69 p 699 N90-24221

RESEARCH FACILITIES Langley aerospace test highlights, 1989 [NASA-TM-102631] p 69

p 699 N90-24221 RESIDUAL STRENGTH

Impact damage and residual strength analysis of composite panels with bonded stiffeners --- for primary aircraft structures p 642 A90-40130

RESIDUAL STRESS Nondestructive measurement of residual stresses in

aircraft transparencies [ AD-421868Ò1 p 689 N90-23762

**RESIN MATRIX COMPOSITES** 

Structural fiber-reinforced components of thermoplastics p 676 A90-41111 Composites applications - The future is now

p 678 A90-42372

RESONANT FREQUENCIES

Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460

RESONANT VIBRATION

Experimental study of the effects of nonlinearities on ground resonance p 643 A90-40172

REUSABLE ROCKET ENGINES

The SEPR 844 reusable liquid rocket engine for Mirage combat aircraft [AIAA PAPER 90-1835] p 655 A90-40526

REVERSED FLOW

Reverse flow in multistage axial compressors p 623 A90-40942

REYNOLDS NUMBER The gun tunnel of the Brunswick Institute for Fluid Mechanics: Current development status

p 673 N90-24227

RIBLETS

Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693

RIGID ROTOR HELICOPTERS

Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 RIGID STRUCTURES

UH-60A helicopter stability augmentation study p 670 A90-42471

RIVETS

Modeling growth of fatigue cracks which originate at **ROBUSTNESS (MATHEMATICS)** 

Guaranteed cost control via optimal parametric LQ p 693 A90-40810 Flight control application of eigenstructure assignment with optimization of robustness to structured state space p 693 A90-40885

ROCKET ENGINE DESIGN Turbofans turn to UHB propulsion p 659 A90-41165 ROCKET ENGINES

Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump

[NASA-TP-3005] p 665 N90-23403

**ROCKET NOZZLES** 

CFD applications in an aerospace engine test facility (AIAA PAPER 90-2003) p 681 A90-40590 p 681 A90-40590 **ROCKET TEST FACILITIES** CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590

**ROLLER BEARINGS** 

Retirement lives of rolling element bearings p 680 A90-39980

**ROLLING MOMENTS** A new simplification method for analysing the rapid rolling stability of aircraft p 669 A90-42367

**ROTARY WING AIRCRAFT** 

Experimental study of the effects of nonlinearities on ound resonance p 643 A90-40172 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas

p 630 A90-42439 The modular HUM system --- Health and Usage Monitoring instruments for rotary wing aircraft failure p 618 A90-42476

A hydrodynamic turbo-fan/shaft convertible engine p 665 A90-42487 Extension of a three-dimensional viscous wing flow

analysis [NASA-CR-182023] p 631 N90-23348 ROTARY WINGS

Certification plan for an all-composite main rotor flexbeam p 642 A90-39992

Parameter identification of aeroelastic modes of rotary		
	Improving tilt rotor aircraft performance with	En route noise of two turboprop aircraft
wings from transient time histories p 642 A90-40166	variable-diameter rotors p 646 A90-42445	[DLR-MITT-89-18] p 697 N90-24859
Viscous flow around a propeller-shaft configuration with	Kane's methods in rotorblade dynamics	Sound propagation elements in evaluation of en route
infinite-pitch rectangular blades p 683 A90-40938	p 646 A90-42458	noise of advanced turbofan aircraft p 697 N90-24861
Use of pulse radars for helicopters detection - Design	Active control of tiltrotor blade in-plane loads during	When propfans cruise, will LDN 65 fly
constraints p 683 A90-41073	maneuvers p 670 A90-42463	p 697 N90-24864
Recent propeller development and studies conducted	Aeroelastic response characteristics of a rotor executing	Social survey findings on en route noise annoyance
at ONERA	arbitrary harmonic blade pitch variations	issues p 698 N90-24868
[ONERA, TP NO. 1990-16] p 683 A90-41201		En route noise annoyance laboratory test: Preliminary
Wind-tunnel measurement of noise emitted by helicopter	p 646 A90-42464	results p 698 N90-24870
rotors at high speed	Agusta methodology for pitch link loads prediction in	Problems related to aircraft noise in Switzerland
[ONERA, TP NO. 1990-28] p 695 A90-41207	preliminary design phase p 646 A90-42465	p 698 N90-24871
Application of mathematical modeling to the study of	Design and manufacturing of composite materials blade	RUDDERS
rigid helicopter rotors p 643 A90-41738	models p 618 A90-42492	Influence of some geometrical and design parameters
	Extension-torsion coupling behavior of advanced	
Unsteady deformations of elastic rotor blades	composite tilt-rotor blades p 651 N90-25057	on the hinge moment characteristics of rudders
p 687 A90-42341		p 643 A90-41739
A study of the influence of a helicopter rotor blade on	ROTOR BLADES (TURBOMACHINERY)	RUNGE-KUTTA METHOD
the following blades using Euler equations	Analysis of composite rotor blades via Saint Venant's	A computer code for the prediction of aerodynamic
p 630 A90-42435	solutions p 688 A90-42491	characteristics of lifting airfoils at transonic speed
A review of tilt rotor download research	ROTOR BODY INTERACTIONS	[DLC-EST-TN-030] p 632 N90-23359
p 630 A90-42437	Comparison with experiment of various computational	RUNWAY CONDITIONS
Improving helicopter aerodynamics - A step ahead	methods of airflow on three helicopter fuselages	Analyses of Arrow Air DC-8-63 accident of December
p 631 A90-42443	p 630 A90-42436	12, 1985 - Gander, Newfoundland p 635 A90-40687
Kane's methods in rotorblade dynamics	A comprehensive approach to coupled rotor-fuselage	RUNWAYS
p 646 A90-42458	dynamics p 646 A90-42460	Criteria for coal tar seal coats on airport pavements.
Eight years of flight operations with composite		Volume 2: Laboratory and field studies
rotorblades p 635 A90-42481	A model for active control of helicopter air resonance	[AD-A220167] p 674 N90-24277
	in hover and forward flight p 670 A90-42462	[AD-A220107] p 074 1490-24277
EH-101 main rotor hub application of thick carbon fiber	ROTOR DYNAMICS	_
unidirectional tension bands p 618 A90-42489	The development of a probabilistic turbine rotor design	S
Design and manufacturing of composite materials blade	system .	•
models p 618 A90-42492	(AIAA PAPER 90-2176) p 662 A90-42060	S-N DIAGRAMS
EH101 vibration control p 647 A90-42496	Kane's methods in rotorblade dynamics	_
Aerodynamic characteristics of two rotorcraft airfoils	p 646 A90-42458	Designing rotorcraft dynamic components to reliability
designed for application to the inboard region of a main	Experimental performance and acoustic investigation of	requirements p 641 A90-39978
rotor blade	modern, counterrotating blade concepts	SAFETY MANAGEMENT
[NASA-TP-3009] p 633 N90-24239	[NASA-CR-185158] p 649 N90-23393	The safety analysis approach for the EH101
HPLC analysis of helicopter rotor blade materials	ROTOR SPEED	p 635 A90-42456
[AD-A221121] p 650 N90-24270	An experimental investigation of turbine rotor wakes for	Aviation security: Corrective actions underway, but better
ROTATING BODIES	the development of a fiber optic pressure sensor	inspection guidance still needed. Report to the
Rotating system load monitoring using minimum fixed		Chairwoman, Government Activities and Transportation
system instrumentation p 651 A90-39982	[AIAA PAPER 90-2411] p 687 A90-42163	Subcommittee, Committee on Government Operations.
	Improving helicopter aerodynamics - A step ahead	House of Representatives
The interaction of a supersonic streamwise vortex and	p 631 A90-42443	[GAO/RCED-88-160] p 635 N90-23367
a normal shock wave p 633 N90-24241	Experimental evaluation of a tuned electromagnetic	SANDWICH STRUCTURES
ROTATING DISKS	damper for vibration control of cryogenic turbopump	
Generation of circumferential velocity contours	rotors	Damage tolerance of carbon fibre reinforced plastic
associated with pulsed point suction on a rotating disk	[NASA-TP-3005] p 665 N90-23403	sandwich panels p 675 A90-40047
p 691 N90-25065	ROTORCRAFT AIRCRAFT	SCALE MODELS
ROTATING SHAFTS	Fatigue methodology III; Proceedings of the AHS	High Mach exhaust system concept scale model test
Helicopter surveillance - A look at current and proposed	National Technical Specialists' Meeting on Advanced	results
future programs p 642 A90-39986	Rotorcraft Structures, Scottsdale, AZ, Oct. 3-5, 1989	[AIAA PAPER 90-1905] p 655 A90-40552
ROTATING STALLS	p 641 A90-39976	A simple dynamic engine model for use in a real-time
An experimental investigation of rotating stall in a		aircraft simulation with thrust vectoring
centrifugal compressor with vaneless diffuser	Considerations of reliability design for rotorcraft	[AIAA PAPER 90-2166] p 662 A90-42054
	p 680 A90-39977	SCATTEROMETERS
		Dual cross-polarization planar arrays in the C and X
p 621 A90-40513	Designing rotorcraft dynamic components to reliability	
Reverse flow in multistage axial compressors	requirements p 641 A90-39978	
Reverse flow in multistage axial compressors p 623 A90-40942	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft	bands p 638 A90-40979
Reverse flow in multistage axial compressors p 623 A90-40942 ROTOR AERODYNAMICS	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643	bands p 638 A90-40979 SCHEDULING
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAN PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685  Counter-rotating propellant analysis using a frequency	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685  Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAN PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 SEALS (STOPPERS)
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685  Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 SEALS (STOPPERS) Gas turbine engine brush seal applications
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 SEALS (STOPPERS) Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041
Reverse flow in multistage axial compressors p 623 A90-40942 ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488	bands p 638 A90-40979 SCHEDULING Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373 SEALS (STOPPERS) Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041 SEATS
Reverse flow in multistage axial compressors p 623 A90-40942 ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas  p 630 A90-42439 Computation of viscous aerodynamic characteristics of	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR
Reverse flow in multistage axial compressors p 623 A90-40942 ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-Th4-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-Th4-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas  Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TH-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42445 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056  Experiments on Mode S secondary surveillance radar
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas  Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics P 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics P 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1- The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas  P 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  P 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust  Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts  [NASA-CR-185158] p 649 N90-2393	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 ROTTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740 Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1- The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFF aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-Th4-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation [AIAA PAPER 90-2125] p 624 A90-42032
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185156] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-2437	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft arrolled for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 ROTORS Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-2377 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1- The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-Th4-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation [AIAA PAPER 90-2125] p 624 A90-42032
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42447 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [INASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the latigue substantiation of the H-60	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFF aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A20312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 698 N90-24854	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1- The participation of the French Direction de la Navigation Aerienne  P 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  P 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 665 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24854	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42447 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42459 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [INASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the latigue substantiation of the H-60	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24855	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-Th4-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  P 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A20312] p 641 N90-24263 FAA/NASA En Route Noise Symposium (NASA-CP-3067) p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24855 En route noise: NASA propfan test aircraft (corrected	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil  p 627 A90-42394  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185156] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the latigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986 Helicopter surveillance - A look at current and proposed future programs p 644 A90-39986	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23437 IFR aircraft handled torecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 699 N90-24854 PTA en route noise measurements p 696 N90-24855 En route noise: NASA propfan test aircraft (corrected data - simplified procedure)	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1- The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [INSA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 Application of mathematical modeling to the study of	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24855 En route noise measurements  p 696 N90-24855 En route noise: NASA propfan test aircraft (corrected data - simplified procedure) [DOT-TSC-FA953-LR4] p 696 N90-24856	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690  Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle separators
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications  P 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42472 Experimental performance and acoustic investigation of modern, counterrotating blade concepts  [NASA-CR-185158] p 649 N90-2393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets  [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 643 A90-41738	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled torecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A20312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24854 PTA en route noise measurements p 696 N90-24855 En route noise: NASA propfan test aircraft (calculated	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 Unsteady deformations of elastic rotor blades	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24854 PTA en route noise measurements p 696 N90-24855 En route noise: NASA propfan test aircraft (calculated source noise: NASA propfan test aircraft (calculated source noise)	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1 The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-165158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986 Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-42431 Unsteady deformations of elastic rotor blades p 687 A90-42431	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239 ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFFI aircraft handled torecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium (NASA-CP-3067) p 696 N90-24853 Proposed definition of the term en route in en route aircraft noise p 696 N90-24855 En route noise measurements  p 696 N90-24855 En route noise: NASA propfan test aircraft (calculated source noise [DOT-TSC-FA953-LR5] p 697 N90-24857	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  p 639 A90-41056  Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle separators [AIAA PAPER 90-2136] p 661 A90-42038
Reverse flow in multistage axial compressors p 623 A90-40942  ROTOR AERODYNAMICS  Acoustics of ultralight airplanes p 643 A90-40685 Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937 Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas p 630 A90-42439 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Improving helicopter aerodynamics - A step ahead p 631 A90-42443 Helicopter ground and air resonance dynamics p 646 A90-42457 Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter gust p 671 A90-42472 Aeroelastic effects on stability and control of hingeless rotor helicopters p 647 A90-42473 Experimental performance and acoustic investigation of modern, counterrotating blade concepts [NASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade sets [NASA-TM-4201] p 632 N90-24237 ROTOR BLADES Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 Unsteady deformations of elastic rotor blades	requirements p 641 A90-39978 Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 Concept development of automatic guidance for rotorcraft obstacle avoidance p 669 A90-41632 The safety analysis approach for the EH101 p 635 A90-42456 Contribution of engine improvement on next future rotorcraft p 665 A90-42488 Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade [NASA-TP-3009] p 633 N90-24239  ROTORS Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403 Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243  ROUTES Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 IFR aircraft handled forecast by air route traffic control center: Fiscal years 1990 to 2005 [AD-A220312] p 641 N90-24263 FAA/NASA En Route Noise Symposium [NASA-CP-3067] p 696 N90-24854 PTA en route noise measurements p 696 N90-24855 En route noise: NASA propfan test aircraft (calculated source noise: NASA propfan test aircraft (calculated source noise)	bands p 638 A90-40979  SCHEDULING  Analysis of sequencing and scheduling methods for arrival traffic  [NASA-TM-102795] p 636 N90-23373  SEALS (STOPPERS)  Gas turbine engine brush seal applications  [AIAA PAPER 90-2142] p 685 A90-42041  SEATS  Operational effects on crashworthy seat attenuators  [AD-A221148] p 637 N90-24259  SECONDARY RADAR  Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne  Experiments on Mode S secondary surveillance radar 1 The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057  SEPARATED FLOW  Drag reduction by controlling flow separation using stepped afterbodies p 622 A90-40690 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740  Viscous-inviscid interaction method for calculating the flow in compressor cascade blade passages and wake with separation  [AIAA PAPER 90-2125] p 624 A90-42032  Flow separation on a supercritical airfoil p 627 A90-42394  A study of supermanuever aerodynamics  [AD-A218378] p 631 N90-23349  SEPARATORS  Viscous flow analysis for advanced inlet particle separators  [AIAA PAPER 90-2136] p 661 A90-42038

SUBJECT INDEX		STATE ESTIMATION
SERVICE LIFE	SILICONES	SPACECRAFT PROPULSION
Retirement lives of rolling element bearings p 680 A90-39980	Equilibrium swelling of elastomeric materials in solvent environments	Hydrogen in future energy and propulsion technology p 692 A90-41736
Development and verification of software for flight safety	[DE90-010164] p 678 N90-24430 SIMPLIFICATION	SPACECRAFT STRUCTURES
critical strapdown systems p 694 A90-42454 SERVOCONTROL	On simplified analytical flutter clearance procedures for	Development and application of an optimization procedure for space and aircraft structures
Direct drive servovalves: Why and how - The Magnaghi	light aircraft	p 679 A90-39186
Milano answer p 688 A90-42484 SHAFTS (MACHINE ELEMENTS)	SINGLE STAGE TO ORBIT VEHICLES	SPACING Simulator evaluation of the final approach spacing tool
Flutter of shaft-supported low aspect-ratio control	The challenge of demonstrating the X-30 p 659 A90-41162	[NASA-TM-102807] p 636 N90-23374
surfaces p 667 A90-38912 Viscous flow around a propeller-shaft configuration with	Hypersonic (T-D) 'pinch' and aerospaceplane	SPALLING Initiation of spalling in aircraft gas turbine bearings
infinite-pitch rectangular blades p 683 A90-40938	propulsion , [AIAA PAPER 90-2474] p 675 A90-42189	[AIAA PAPER 90-2291] p 686 A90-42110
Experimental evaluation of a tuned electromagnetic	SKIN FRICTION	SPATIAL MARCHING Application of a new adaptive grid for aerodynamic
damper for vibration control of cryogenic turbopump rotors	Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693	analysis of shock containing single jets
[NASA-TP-3005] p 665 N90-23403	Direct measurements of skin friction in a scramjet	[AIAA PAPER 90-2025] p 624 A90-41988
SHEAR FLOW  The computation of turbulent thin shear flows associated	combustor [AIAA PAPER 90-2342] p 626 A90-42132	SPECIFICATIONS IAPSA 2 small-scale system specification
with flow around multielement aerofoils	SLENDER BODIES	[NASA-CR-182006] p 695 N90-24103
p 633 N90-24240 SHEAR LAYERS	Analysis of aeroelastic divergence for the slender flight vehicles p 680 A90-39298	SPECTRORADIOMETERS  UV spectroradiometric output of an F404 turbojet aircraft
Investigation of supersonic mixing layers	Calculation of stability derivatives for slender bodies	engine p 652 A90-40195
p 623 A90-40926	using boundary element method p 620 A90-40181 Comparison of high-angle-of-attack slender-body theory	SPEECH RECOGNITION  Evaluation of speech recognizers for use in advanced
Numerical simulation of the growth of instabilities in supersonic free shear layers p 623 A90-40941	and exact solutions for potential flow over an ellipsoid	combat helicopter crew station research and
SHEAR STRESS	p 622 A90-40692 SLENDER CONES	development [NASA-CR-177547] p 650 N90-24265
Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985	. Comments on 'Effect of nose bluntness and cone angle	Automatic speech recognition in air-ground data link
SHIELDING	on slender-vehicle transition' p 620 A90-39814  The application of concentric vortex simulation to	p 690 N90-25037
Forward canopy feasibility and Thru-The-Canopy (TTC) ejection system study	calculating the aerodynamic characteristics of bodies of	SPEED CONTROL  Analytical evaluation of helicopter true air speed and
[AD-A220360] p 637 N90-24258	revolution at high angles of attack p 627 A90-42357	associated flight tests p 647 A90-42499
SHOCK LOADS Wind tunnel tests of a 20-gore disk-gap-band	SLENDER WINGS Various sources of wing rock p 622 A90-40679	SPHERES
parachute	Coupled aerodynamic forces due to unsteady stall on	Coherent vortex structures in the wake of a sphere and a circular disk at rest and under forced vibrations
[AD-A221326] p 634 N90-24251 SHOCK TUBES	a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41203	p 623 A90-40749
Short time Force and moment measurement System	SLOT ANTENNAS	SPIN DYNAMICS  Miniaturization of flight deflection measurement
for shock tubes (SFS) for measuring times less than 10 ms p 674 N90-24233	Applications of slotted cable antennas in the instrument landing system p 639 A90-41708	system
SHOCK WAVE GENERATORS	SOFTWARE ENGINEERING	[NASA-CASE-LAR-13628-1] p 689 N90-23707 SPRAY CHARACTERISTICS
Computational modeling of inlet hammershock wave generation	Automated aircraft engine costing using artificial intelligence	Further validation of a semi-analytical approach for fuel
[AIAA PAPER 90-2005] p 621 A90-40592	[AIAA PAPER 90-1887] p 660 A90-41981	injectors of different concepts [AIAA PAPER 90-2190] p 686 A90-42067
SHOCK WAVE INTERACTION  Computation of multiple normal shock wave/turbulent	SOFTWARE TOOLS  Digital map reader for helicopters p 653 A90-42448	Influences on the uniformity of sprays produced by gas
boundary layer interactions	SOLAR ARRAYS	turbine high shear nozzle/swirler assemblies
[AIAA PAPER 90-2133] p 685 A90-42037 Flow separation on a supercritical airfoil	Preliminary design of a long-endurance Mars aircraft [AIAA PAPER 90-2000] p 674 A90-40587	[AIAA PAPER 90-2193] p 686 A90-42068 SPRAYERS
p 627 A90-42394	SOLID LUBRICANTS	Symmetry assessment of an air-blast atomizer spray
SHOCK WAVES  Application of a new adaptive grid for aerodynamic	Evaluation of solid lubricant powder delivery system for turbine bearing lubrication	p 682 A90-40930 SPREAD SPECTRUM TRANSMISSION
analysis of shock containing single jets	[AIAA PAPER 90-2046] p 684 A90-41997	Throughput and delay characteristics for a
[AIAA PAPER 90-2025] p 624 A90-41988 An improvement on upwinding technique used in the	High temperature powder lubricated dampers for gas turbine engines	slow-frequency hopped aircraft-to-aircraft packet radio network
Galerkin finite element method for the computation of	[AIAA PAPER 90-2048] p 684 A90-41999	[AD-A220525] p 688 N90-23609
inviscid transonic flow with shock waves p 627 A90-42361	SOLID PROPELLANT COMBUSTION  Experimental and computational flammability limits in a	STABILITY AUGMENTATION  System concept and performance criteria of modern
SHORT HAUL AIRCRAFT	solid fuel ramjet	helicopter navigation p 640 A90-42452
Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA)	[AIAA PAPER 90-1964] p 676 A90-40574 SOLID PROPELLANT ROCKET ENGINES	UH-60A helicopter stability augmentation study p 670 A90-42471
[NASA-TM-102250] p 671 N90-23413	5DOF dynamic loads on a jet vane	Lateral-directional stability and control characteristics of
SHORT TAKEOFF AIRCRAFT  Multiple model adaptive controller for the STOL F-15	[AIAA PAPER 90-2382] p 675 A90-42147 SOLID PROPELLANTS	the Quiet Short-Haul Research Aircraft (QSRA) [NASA-TM-102250] p 671 N90-23413
with sensor/actuator failures p 668 A90-40878	Inverse heat transfer studies and the effects of propellant	STABILITY DERIVATIVES
Direct lift STOVL engine integration [AIAA PAPER 90-2274] p 644 A90-42103	aluminum on TVC jet vane heating and erosion [AIAA PAPER 90-1860] p 655 A90-40533	Calculation of stability derivatives for slender bodies using boundary element method p 620 A90-40181
SHROUDED NOZZLES	SOLID ROCKET PROPELLANTS	STABILIZATION
Supersonic rectangular isothermal shrouded jets [AIAA PAPER 90-2028] p 621 A90-40599	Metallized fuel particle size study in a solid fuel ramjet [AD-A220079] p 679 N90-24451	Calculation of the aeroelastic blade stabilization with linearized process
SHROUDED PROPELLERS	SOLVENTS	[MITT-87-01] p 666 N90-24272
Design and analysis of a large-plug inlet ADP nacelle and pylon Advanced Ducted Prop	Equilibrium swelling of elastomeric materials in solvent environments	STALLING  Development of the stall warning/stick pusher system
[AIAA PAPER 90-2015] p 673 A90-41986	[DE90-010164] p 678 N90-24430	for the Boeing/de Havilland Dash 8 Series 300
SHROUDS  Redesign of an electro-optical shroud in	SONIC BOOMS Summary of sonic boom rise times observed during FAA	p 645 A90-42420 STANDARDS
graphite/epoxy p 676 A90-40215	community response studies over a 6-month period in the	The effect of noise-abatement profiles on noise
SIGNAL PROCESSING Differential-geometrical technique of signal	Oklahoma City area [NASA-CR-4277] p 696 N90-24852	immissions and human annoyance underneath a subsequent climbpath p 698 N90-24865
transformation and estimation of position, rate and	SOUND PROPAGATION	STANDING WAVES
acceleration parameters using supplementary data sources p 638 A90-41004	Fuselage boundary-layer effects on sound propagation and scattering p 695 A90-39781	Interaction between a high-level steady acoustic field and a ducted turbulent flow
The TVD 900 - A modern signal processing applied to	Sound propagation elements in evaluation of en route	[ONERA, TP NO. 1990-27] p 695 A90-41206
primary civilian ATC radar p 638 A90-41034 MLS mathematical model validation study using airborne	noise of advanced turbofan aircraft p 697 N90-24861 SOUND TRANSMISSION	STAR TRACKERS  A daylight stellar sensor using a charge-coupled
MLS data from Midway Airport engineering flight tests,	Experiments on the active control of the transmission	device p 637 A90-39002
August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378	of sound through a clamped rectangular plate p 695 A90-41109	STATE ESTIMATION A proposed Kalman filter algorithm for estimation of
SILICON CARBIDES	SPACE FLIGHT	unmeasured output variables for an F100 turbofan
Metal matrix composite fan blade development [AIAA PAPER 90-2178] p 677 A90-42062	Langley aerospace test highlights, 1989 [NASA-TM-102631] p 699 N90-24221	engine [AIAA PAPER 90-1920] p 656 A90-40558
SILICON POLYMERS	SPACECRAFT DESIGN	Estimating short-period dynamics using an extended

Aerodynamic work for Hermes spaceplane
p 675 A90-41115

Polysilicon active-matrix liquid crystal displays for cockpit applications p 681 A90-40393

applications

[AIAA PAPER 90-1920] p 656 A90:40558 Estimating short-period dynamics using an extended Kalman filter [NASA-TM-101722] p 648 N90-22222

STATE VECTORS			
STATE VECTORS			
A proposed Kalman filter algorith	m for e	stimatio	n of
unmeasured output variables for	an F10	0 turbo	ofan
engine			
[AIAA PAPER 90-1920]	p 656	A90-40	558
STATIC CHARACTERISTICS			
Static aeroetastic tailoring for oblique			
	p 667	A90-40	689
STATIC LOADS			
Agusta methodology for pitch link			
	p 646	A90-42	465
STATIC PRESSURE	_		
Correlation of radial-to-axial va	aneless	turns	tor
centrifugal compressors			
(AIAA PAPER 90-1917)		A90-40	
The interaction of a supersonic stre			
a normal shock wave	p 633	N90-24	241
STATISTICAL ANALYSIS			
A comparison of lightning network	data v	viun sum	ace
weather observations	- 000	NOO 00	
[AD-A220003]		N90-23	
Adaptive control of a system with Application of an impulse respons			
helicopter vibration problem	p 694		
STATISTICAL CORRELATION	p 034	1450-23	<b>550</b>
Additive evaluation criteria for aircra	off poice		
Additive evaluation citeria for aircra	p 698		967
STEADY FLOW	p 030	1430-24	607
A new Lagrangian method for stea	dy sune	rsonic f	low
computation. 1 - Godunov scheme			
STEADY STATE	p 001		
Euler and Navier-Stokes compu	tations	for ai	rfoil
geometries using unstructured meshe			

STEELS Advanced materials for landing gear p 677 A90-41900

p 630 A90-42425

STRAIN DISTRIBUTION

SH-2F airframe fatigue test program p 642 A90-39989 Finite element analysis of structural components using viscoplastic models with application to a cowl lip

problem [NASA-CR-185189] p 690 N90-23769 STRAIN HARDENING

The effects of toughening stresses on liquid impact p 692 A90-41315 induced fracture

STRAIN MEASUREMENT Estimation of rotor blade incidence and blade

deformation from the measurement of pressures and strains in flight p 647 A90-42497 STRAKES

Strake camber and thickness design procedure for low alpha supersonic flow p 622 A90-40678 Actuated forebody strakes

p 648 N90-23390 (NASA-CASE-LAR-13983-1) STRAPDOWN INERTIAL GUIDANCE

Modern strapdown system for helicopter

p 653 A90-42451 System concept and performance criteria of modern p 640 A90-42452 helicopter navigation Development and verification of software for flight safety p 694 A90-42454 critical strapdown systems STREAM FUNCTIONS (FLUIDS)

Calculation of viscous-inviscid strong interaction for transonic flows over aerofoils p 627 A90-42364 STRESS ANALYSIS

Impact damage and residual strength analysis of composite panels with bonded stiffeners --- for primary p 642 A90-40130 The computation of turbulent thin shear flows associated

with flow around multielement aerofoils p 633 N90-24240

STRESS CONCENTRATION

Stress concentration factors - Comparison of theory with p 680 A90-39979 STRESS CYCLES

Stress concentration factors - Comparison of theory with p 680 A90-39979

STRESS DISTRIBUTION

Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23769

STRESS INTENSITY FACTORS

The effects of toughening stresses on liquid impact induced fracture p 692 A90-41315 STRESS MEASUREMENT

Nondestructive measurement of residual stresses in aircraft transparencies [AD-A218680] p 689 N90-23762

STRESS-STRAIN RELATIONSHIPS

Finite element analysis of structural components using viscoplastic models with application to a cowl lip NASA-CR-1851891 p 690 N90-23769 STRESS-STRAIN-TIME RELATIONS

Considerations of reliability design for rotorcraft p 680 A90-39977

STRUCTURAL ANALYSIS

Analysis of composite rotor blades via Saint Venant's p 688 A90-42491 STARS: An integrated general-purpose finite element

structural, aeroelastic, and aeroservoelastic analysis computer program p 689 N90-23768 [NASA-TM-101709]

Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem

[NASA-CR-185189]

p 690 N90-23769

STRUCTURAL DESIGN

Multilevel optimization of large-scale structures in a parallel computing environment p 693 A90-39180 Development and application of an optimization procedure for space and aircraft structures

p 679 A90-39186 Redesign of an electro-optical shroud p 676 A90-40215 graphite/epoxy

Design of new Polish primary radars AVIA DM/CM p 638 A90-41035

Recent propeller development and studies conducted at ONERA

[ONERA, TP NO. 1990-16] p 683 A90-41201 Influence of some geometrical and design parameters on the hinge moment characteristics of rudders p 643 A90-41739

Metal matrix composites structural design experience [AIAA PAPER 90-2175] p 677 A90-42059 Component arrangement studies for an 8000 sho

turboshaft high technology core [AIAA PAPER 90-2398] p 663 A90-42159 Design and manufacturing of composite materials blade

p 618 A90-42492 models p 618 N90-23340 Aircraft drawings index

Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398

Modeling growth of fatigue cracks which originate at rivet holes p 691 N90-25060

Flexural fatigue life prediction of closed hat-section using materially nonlinear axial fatigue characteristics

p 691 N90-25062 STRUCTURAL DESIGN CRITERIA

Optimum design of composite wing structures subjected p 680 A90-39276 to displacement constraints Design and analysis aid for evaluating aircraft p 694 A90-41188 structures

STRUCTURAL FAILURE

Development of a finite element based delamination analysis for laminates subject to extension, bending, and

STRUCTURAL RELIABILITY

The collection of usage data to improve structural p 651 A90-39983 integrity of operational helicopters Potential application of automotive fatigue technology p 681 A90-39987 in rotorcraft design Damage tolerance of carbon fibre reinforced plastic

p 675 A90-40047 The influence of material quality on airframe structural

p 676 A90-41336 durability A 'new' philosophy of structural reliability, fail safe versus safe life p 688 A90-42490 Correlation/validation of finite element code analyses

for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398

STRUCTURAL STABILITY

Feasibility study for a microwave-powered ozone sniffer aircraft

[NASA-CR-186660] p 650 N90-23397

STRUCTURAL VIBRATION

Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration

STRUCTURAL WEIGHT

AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

[NASA-CR-186663]

p 649 N90-23395 STRUTS

An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack p 631 N90-23353

AD-A2197931

SUBSONIC AIRCRAFT

Investigation of very high bypass ratio engines for p 659 A90-40945 subsonic transports Noise-source measurements by thin-film pressure transducers in a subsonic turbofan model p 659 A90-41212

[ONERA, TP NO. 1990-36]

SUBSONIC FLOW

STARS: An integrated general-purpose finite element structural, aeroelastic, and aeroservoelastic analysis computer program

p 689 N90-23768 SUBSONIC SPEED

AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

[NASA-CR-186663] p 649 N90-23395 Flow unsteadiness effects on boundary layers NASA-CR-186067] p 690 N90-24557

SURSTRUCTURES Unique failure behavior of metal/composite aircraft

structural components under crash type loads p 690 N90-24660 [NASA-TM-102679] SUCTION

Generation of circumferential velocity associated with pulsed point suction on a rotating disk p 691 N90-25065

SUPERCHARGERS

Numerical simulation of the behaviour of internal combustion supercharged engines

[AIAA PAPER 90-1873] p 655 A90-40539 SUPERCOMPUTERS

Supercomputer applications in gas turbine flowfield p 620 A90-40495

SUPERCRITICAL AIRFOILS

Sidewall boundary-layer removal and wall adaptation p 672 A90-40680

A transonic airfoil design method and examples p 627 A90-42351

Flow separation on a supercritical airfoil p 627 A90-42394

SUPERHIGH FREQUENCIES

Reduced insertion loss of X-band RF fiber optic links p 695 A90-41240

SUPERSONIC AIRCRAFT

Hydrogen in future energy and propulsion technology p 692 A90-41736 Airframe/propulsion integration of supersonic cruise

[AIAA PAPER 90-2151] p 644 A90-42047

A remote tip-driven fan powered supersonic fighter concept p 663 A90-42167 [AIAA PAPER 90-2415]

Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft NASA-CR-1866701 p 649 N90-23394

SUPERSONIC BOUNDARY LAYERS

Wave structure of artificial perturbations in a supersonic boundary layer on a plate p 619 A90-39518

SUPERSONIC COMBUSTION

Modeling supersonic combustion using a fully-implicit umerical method

[AIAA PAPER 90-2307] p 677 A90-42117

SUPERSONIC COMBUSTION RAMJET ENGINES

Linear dynamics of supersonic ramjet

p 655 A90-40519 Hydrocarbon-fueled scramjet combustor investigation [AIAA PAPER 90-2337] p 658 A90-40622 p 659 A90-40927 Transverse fuel-injection model for a scramjet propulsion system

governing parameters Some plasma torch igniter/flameholder in a scramjet combustor [AIAA PAPER 90-2098] p 661 A90-42017

Direct measurements of skin friction in a scramjet combustor

[AIAA PAPER 90-2342] p 626 A90-42132 Hypersonic (T-D) 'pinch' and aerospaceplane propulsion

[AIAA PAPER 90-2474] p 675 A90-42189

SUPERSONIC COMPRESSORS

Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings [AIAA PAPER 90-2126] p 625 A90-42033

SUPERSONIC FLIGHT

Taking a new look at cockpit vertical situation displays

p 652 A90-40382 SUPERSONIC FLOW

Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing

p 619 A90-39465 The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges

p 620 A90-39519 Aerodynamic detuning for control of supersonic rotor

forced response [AIAA PAPER 90-2018] p 621 A90-40596

Strake camber and thickness design procedure for low p 622 A90-40678 alpha supersonic flow Determination of aerodynamic sensitivity coefficients based on the transonic small perturbation formulation

p 622 A90-40682 Numerical simulation of the growth of instabilities in supersonic free shear layers p 623 A90-40941

Three dimensional transonic and supersonic flow	SURVEYS	TECHNOLOGICAL FORECASTING
prediction in axi-vectored nozzles using a finite volume method	Social survey findings on en route noise annoyance issues p 698 N90-24868	Exploration of concepts for multi-role fighters [AIAA PAPER 90-2276] p 644 A90-4210
[AIAA PAPER 90-2026] p 624 A90-41989	An aircraft noise study in Norway p 698 N90-24872	[AIAA PAPER 90-2276] p 644 A90-4210 Contribution of engine improvement on next futur
Inviscid and viscous flows in transonic and supersonic	SWELLING	rotorcraft p 665 A90-4248
cascades using an implicit upwind relaxation algorithm	Equilibrium swelling of elastomeric materials in solvent	TECHNOLOGY ASSESSMENT
[AIAA PAPER 90-2128] p 625 A90-42034	environments [DE90-010164] p 678 N90-24430	ILS - Past and present p 639 A90-4170
Radio frequency (RF) heated supersonic flow laboratory	SWEPT WINGS	ILS - A safe bet for your future landings
[AIAA PAPER 90-2469] p 673 A90-42186	Various sources of wing rock p 622 A90-40679	p 639 A90-4170
A new Lagrangian method for steady supersonic flow	SWIRLING	Co-development of CT7-6 engines - A continued traditio in technology and reliability p 665 A90-4248
computation. I - Godunov scheme p 631 A90-42506	Development of the jet-swirl high loading combustor [AIAA PAPER 90-2451] p 658 A90-40633	Preliminary design of a supersonic Short Takeoff an
STARS: An integrated general-purpose finite element	Laser Doppler velocimetry investigation of swirter	Vertical Landing (STOVL) fighter aircraft
structural, aeroelastic, and aeroservoelastic analysis	flowfields p 682 A90-40929	[NASA-CR-186670] p 649 N90-2339
computer program [NASA-TM-101709] p 689 N90-23768	The influence of swirl on velocity, temperature and	A study of the technology required for advanced vertical
SUPERSONIC FLUTTER	species characteristics in a can combustor	take-off aircraft [ETN-90-96786] p 650 N90-2426
Supersonic flutter of shear deformable laminated	[AIAA PAPER 90-2454] p 664 A90-42177 SWITZERLAND	[ETN-90-96786] p 650 N90-2426 TECHNOLOGY TRANSFER
composite flat panels p 683 A90-41104	Problems related to aircraft noise in Switzerland	Propulsion system-flight control integration-flight
SUPERSONIC INLETS	p 698 N90-24871	evaluation and technology transition
Experimental investigation of terminal shock sensors in	SYMMETRY	[AIAA PAPER 90-2280] p 644 A90-4210
mixed-compression inlets [AIAA PAPER 90-1931] p 681 A90-40560	Symmetry assessment of an air-blast atomizer spray p 682 A90-40930	TELEVISION CAMERAS
Aerodynamic detuning for control of supersonic rotor	SYNTHETIC APERTURE RADAR	Holographic combiner design to obtain uniform symbol brightness at head-up display video camera
forced response	Synthetic aperture radar imagery of airports and	p 652 A90-4039
[AIAA PAPER 90-2018] p 621 A90-40596	surrounding areas: Denver Stapleton International	TEMPERATURE DISTRIBUTION
A numerical investigation of supersonic inlet using	Airport	Three-dimensional analysis on flow and temperature
implicit TVD scheme [AlAA PAPER 90-2135] p 621 A90-40612	[NASA-CR-4305] p 637 N90-24257 SYSTEM EFFECTIVENESS	distributions for aircraft fuel thermal stability
[AIAA PAPER 90-2135] p 621 A90-40612 SUPERSONIC JET FLOW	Conceptual design for aerospace vehicles	[AD-A219651] p 678 N90-2357
Perturbations of higher modes in a supersonic jet	p 651 N90-25043	TEMPERATURE GRADIENTS
p 619 A90-39516	SYSTEM FAILURES	Analysis of thermal gradient effects in oil ring seals p 682 A90-4071
Supersonic rectangular isothermal shrouded jets	Multiple model adaptive controller for the STOL F-15	TEMPERATURE SENSORS
[AIAA PAPER 90-2028] p 621 A90-40599	with sensor/actuator failures p 668 A90-40878 SYSTEMS ANALYSIS	Fiber-optic turbine inlet temperature measuremen
Application of a new adaptive grid for aerodynamic	Multi-level models for diagnosis of complex	system (FOTITMS)
analysis of shock containing single jets	electro-mechanical systems p 693 A90-38888	[AIAA PAPER 90-2033] p 657 A90-4060
[AIAA PAPER 90-2025] p 624 A90-41988	Helicopter Airborne Laser Positioning System (HALPS)	TENSILE TESTS
SUPERSONIC NOZZLES  The sensitivity of near-field acoustics to the orientation	[NASA-TM-102814] p 654 N90-23399	EH-101 main rotor hub application of thick carbon fibe unidirectional tension bands p 618 A90-42489
of twin two-dimensional supersonic nozzles	Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and	TERRAIN FOLLOWING AIRCRAFT
[AIAA PAPER 90-2149] p 625 A90-42045	ancran, volume 1: Aircran system delimiton, design and analysis	Application of optimal tracking methods to aircraft terrain
SUPERSONIC SPEED	[AD-A218493] p 671 N90-23409	following
High speed civil transport	SYSTEMS ENGINEERING	[AD-A221099] p 641 N90-24264
[NASA-CR-186661] p 649 N90-23396	MLS mathematical model validation study using airborne	TF-30 ENGINE
		Concept demonstration of the use of interactive faul
SUPERSONIC TURBINES	MLS data from Midway Airport engineering flight tests,	
Investigation of unsteady flow through transonic turbine	August 1988	diagnosis and isolation for TF30 engines
Investigation of unsteady flow through transonic turbine stage. I - Analysis	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378	diagnosis and isolation for TF30 engines p 617 A90-41177
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161	August 1988	diagnosis and isolation for TF30 engines p 617 A90-41177 THERMAL ENVIRONMENTS
Investigation of unsteady flow through transonic turbine stage. I - Analysis	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft	diagnosis and isolation for TF30 engines p 617 A90-41177
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A200393]  THERMAL FATIGUE
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers p 623 A90-40926	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186870] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398  THERMAL FATIGUE Recent advances in fatigue life analysis methods for
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A200393]  THERMAL FATIGUE
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41338  THERMAL RESISTANCE Finite element analysis of structural components using
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41338  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lig
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS \$TABILITY  Analysis of airframe/engine interactions - An integrated control perspective	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A2020393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods fo aerospace applications p 677 A90-41338  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41337  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23768
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS \$TABILITY  Analysis of airframe/engine interactions - An integrated control perspective	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23398  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41338  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23768  THERMAL STABILITY
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers  p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack  [AD-A219793] p 631 N90-23353	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS \$TABILITY  Analysis of airframe/engine interactions - An integrated control perspective	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41337  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes  [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack  [AD-A219793] p 631 N90-23353  Subsonic sting interference on the aerodynamic	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A229393] p 654 N90-23398  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41338  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23768  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS \$TABILITY  Analysis of airframe/engine interactions - An integrated control perspective	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES Redesign of an electro-optical shroud in
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES Redesign of an electro-optical shroud in graphite/epoxy THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41337  THERMAL FATIGUE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23769  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-40215  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for acrospace applications  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem  [NASA-CR-185189]  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651]  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670]  p 649  N90-23394
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693  SURGES An experimental study of fault propagation in a jet-engine	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEM SITTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS \$TABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393]  THERMAL FATIGUE Recent advances in fatigue life analysis methods to acrospace applications p 677 A90-41336  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES Redesign of an electro-optical shroud in graphite/apoxy p 676 A90-40215  THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] THERMOPLASTIC RESINS
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-237657  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMODLASTIC RESINS  Structural components of fiber-reinforced
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693  SURGES An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods to aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/apoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186870] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics
Investigation of unsteady flow through transonic turbine stage. I - Analysis  [AIAA PAPER 90-2408] p 626 A90-42161  Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS  Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693  SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401  SURVEILLANCE  Aviation security: Corrective actions underway, but better	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS \$TABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 SH-2F airframe fatigue test program	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lig problem [NASA-CR-185189] p 690 N90-237657  THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES Redesign of an electro-optical shroud in graphite/epoxy THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS Structural components of fiber-reinforced thermoplastics P 676 A90-41111  THIN AIRFOILS A visualization study of the interaction of a free vortex
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed tuture programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41111
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed tuture programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/apoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 SH-2F airframe fatigue test program  P 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control  TAKEOFF	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-237657  THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-402157  THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS The problem of supersonic flow past a thin wing of finite
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693  SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401  SURVEILLANCE  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed tuture programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF Analyses of Arrow Air DC-8-63 accident of December	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41111  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39515
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986  SH-2F airframe fatigue test program  p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] p 654 N90-23397  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-413367  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-237657  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-402157  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39515
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926 SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260 SUPERSONICS  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242 SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693 SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401 SURVEILLANCE  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367 SURVEILLANCE RADAR  The TVD 900 - A modern signal processing applied to	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed tuture programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF Analyses of Arrow Air DC-8-63 accident of December	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393] p 654 N90-23398  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for acrospace applications p 677 A90-41338  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem [NASA-CR-185189] p 690 N90-23768  THERMAL STABLITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651]  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN MIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39518
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483 TAKEOFF Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-411115  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-411115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39515  THREE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395  SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926  SUPERSONICS Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260  SUPPORT INTERFERENCE An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242  SURFACE GEOMETRY Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693  SURGES An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401  SURVEILLANCE Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-180] p 635 N90-23367  SURVEILLANCE RADAR The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 Design of new Polish primary radars AVIA DM/CM	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed tuture programs p 642 A90-39986  SH-2F airframe fatigue test program p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 698 N90-24870	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A220393] THERMAL FATIGUE Recent advances in fatigue life analysis methods to aerospace applications p 677 A90-41336 THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765 THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] THERMAL STRESSES Redesign of an electro-optical shroud in graphite/epoxy THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] THERMOPLASTIC RESINS Structural components of fiber-reinforced thermoplastics p 676 A90-41111 THIN AIRFOILS A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115 THIN WINGS The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39518 THREE AXIS STABILIZATION An image analysis method for vehicle stabilization p 668 A90-40914
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39989  SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278 En route noise annoyance laboratory test: Preliminary results p 698 N90-24870 A quantitative technique to estimate microburst wind	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem  [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability  [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft  [NASA-CR-186670] p 649 N90-23394  THERMODLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-411115  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-411115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39515  THREE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378 SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 SYSTEMS \$TABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 SH-2F airframe fatigue test program p 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control TAKEOFF Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-42483 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278 En route noise annoyance laboratory test: Preliminary results p 699 N90-24870 A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS Correlation/validation of finite element code analyses for vibration assessment of avionic equipment [AD-A20393] THERMAL FATIGUE Recent advances in fatigue life analysis methods to aerospace applications p 677 A90-41336 THERMAL RESISTANCE Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] [NASA-CR-185189] THERMAL STABILITY Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] THERMAL STRESSES Redesign of an electro-optical shroud in graphite/apoxy THERMODYNAMIC CYCLES Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] THERMOPLASTIC RESINS Structural components of fiber-reinforced thermoplastics p 676 A90-41111 THIN AIRFOILS A visualization study of the interaction of a free vortew with the wake behind an airfoil p 623 A90-41115 THIN WINGS The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39518 THREE AXIS STABILIZATION An image analysis method for vehicle stabilization p 668 A90-40328 A time-marching method to calculate unsteady airloads A time-marching method to calculate unsteady airloads
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926 SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260 SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260 SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242 SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693 SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401 SURVEILLANCE  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367 SURVEILLANCE RADAR  The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 Design of new Polish primary radars AVIA DM/CM p 638 A90-41035 Performances and new surveillance possibilities in SSR Mode S Apolications of Mode S secondary surveillance radar	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 TAIL ROTORS  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986  SH-2F airframe fatigue test program p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance En route noise annoyance laboratory test: Preliminary results p 698 N90-24870  A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for acrospace applications p 677 A90-41338  THERMAL FATIGUE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem [NASA-CR-185189] p 690 N90-23768  THERMAL STABLITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651]  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN MIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39515  THERE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914  THREE DIMENSIONAL BODIES  Computer-aided analysis of three-dimensional multiloop mechanisms  A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized on three-dimensional wings.
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926 SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260 SUPERSONICS  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242 SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693 SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401 SURVEILLANCE  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367 SURVEILLANCE RADAR  The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 Design of new Polish primary radars AVIA DM/CM p 638 A90-41035 Performances and new surveillance possibilities in SSR Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986  SH-2F airframe fatigue test program p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278  En route noise annoyance laboratory test: Preliminary results p 698 N90-24870  A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040  TARGET ACQUISITION  Neural networks for adaptive shape tracking	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A220393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for acrospace applications p 677 A90-41387  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23769  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy p 676 A90-40215  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-2339/  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortew with the wake behind an airfoil p 623 A90-41111  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39515  THERE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914  THREE DIMENSIONAL BODIES  Computer-aided analysis of three-dimensional multiloop mechanisms p 669 A90-42326  A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized formulation
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394 Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985 Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986 SH-2F airframe fatigue test program  P 642 A90-39989 Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278 En route noise annoyance laboratory test: Preliminary results p 698 N90-24870 A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040  TARGET ACQUISITION Neural networks for adaptive shape tracking p 638 A90-39959	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods to aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability (AD-A219651) p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/apoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft (NASA-CR-186670) p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39518  THREE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914  THREE DIMENSIONAL BODIES  Computer-aided analysis of three-dimensional multiloop mechanisms p 669 A90-42326  A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized formulation [DLR-FB-89-58]
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408]	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39985  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986  SH-2F airframe fatigue test program p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278  En route noise annoyance laboratory test: Preliminary results p 698 N90-24870  A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040  TARGET ACQUISITION  Neural networks for adaptive shape tracking	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393]  THERMAL FATIGUE  Recent advances in fatigue life analysis methods for acrospace applications p 677 A90-41338  THERMAL FATIGUE  Finite element analysis of structural components using viscoplastic models with application to a cowl lipproblem [NASA-CR-185189] p 690 N90-23768  THERMAL STABLITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651]  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/epoxy  THERMODYNAMIC CYCLES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges  p 620 A90-39519  THERE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914  THREE DIMENSIONAL BODIES  Computer-aided analysis of three-dimensional multiloop mechanisms p 669 A90-42326  A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized formulation [DLR-FB-89-58] p 634 N90-24254  A dime-marching method for calculating unsteady a firme-marching method for calculating unsteady
Investigation of unsteady flow through transonic turbine stage. I - Analysis [AIAA PAPER 90-2408] p 626 A90-42161 Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 SUPERSONIC WIND TUNNELS Investigation of supersonic mixing layers p 623 A90-40926 SUPERSONICS  Aerodynamic development perspective for traffic aeroplanes [DGLR-89-141] p 637 N90-24260 SUPPORT INTERFERENCE  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-2353 Subsonic sting interference on the aerodynamic characteristics of a family of slanted-base ogive-cylinders [NASA-CR-4299] p 633 N90-24242 SURFACE GEOMETRY  Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693 SURGES  An experimental study of fault propagation in a jet-engine controller [NASA-CR-181335] p 665 N90-23401 SURVEILLANCE  Aviation security: Corrective actions underway, but better inspection guidance still needed. Report to the Chairwoman, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives [GAO/RCED-88-160] p 635 N90-23367 SURVEILLANCE RADAR  The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 Design of new Polish primary radars AVIA DM/CM p 638 A90-41035 Performances and new surveillance possibilities in SSR A90-41036 Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056	August 1988 [DOT/FAA/CT-TN90/2] p 640 N90-23378  SYSTEMS INTEGRATION  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p 649 N90-23394  Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400  SYSTEMS STABILITY  Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557  T  TAIL ASSEMBLIES  An experimental investigation of support strut interference on a three-percent fighter model at high angles of attack [AD-A219793] p 631 N90-23353  TAIL ROTORS  Improvements to the fatigue substantiation of the H-60 composite tail rotor blade p 642 A90-39986  Helicopter surveillance - A look at current and proposed future programs p 642 A90-39989  Use of smart actuators for the tail rotor collective pitch control p 688 A90-42483  TAKEOFF  Analyses of Arrow Air DC-8-63 accident of December 12, 1985 - Gander, Newfoundland p 635 A90-40687 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278  En route noise annoyance laboratory test: Preliminary results p 698 N90-24870  A quantitative technique to estimate microburst wind shear hazard to aircraft p 692 N90-25040  TARGET ACQUISITION  Neural networks for adaptive shape tracking p 638 A90-39959	diagnosis and isolation for TF30 engines p 617 A90-41177  THERMAL ENVIRONMENTS  Correlation/validation of finite element code analyses for vibration assessment of avionic equipment (AD-A20393)  THERMAL FATIGUE  Recent advances in fatigue life analysis methods to aerospace applications p 677 A90-41336  THERMAL RESISTANCE  Finite element analysis of structural components using viscoplastic models with application to a cowl lip problem [NASA-CR-185189] p 690 N90-23765  THERMAL STABILITY  Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability (AD-A219651) p 678 N90-23571  THERMAL STRESSES  Redesign of an electro-optical shroud in graphite/apoxy p 676 A90-40215  THERMAL STRESSES  Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft (NASA-CR-186670) p 649 N90-23394  THERMOPLASTIC RESINS  Structural components of fiber-reinforced thermoplastics p 676 A90-41111  THIN AIRFOILS  A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41115  THIN WINGS  The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39518  THREE AXIS STABILIZATION  An image analysis method for vehicle stabilization p 668 A90-40914  THREE DIMENSIONAL BODIES  Computer-aided analysis of three-dimensional multiloop mechanisms p 669 A90-42326  A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized formulation [DLR-FB-89-58]

#### THREE DIMENSIONAL BOUNDARY LAYER Direct measurements of skin friction in a scramjet p 626 A90-42132 [AIAA PAPER 90-2342] Experimental study of the flow around an helicopter fuselage - Comparison with three-dimensional boundary p 630 A90-42438 layer calculations Generation of circumferential velocity contours associated with pulsed point suction on a rotating disk p 691 N90-25065 THREE DIMENSIONAL FLOW measurement, display, Three-dimensional interpretation of fluid flow datasets p 679 A90-38854 Navier-Stokes solutions for vortical flows over a tangent-ogive cylinder p 620 A90-39780 Numerical solution of 3-D hybrid problems in irbomachinery p 621 A90-40501 turbomachinery Application of CFD to pitch/yaw thrust vectoring spherical convergent flap nozzles p 657 A90-40597 (AIAA PAPER 90-2023) Three-component LDA measurements in an axial-flow p 683 A90-40943 compressor Three dimensional transonic and supersonic flow prediction in axi-vectored nozzles using a finite volume method p 624 A90-41989 [AIAA PAPER 90-2026] Calculation of three-dimensional jet interaction flowfields [AIAA PAPER 90-2099] p 624 A90-42018 Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design [AIAA PAPER 90-2129] p 625 A90-42035 Application of 3-D flow analysis to the design of a high p 628 A90-42395 work transonic turbine Extension of a three-dimensional viscous wing flow analysis [NASA-CR-182023] p 631 N90-23348 Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability [AD-A219651] p 678 N90-23571 Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions [AD-A219621] p 689 N90-23687 THREE DIMENSIONAL MODELS 3-D Euler calculations for aft-propfan integration [AIAA PAPER 90-2147] p 625 A90-42044 Introducing the VRT gas turbine combustor p 688 N90-23591 [NASA-TM-103176] Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 Development of a finite element based delamination analysis for laminates subject to extension, bending, and p 679 N90-25049 THRUST A modeling technique for STOVL ejector and volume (ÁIAA PAPER 90-2417) p 663 A90-42168 THRUST AUGMENTATION Advanced material applications for direct lift engines AIAA PAPER 90-2753] p 664 A90-42226 Rotary-Jet thrust augmentor with jet-flapped blades (AIAA PAPER 90-2753) p 633 N90-24243 THRUST BEARINGS Retirement lives of rolling element bearings p 680 A90-39980 Initiation of spalling in aircraft gas turbine bearings [AIAA PAPER 90-2291] p 686 A90-42110 THRUST DISTRIBUTION A simple dynamic engine model for use in a real-time aircraft simulation with thrust vectoring p 662 A90-42054 [AIAA PAPER 90-2166] THRUST REVERSAL Flight test results of the F-15 SMTD thrust vectoring/thrust reversing exhaust nozzie STOL/Maneuvering Technology Demonstrator p 660 A90-41982 [AIAA PAPER 90-1906] THRUST VECTOR CONTROL Inverse heat transfer studies and the effects of propellant aluminum on TVC jet vane heating and erosion [AIAA PAPER 90-1860] p 655 A90-40533 Application of CFD to pitch/yaw thrust vectoring spherical convergent flap nozzles [AIAA PAPER 90-2023] p 657 A90-40597 Confined jet thrust vector control nozzle studies p 657 A90-40598 [AIAA PAPÉR 90-2027] Flight test results of the F-15 SMTD thrust reversing rectoring/thrust nozzle exhaust STOL/Maneuvering Technology Demonstrator [AJAA PAPER 90-1906] AIAA PAPER 90-1906) p 660 A90-41982 A simple dynamic engine model for use in a real-time aircraft simulation with thrust vectoring [AIAA PAPER 90-2166] p 662 A90-42054 5DOF dynamic loads on a jet vane [AIAA PAPER 90-2382] p 675 A90-42147 Computation of vectoring nozzle performance [AIAA PAPER 90-2752] p 627 A90-42225

TORQUE The influence of control-surface compensation TORSION

```
THRUST-WEIGHT RATIO
    Bonded airfoil attachments - A path to rotor structural
  [AIAA PAPER 90-2177]
                                    p 686 A90-42061
THUNDERSTORMS
    A comparison of lightning network data with surface
   eather observations
  [AD-A2200031
                                    p 692 N90-23832
TILT ROTOR AIRCRAFT
    A review of tilt rotor download research
                                    p 630 A90-42437
    Eurofar - Status of the European tilt-rotor project
                                    p 645 A90-42441
    Improving tilt rotor aircraft
                                   performance
                                    n 646 A90-42445
  variable-diameter rotors
    Active control of tiltrotor blade in-plane loads during
                                    p 670 A90-42463
    Extension-torsion coupling behavior of advanced
  composite tilt-rotor blades
                                    p 651 N90-25057
   Helicopter stability and control modeling improvements
  and verification on two helicopters p 671 A90-42474
TIME MARCHING
   Modeling gas turbine combustor performance under
  transient conditions
 (AIAA PAPER 90-21611
   A time-marching method to calculate unsteady airloads
  on three-dimensional wings. Part 1: Linearized
  formulation
                                    p 634 N90-24254
  (DLR-FB-89-58)
   A time-marching method for calculating unsteady
  airloads on three-dimentional wings. Part 2: Full-potential
  formulation
                                    p 635 N90-24255
 (DLR-FB-89-59)
TIME MEASUREMENT
TIP DRIVEN ROTORS
 concept
  [AIAA PAPER 90-2415]
TIP SPEED
   En route noise of turboprop
```

Short time Force and moment measurement System for shock tubes (SFS) for measuring times less than 10 p 674 N90-24233 A remote tip-driven fan powered supersonic fighter

p 663 A90-42167

aircraft and their cceptability: Report of tests p 697 N90-24858 TITANILIM Metal matrix composite fan blade development

A90-42062 AIAA PAPER 90-2178) TITANIUM ALLOYS

Fatigue crack growth investigation of a Ti-6AI-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program p 678 N90-23538 [AD-A220239]

parameters on the hinge moment characteristics p 643 A90-41737 Influence of some geometrical and design parameters

on the hinge moment characteristics of rudders p 643 A90-41739

Development of a finite element based delamination

analysis for laminates subject to extension, bending, and p 679 N90-25049 torsion **TORSIONAL STRESS** 

Agusta methodology for pitch link loads prediction in preliminary design phase p 646 A90-42465 TORSIONAL VIBRATION

Agusta methodology for pitch link loads prediction in preliminary design phase p 646 A90-42465 TRACKING (POSITION)

Neural networks for adaptive shape tracking p 638 A90-39959

TRAILING EDGES Modelling of boundary layer and trailing edge thickness

effects for the Euler equations n 629 A90-42412 transpiration Euler code predicted separation at the airfoil trailing [FFA-TN-1989-30] n 632 N90-23364

TRAJECTORY CONTROL Ultimate boundedness control of uncertain systems with application to roll coupled aircraft maneuver

p 668 A90-40886

TRAJECTORY MEASUREMENT Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference

Instrumentation System (CIRIS) [AD-A220106] p 654 N90-23400 TRANSIENT OSCILLATIONS Parameter identification of aeroelastic modes of rotary

vings from transient time histories p 642 A90-40166 TRANSIENT PRESSURES Composite reduced Navier Stokes procedures for flow

roblems with strong pressure interactions (AD-A2196211 p 689 N90-23687

```
TRANSIENT RESPONSE
```

Adjusting turbine engine transient performance for the effects of environmental variances

[AIAA PAPER 90-25011 p 658 A90-40639 Modeling gas turbine combustor performance under transient conditions

[AIAA PAPER 90-2161] p 661 A90-42051 Estimating short-period dynamics using an extended Kalman filte

p 648 N90-23392 (NASA-TM-1017221 An experimental study of fault propagation in a jet-engine controller

[NASA-CR-181335] p 665 N90-23401 TRANSITION FLOW

Wave structure of artificial perturbations in a supersonic boundary layer on a plate p 619 A90-39518 TRANSONIC FLOW

Boundary layer stability in the case of transonic external p 619 A90-39514 Transonic flow around airfoils with relaxation and energy supply by homogeneous condensation

p 620 A90-39782 Determination of aerodynamic sensitivity coefficients based on the transonic small perturbation formulation p 622 A90-40682

Three dimensional transonic and supersonic flow prediction in axi-vectored nozzles using a finite volume

[AIAA PAPER 90-2026] p 624 A90-41989 Investigation of unsteady flow through a transonic turbine stage. II - Data/prediction comparison for time-averaged and phase-resolved pressure data

[AIAA PAPER 90-2409] n 626 A90-42162 A transonic airfoil design method and examples

p 627 A90-42351 Calculation of the complete transonic unsteady small disturbance equation by ADI method

p 627 A90-42353 An improvement on upwinding technique used in the Galerkin finite element method for the computation of

inviscid transonic flow with shock waves p 627 A90-42361 Numerical analysis of viscous-inviscid interaction in

p 627 A90-42363 transonic flow Calculation of viscous-inviscid strong interaction for p 627 A90-42364 transonic flows over aerofoils

Application of the KTRAN transonic small disturbance code to the complete CF-18 aircraft with stores p 629 A90-42416

CFD and transonic helicopter sound p 696 A90-42433

Transonic wing charge improvements by passive shock boundary layer interference control: Development status and prospects

[ETN-90-96463] p 650 N90-24267 TRANSONIC SPEED

Flow unsteadiness effects on boundary layers NASA-CR-186067] p 690 N90-24557

TRANSONIC WIND TUNNELS Sidewall boundary-layer removal and wall adaptation studies p 672 A90-40680

New transonic test sections for the NAE 5ftx5ft trisonic wind tunnel p 630 A90-42431

New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel [AD-A220933] p 674 · N90-24278

TRANSPIRATION

Modelling of boundary layer and trailing edge thickness effects for the Euler equations using transpiration n 629 A90-42412

TRANSPORT AIRCRAFT

Critical review of design philosophies for recent transport WIG effect vehicles --- Wing-in Ground

p 684 A90-41753 Fire hazards of aerosol cans in aircraft cargo compartments

p 636 N90-23369 [DOT/FAA/CT-89/32] AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

aircraft [NASA-CR-186663] p 649 N90-23395

High speed civil transport

[NAŠA-CR-186661] p 649 N90-23396 TRANSPUTERS

Implementation of a transputer-based flight controller p 667 A90-38966 TREND ANALYSIS

Trend analysis and diagnostics codes for training purposes

[AIAA PAPER 90-2394] p 617 A90-42156 **TRENDS** Unique failure behavior of metal/composite aircraft

structural components under crash type loads p 690 N90-24660 INASA-TM-1026791

[AIAA PAPER 90-2403]

TURBULENCE TRISONIC WIND TUNNELS Sound propagation elements in evaluation of en route New transonic test sections for the NAE 5 ft x 5 ft trisonic noise of advanced turbofan aircraft p 697 N90-24861 The interaction of a supersonic streamwise vortex and **TURBOFAN ENGINES** p 633 N90-24241 wind tunnel a normal shock wave Identification of multivariable models of jet engines [AD-A220933] p 674 N90-24278 New transonic test sections for the NAE 5 ft x 5 ft trisonic [AIAA PAPER 90-1874] p 655 A90-40540 TURBINE BLADES wind tunnel The influence of the inlet Mach number on the boundary Design of digital self-selecting multivariable controllers [AD-A220933] p 674 N90-24278 layer development on turbomachinery blade surfaces for jet engines TURBULENCE MODELS [AIAA PAPER 90-1875] p 621 A90-40504 Turbulence model performance in V/STOL flow field A proposed Kalman filter algorithm for estimation of Simulation of inviscid blade-row interaction using a contehumia linearised potential code [AIAA PAPER 90-1916] unmeasured output variables for an F100 turbofan [AIAA PAPER 90-2248] p 625 A90-42094 engine p 621 A90-40555 Euler and Navier-Stokes computations for airfoil [AIAA PAPER 90-1920] p 656 A90-40558 Reverse flow in multistage axial compressors geometries using unstructured meshes p 623 A90-40942 Investigation of very high bypass ratio engines for ubsonic transports p 659 A90-40945 p 630 A90-42425 subsonic transports Application of 3-D Navier-Stokes computation to bowed Extension of a three-dimensional viscous wing flow Turbofans turn to UHB propulsion p 659 A90-41165 stacking turbine vane design [AIAA PAPER 90-2129] p 625 A90-42035 Noise-source measurements by thin-film pressure [NASA-CR-182023] p 631 N90-23348 transducers in a subsonic turbofan model The investigation of heat transfer in cooled blades of TURBULENT BOUNDARY LAYER p 659 A90-41212 [ONERA, TP NO. 1990-36] gas turbines Gearbox system design for ultra-high bypass engines
AIAA PAPER 90-2152] p 685 A90-42048 Effect of detailed surface geometry on riblet drag (AIAA PAPER 90-2144) p 685 A90-42043 reduction performance p 622 A90-40693 [AIAA PAPER 90-2152] Boundary-layer transition and separation on a turbine Computation of multiple normal shock wave/turbulent A simple dynamic engine model for use in a real-time aircraft simulation with thrust vectoring [AIAA PAPER 90-2166] p 662 A90-42054 blade in a plane cascade boundary layer interactions [AIAA PAPER 90-2263] p 625 A90-42102 [AIAA PAPÉR 90-2133] n 685 A90-42037 Investigation of unsteady flow through transonic turbine Direct measurements of skin friction in a scramiet Ultra high bypass turbofan technologies for the stage, I - Analysis combustor twenty-first century
[AIAA PAPER 90-2397] [AIAA PAPER 90-2408] p 626 A90-42161 [AIAA PAPER 90-2342] p 626 A90-42132 p 662 A90-42158 Investigation of unsteady flow through a transonic turbine TURBULENT FLOW Experimental turbofan using liquid hydrogen and liquid stage. II - Data/prediction comparison for time-averaged Interaction between a high-level steady acoustic field and phase-resolved pressure data natural das as fuel and a ducted turbulent flow [ONERA, TP NO. 1990-27] [AIAA PAPER 90-2421] p 663 A90-42170 [AIAA PAPER 90-2409] p 626 A90-42162 p 695 A90-41206 CFE738 - A case for joint engine development
[AIAA PAPER 90-2522] p 664 A9 Application of 3-D flow analysis to the design of a high Computation of flow through a centrifugal impeller with work transonic turbine p 628 A90-42395 p 664 A90-42197 tip leakage A hydrodynamic turbo-fan/shaft convertible engine Calculation of the aeroelastic blade stabilization with [AIAA PAPER 90-2021] p 684 A90-41987 p 665 A90-42487 linearized process Measurements of turbulent dual-jet interaction A/F32T-9 large turbo fan engine enclosed noise suppressor system (T-9 NSS), exterior far-field and interior [MITT-87-01] p 666 N90-24272 [AIAA PAPER 90-2105] p 624 A90-42019 TURBINE ENGINES Numerical analysis of the flows in annular slinger noise, McConnell AFB, Kansas Composite electronic enclosures for engine-mounted combustors [AD-A220535] p 665 N90-23402 environments (AIAA PAPER 90-2164) p 685 A90-42052 TURBOJET ENGINE CONTROL [AIAA PAPER 90-2030] p 657 A90-40601 Electrical analog circuit for heat transfer measurements on a flat plate simulating turbine vane heat transfer in An experimental study of fault propagation in a jet-engine Adjusting turbine engine transient performance for the effects of environmental variances controller turbulent flow [NASA-CR-181335] p 665 N90-23401 [AIAA PAPER 90-2501] p 658 A90-40639 [AIAA PAPER 90-2412] p 687 A90-42164 Military engines - Cradle of technology **TURBOJET ENGINES** The computation of turbulent thin shear flows associated p 660 A90-41758 UV spectroradiometric output of an F404 turbojet aircraft with flow around multielement aerofoils p 652 A90-40195 Evaluation of solid lubricant powder delivery system for engine p 633 N90-24240 On the use of external burning to reduce aerospace turbine bearing lubrication [AIAA PAPER 90-2046] TVD SCHEMES vehicle transonic drag [AIAA PAPER 90-1935] p 684 A90-41997 A numerical investigation of supersonic inlet using p 656 A90-40562 Metal matrix composites structural design experience implicit TVD scheme [AIAA PAPER 90-2135] GE's CF34 engine for business and regional jets [AIAA PAPER 90-2175] p 677 A90-42059 p 621 A90-40612 p 661 A90-41992 [AIAA PAPER 90-2041] Metal matrix composite fan blade development TWO DIMENSIONAL BODIES Airframe/propulsion integration of supersonic cruise [AIAA PAPER 90-2178] p 677 A90-42062 The sensitivity of near-field acoustics to the orientation Turbine configuration impact on advanced IHPTET engine system mission capabilities of twin two-dimensional supersonic nozzles [AIAA PAPER 90-2151] p 644 A90-42047 [AIAA PAPER 90-2149] p 625 A90-42045 On and off-design performance prediction of single spool turbojets using gasdynamics (AIAA PAPER 90-2739) p 664 A90-42221 TWO DIMENSIONAL FLOW Co-development of CT7-6 engines - A continued tradition Transonic flow around airfoils with relaxation and energy [AIAA PAPER 90-2393]
TURBOMACHINE BLADES in technology and reliability p 662 A90-42155 p 665 A90-42485 supply by homogeneous condensation TURBINE INSTRUMENTS p 620 A90-39782 Quasi-3D viscous flow computations in subsonic and Partial similarity and a real-time model of twin-spool gas Investigation of supersonic mixing layers transonic turbomachinery bladings [AIAA PAPER 90-2126] p 654 A90-40512 turbine p 623 A90-40926 **TURBINE PUMPS** p 625 A90-42033 Modeling supersonic combustion using a fully-implicit numerical method TURBOMACHINERY Experimental evaluation of a tuned electromagnetic Numerical solution of 3-D hybrid problems in urbomachinery p 621 A90-40501 damper for vibration control of cryogenic turbopump [AIAA PAPER 90-2307] p 677 A90-42117 turbomachinery Application of the moving surface boundary layer control to a two dimensional airfoil p 628 A90-42405 Non-steady flow loss mechanisms associated with [NASA-TP-3005] p 665 N90-23403 vaneless diffusers TURBINE WHEELS Finite volume solutions of two-dimensional Euler [AIAA PAPER 90-2508] p 682 A90-40641 Non-steady flow loss mechanisms associated with equations on adapted structured meshes TURBOPROP AIRCRAFT vaneless diffusers p 629 A90-42413 3-D Euler calculations for aft-propfan integration [AIAA PAPER 90-2508] p 682 A90-40641 Finite element simulation of unsteady two-dimensional [AIAA PAPER 90-2147] p 625 A90-42044 A review of tilt rotor download research p 629 A90-42423 incompressible viscous flows
TWO DIMENSIONAL MODELS p 630 A90-42437 En route noise of turboprop aircraft and their acceptability: Report of tests p 697 N90-24858 **TURBOCOMPRESSORS** Numerical modeling of an impinging jet in cross-flow En route noise of two turboprop aircraft Numerical simulation of the behaviour of internal [AIAA PAPER 90-2246] p 686 A90-42093 [DLR-MITT-89-18] combustion supercharged engines [AIAA PAPER 90-1873] p 697 N90-24859 Numerical simulations of gas turbine combustor flows p 655 A90-40539 **TURBOPROP ENGINES** [AIAA PAPER 90-2305] p 686 A90-42116 Planet gear sleeve spinning analysis [AIAA PAPER 90-2154] Stall margin improvement in axial-flow compressors by PTA en route noise measurements p 681 A90-40613 circumferential variation of stationary blade setting p 696 N90-24855 Investigation of the near wake of a propfan angles TWO PHASE FLOW [AIAA PAPER 90-1912] p 656 A90-40554 p 622 A90-40686 An analytic study of nonsteady two-phase laminar Reverse flow in multistage axial compressors Finite-element analysis of large spur and helical gear boundary layer around an airfoil p 691 N90-25051 p 623 A90-40942 p 683 A90-40940 TWO STAGE TURBINES Three-component LDA measurements in an axial-flow Bonded airfoil attachments - A path to rotor structural Partial similarity and a real-time model of twin-spool gas p 654 A90-40512 A90-40943 p 683 efficiency turbine Military engines - Cradle of technology Turbine configuration impact on advanced IHPTET [AIAA PAPER 90-2177] p 686 A90-42061 p 660 A90-41758 engine system mission capabilities [AIAA PAPER 90-2739] Advanced gearbox technology Design and performance of a small, high speed axial [NASA-CR-179625] p 664 A90-42221 p 666 N90-24274 compressor **TURBOSHAFTS** [AIAA PAPER 90-1911] A90-41983 p 624 Directivity of the noise radiation emitted from the inlet U pre-diffuser The performance of a combustor duct of a turboshaft helicopter engine incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 [ONERA, TP NO. 1990-26] p 695 A90-41205 A90-42053 U-2 AIRCRAFT Characterization of helicopter turboshaft engine noise Linearized unsteady aerodynamics for turbomachinery NASA/USRA high altitude reconnaissance aircraft p 660 A90-41759 p 650 N90-24266 aeroelastic applications [AIAA PAPER 90-2355] INASA-CR-1866851 Component arrangement studies for an 8000 shp UH-60A HELICOPTER p 626 A90-42137 turboshaft high technology core [AIAA PAPER 90-2398] TURBOFAN AIRCRAFT UH-60A helicopter stability augmentation study p 663 A90-42159 Propulsion control system designs for advanced Navy p 670 A90-42471 Co-development of CT7-6 engines - A continued tradition ULTRALIGHT AIRCRAFT multimission aircraft

in technology and reliability

p 663 A90-42160

p 665 A90-42485

Acoustics of ultralight airplanes

p 643 A90-40685

p 665 N90-23403

p 694 N90-23990

p 654 N90-23398

p 653 A90-42477

p 646 A90-42464

p 672 A90-40476

ULTRASONIC TESTS  Ultrasonic regression rate mea	surement	in solid fue
ramjets		
[AIAA PAPER 90-1963]  Nondestructive measurement of	p 656 f residual	A90-4057
aircraft transparencies		
(AD-A218680) ULTRAVIOLET RADIATION	р 689	N90-2376
UV spectroradiometric output of a engine	an F404 tur p 652	
UNSTEADY AERODYNAMICS	·	
Flow visualization via laser-in bubble sheets	nduced ref p 680	
Lift response of a rectangular w		
change in forward speed	p 620	A90-3980
Aerodynamic detuning for contr forced response	ol of supe	ersonic roto
[AIAA PAPER 90-2018]	p 621	A90-4059
Various sources of wing rock	p 622	
Flow structure generated by o segments	p 622	A90-4069
Counter-rotating propellant anal		
domain panel method Coupled aerodynamic forces du	p 623 e to unste	A90-4093
a high-aspect-ratio wing oscillating	at high an	nplitude
[ONERA, TP NO. 1990-24]	p 623	A90-4120
Flow induced forced response radial cascade including profile		
[AIAA PAPER 90-2352]	p 626	A90-4213
Linearized unsteady aerodynami aeroelastic applications	ics for turt	omachinen
[AIAA PAPER 90-2355]	p 626	A90-4213
Calculation of the complete trai		teady smal
disturbance equation by ADI metho	p 627	A90-42350
Flow separation on a supercritical		400 4000
Nonlinear unsteady airfoil respor		
and the second second	p 628	A90-42400
Computation of viscous aerodyn	amic chara	icteristics o
Computation of viscous aerodyn 2-D airfoils for helicopter application	ns	
2-D airfoils for helicopter application	ns p 631	A90-42440
2-D airfoils for helicopter application STARS: An integrated general-particular acroelastic, and aeros	ns p 631 ourpose fin	A90-42440 lite elemen
2-D airfoils for helicopter application STARS: An integrated general-p	ns p 631 ourpose fin	A90-42440 lite elemen
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709] A time-marching method to calcu-	ns p 631 purpose fir ervoelast p 689 ilate unste	A90-42440 ite elemen ic analysis N90-23768 ady airloads
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings.	ns p 631 purpose fin ervoelast p 689	A90-42440 ite elemen ic analysis N90-23768
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709] A time-marching method to calcu-	p 631 purpose fir ervoelast p 689 slate unster	A90-42440 ite elemen ic analysis N90-23768 ady airloads
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aerostomputer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for a calculon three-dimensional wings.	p 631 purpose fin ervoelast p 689 elate unster Part 1: p 634 calculatin	A90-42440 ite elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58]	p 631 purpose fir ervoelast p 689 elate unster Part 1: p 634 calculatin s. Part 2: F	A90-42440 ite elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady ull-potentia
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aerostocomputer program [NASA-TM-101709] A time-marching method to calcutor in three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59]	p 631 purpose fin ervoelast p 689 date unste Part 1: p 634 calculatin s. Part 2: F	A90-42440 ite elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady ull-potentia
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aerost computer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59] Calculation of the aeroelastic b	p 631 purpose fin ervoelast p 689 date unste Part 1: p 634 calculatin s. Part 2: F	A90-42440 ite elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady ull-potentia
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aerostocomputer program [NASA-TM-101709] A time-marching method to calcutor on three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59] Calculation of the aeroelastic belinearized process [MITT-87-01]	p 631 purpose fin ervoelast p 689 date unste Part 1: p 634 calculatin s. Part 2: F	A90-42440 ite elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady ull-potentia
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aerost computer program [NASA-TM-101709] A time-marching method to calcuton three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59] Calculation of the aeroelastic belinearized process [MITT-87-01] UNSTEADY FLOW	p 631 p 631 purpose fir ervoelast p 689 plate unste: Part 1: p 634 calculatin s. Part 2: F p 635 lade stabil	A90-4244(ite elemenic analysis N90-23768 ady airloads Linearizec N90-24254 g unstead; ull-potentia N90-24255 ization with
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calcuture on three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers	ns p 631 purpose firervoelast p 689 plate unster Part 1: p 634 calculatin s. Part 2: F p 635 lade stabil p 666	A90-4244( itte elemen ic analysis N90-2376( ady airloads Linearized N90-24254 g unsteady ull-potentia N90-24255 ization with N90-24272 ociated with
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]	ns p 631 purpose firervoelast p 689 plate unste: Part 1: p 634 calculatins, Part 2: F p 635 lade stabil p 666 nisms asso	A90-4244( itte elemen ic analysis N90-23768 ady airloads Linearized N90-24254 g unsteady ull-potentia N90-24255 ization with N90-24272 ociated with A90-40641
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59] Calculation of the aeroelastic bilinearized process [MITT-87-01] UNSTEADY FLOW Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508] Investigation of unsteady flow thr stage. I - Analysis	ns p 631 purpose firervoelast p 689 plate unste: Part 1: p 634 calculatins, Part 2: F p 635 lade stabil p 666 nisms asso	A90-42440 iite elemen ic analysis N90-23766 advairloads Linearized N90-24254 g unstead vill-potentia N90-24255 ization with N90-24272 ociated with A90-40641 onic turbine
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aerostocomputer program [NASA-TM-101709]  A time-marching method to calcutor on three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechan vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow thristage. I. Analysis [AIAA PAPER 90-2408]	ns p 631 surpose firervoelast p 689 slate unster Part 1: p 634 calculatin s. Part 2: F p 635 lade stabil p 666 sisms asso p 682 ough trans	A90-4244( itte elemen ic analysis N90-2376( ady airloads Linearized N90-24254 g unsteady ull-potentia N90-24255 ization with N90-24272 ociated with A90-40641 onic turbine A90-42161
2-D airfoils for helicopter application STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709] A time-marching method to calculon three-dimensional wings. formulation [DLR-FB-89-58] A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59] Calculation of the aeroelastic bilinearized process [MITT-87-01] UNSTEADY FLOW Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508] Investigation of unsteady flow thr stage. I - Analysis	p 631 p 689 p 689 p 689 p 689 p 689 p 634 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 682 ough trans	A90-42440 itte elementic analysis N90-23768 advantable Linearized N90-24256 g unsteady ull-potentia N90-24273 ization with N90-24273 ociated with A90-40641 onic turbine A90-42161 conic turbine A90-42161 conic turbine Cay
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calcuton three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow thristage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow throstigation of unsteady flow throstigatio	p 631 p 689 p 689 p 689 p 689 p 689 p 634 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 682 ough trans	A90-42440 itte elementic analysis N90-23768 advantable Linearized N90-24256 g unsteady ull-potentia N90-24273 ization with N90-24273 ociated with A90-40641 onic turbine A90-42161 conic turbine A90-42161 conic turbine Cay
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709]  A time-marching method to calcuton three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threstage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow threstage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2409]  Finite element simulation of unst	p 631 p 689 p 689 p 689 p 684 p 684 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 682 ough trans son for tim p 626 leady two-	A90-4244( itte elemen ic analysis N90-23768 ady airloads Linearizec N90-24252 g unsteady ull-potentia N90-24252 ization with N90-24272 ciated with A90-40641 onic turbine averagec A90-42162 dimensiona
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calcuon three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic binearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threstage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow threstage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows	ns p 631 surpose firervoelast p 689 slate unsterent 1: p 634 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 662 ough trans p 626 ugh a trans son for tim p 626 leady two- p 629	A90-42440 airloads analysis N90-23766 ady airloads Linearized N90-24256 g unsteady ull-potentia N90-24256 ization with N90-24272 ociated with A90-40641 onic turbine le-averaged A90-42162 dimensiona A90-42423
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709]  A time-marching method to calcutor three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechan vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threatage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow threatage. II - Data/prediction comparing the process of the pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows  Extension of a three-dimensional analysis	p 631 p 689 p 689 p 689 p 689 p 689 p 684 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 682 ough trans p 626 ugh a trans son for tim p 626 leady two- p 629 al viscous	A90-42440 iite elemen ic analysis N90-23768 ady airloads Linearized N90-24259 g unsteady ull-potentia N90-24273 ization with N90-24273 ociated with A90-40641 onic turbine e-averaged A90-42164 dimensiona A90-42426 wing flow
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calcuon three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic bilinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow thristage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow throstage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows  Extension of a three-dimensional analysis [NASA-CR-182023]	p 631 p 689 p 689 plate unste: p 689 plate unste: p 634 calculatin s. Part 2: F p 635 lade stabil p 666 nisms asso p 682 ough trans son for tim p 626 leady two- p 629 al viscous	A90-4244( itte elemen ic analysis N90-23768 ady airloads Linearizec N90-24252 g unsteady ull-potentia N90-24252 ization with N90-24272 ciated with A90-40641 onic turbine e-averagec A90-42162 dimensiona A90-42422 wing flow
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709]  A time-marching method to calcutor three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechan vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threatage. I - Analysis [AIAA PAPER 90-2408]  Investigation of unsteady flow threatage. II - Data/prediction comparing the process of the pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows  Extension of a three-dimensional analysis	ns p 631 surpose firervoelast p 689 slate unster Part 1: p 634 calculatins. Part 2: F p 635 lade stabil p 666 sisms asso p 662 ough a trans son for tim p 626 leady two- p 629 al viscous p 631 rropeller bl	A90-4244( itte elemen ic analysis N90-23768 ady airloads Linearizec N90-24252 g unsteady ull-potentia N90-24252 ization with N90-24272 ciated with A90-40641 onic turbine e-averagec A90-42162 dimensiona A90-42422 wing flow
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-TM-101709]  A time-marching method to calcutor three-dimensional wings formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic belinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechan vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threatage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows  Extension of a three-dimensional analysis [NASA-CR-182023]  Unsteady potential flow past a pressure data [NASA-CR-182023]  Unsteady potential flow past a pressure with the procession of a three-dimensional analysis [NASA-CR-182023]  An interactive boundary-layer metical compression of a three-dimensional analysis [NASA-CR-4307]  An interactive boundary-layer metical comparisons and pressure data pressure da	p 631 p 689 p 689 p 689 p 689 p 689 p 684 calculatin p 634 calculatin p 635 lade stabil p 666 nisms asso p 682 ough trans p 626 ugh a trans son for tim p 628 al viscous p 631 p 6634 hod for uns	A90-4244( itte elemen ic analysis N90-2376( ady airloads Linearized N90-24254 g unsteady ull-potentia N90-24253 ization with N90-24272 ociated with A90-40641 onic turbine - averaged A90-42162 dimensiona A90-42423 wing flow N90-23346 ade section N90-242424
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeroscomputer program [NASA-TM-101709]  A time-marching method to calcuon three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airloads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic binearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechany vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threstage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2408]  Investigation of unsteady flow threstage. II - Data/prediction compariand phase-resolved pressure data [AIAA PAPER 90-2409]  Finite element simulation of unstincompressible viscous flows  Extension of a three-dimensional analysis [NASA-CR-182023]  Unsteady potential flow past a particular compariant of the processible viscous flows  [NASA-CR-4307]	ns p 631 surpose firervoelast p 689 slate unster Part 1: p 634 calculatin s. Part 2: F p 635 lade stabil p 666 sisms asso p 662 ough trans p 626 eady two- p 629 al viscous p 631 propeller bl p 634 hod for unsodel	A90-4244( itte elemen ic analysis N90-2376( ady airloads Linearized N90-24254 g unsteady ull-potentia N90-24253 ization with N90-24272 ociated with A90-40641 onic turbine - averaged A90-42162 dimensiona A90-42423 wing flow N90-23346 ade section N90-242424
2-D airfoils for helicopter application  STARS: An integrated general-structural, aeroelastic, and aeros computer program [NASA-CR-4307]  A time-marching method to calcuton three-dimensional wings. formulation [DLR-FB-89-58]  A time-marching method for airfoads on three-dimentional wings formulation [DLR-FB-89-59]  Calculation of the aeroelastic bilinearized process [MITT-87-01]  UNSTEADY FLOW  Non-steady flow loss mechan vaneless diffusers [AIAA PAPER 90-2508]  Investigation of unsteady flow threstigation of unsteady flo	p 631 p 689 late unsterence for the revolution of the revolution o	A90-42440 itte elementic analysis N90-23768 ady airloads Linearized N90-24256 g unsteady ull-potentia N90-24272 ociated with A90-40641 onic turbine ele-averaged A90-42162 dimensiona A90-42423 wing flow N90-2348 ade section N90-24250 N90

V/STOL AIRCRAFT 2 simulation 2 5 [NASA-CR-186670] aircraft [NASA-TM-103123] [NASA-TM-103170] VANADIUM [AD-A220239] VANELESS DIFFUSERS centrifugal compressors [AIAA PAPER 90-1917] vaneless diffusers [AIAA PAPER 90-2508] VANES stage. I - Analysis [AIAA PAPER 90-2408] work transonic turbine variable-diameter rotors VELOCITY DISTRIBUTION [AIAA PAPER 90-2165] compressor VENTILATION and prospects VERTICAL LANDING landing performance **VERTICAL PERCEPTION VERTICAL TAKEOFF** landing performance Full Authority Digital Engine Control for the AS 355 N TM 319 engines VERTICAL TAKEOFF AIRCRAFT Guaranteed cost control via optimal parametric LQ design Chairwoman, Government Activities and Transportation A study of the technology required for advanced vertical Subcommittee, Committee on Government Operations, take-off aircraft House of Representatives FTN-90-967861 IGAO/RCED-88-1601 p 635 N90-23367 VIBRATION

Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump [NASA-TP-3005] Turbulence model performance in V/STOL flow field Adaptive control of a system with periodic dynamics: [AIAA PAPER 90-2248] p 625 A90-42094 Application of an impulse response method to the Direct lift STOVL engine integration helicopter vibration problem VIBRATION EFFECTS [AIAA PAPER 90-2274] p 644 A90-42103 Correlation/validation of finite element code analyses A modeling technique for STOVL ejector and volume for vibration assessment of avionic equipment [AD-A220393] [AIAA PAPER 90-2417] p 663 A90-42168 VIBRATION MEASUREMENT Advanced material applications for direct lift engines New systems for helicopter and aircraft vibration [AIAA PAPER 90-2753] p 664 A90-42226
Preliminary design of a supersonic Short Takeoff and monitoring
VIBRATION MODE Vertical Landing (STOVL) fighter aircraft Aeroelastic response characteristics of a rotor executing p 649 N90-23394 arbitrary harmonic blade pitch variations Analysis of internal flow in a ventral nozzle for STOVL VIBRATION TESTS p 666 N90-23404 A captive store flight vibration simulation project Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 New systems for helicopter and aircraft vibration Experimental and analytical study of close-coupled monitoring EH101 vibration control ventral nozzles for ASTOVL aircraft p 666 N90-24273 light aircraft [DLR-FB-89-56] Fatigue crack growth investigation of a Ti-6AI-4V forging VIBRATIONAL STRESS under complex loading conditions: NATO/AGARD supplemental engine disk program future programs p 678 N90-23538 VIBRATORY LOADS An experimental investigation of rotating stall in a system instrumentation centrifugal compressor with vaneless diffuser p 621 A90-40513 Correlation of radial-to-axial vaneless turns for VISCOPLASTICITY p 656 A90-40556 Non-steady flow loss mechanisms associated with problem p 682 A90-40641 NASA-CR-1851891 VISCOUS FLOW Investigation of unsteady flow through transonic turbine p 626 A90-42161 Turbine configuration impact on advanced IHPTET engine system mission capabilities [AIAA PAPER 90-2739] p 664 A90-42221 Application of 3-D flow analysis to the design of a high with separation [AIAA PAPER 90-2125] p 628 A90-42395 VARIABLE GEOMETRY STRUCTURES Improving tilt rotor aircraft performance with p 646 A90-42445 Relationship between velocity circulation around a wing profile and vorticity dispersion in a boundary layer p 620 Á90-39539 The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes separators [AIAA PAPER 90-2136] p 661 A90-42053 VELOCITY MEASUREMENT transonic flows over aerofoils Three-component LDA measurements in an axial-flow p 683 A90-40943 Transonic wing charge improvements by passive shock boundary layer interference control: Development status anatysis [NASA-CR-182023] p 650 N90-24267 Influence of ground effect on helicopter takeoff and [AD-A221220] p 646 A90-42468 **VOICE COMMUNICATION** A hydrodynamic turbo-fan/shaft convertible engine p 665 A90-42487 VORTEX BREAKDOWN Taking a new look at cockpit vertical situation displays p 652 A90-40382 a normal shock wave **VORTEX GENERATORS** Influence of ground effect on helicopter takeoff and p 646 A90-42468

p 665 A90-42486

p 693 A90-40810

p 650 N90-24268

p 653 A90-42477 p 647 A90-42496 On simplified analytical flutter clearance procedures for p 672 N90-24276 Helicopter surveillance - A look at current and proposed p 642 A90-39986 Rotating system load monitoring using minimum fixed n 651 A90-39982 VIDEO LANDMARK ACQUISITION AND TRACKING An image analysis method for vehicle stabilization p 668 A90-40914 Finite element analysis of structural components using viscoplastic models with application to a cowl lip p 690 N90-23769 Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing n 619 A90-39465 Viscous flow around a propeller-shaft configuration with finite-pitch rectangular blades p 683 A90-40938
Viscous-inviscid interaction method for calculating the infinite-pitch rectangular blades flow in compressor cascade blade passages and wake p 624 A90-42032 Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings [AIAA PAPER 90-2126] n 625 A90-42033 Inviscid and viscous flows in transonic and supersonic cascades using an implicit upwind relaxation algorithm [AIAA PAPER 90-2128] p 625 A90-42034 Viscous flow analysis for advanced inlet particle o 661 A90-42038 Calculation of viscous-inviscid strong interaction for p 627 A90-42364 Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications p 631 A90-42440 Extension of a three-dimensional viscous wing flow NASA-CR-182023] p 631 N90-23348 An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model p 634 N90-24250 Automatic speech recognition in air-ground data link p 690 N90-25037 The interaction of a supersonic streamwise vortex and p 633 N90-24241 Ground evaluation of seeding an in-flight wingtip vortex using infrared imaging flow visualization technique p 635 N90-25035 **VORTEX STREETS** Vorticity distribution of vortex street in the wake of a circular cylinder p 623 A90-41751 VORTICES Vortex theory for the screw propeller with a hub p 620 A90-39538

Coherent vortex structures in the wake of a sphere and

A visualization study of the interaction of a free vortex

The application of concentric vortex simulation to

calculating the aerodynamic characteristics of bodies of

p 623 A90-40749

p 623 A90-41119

p 627 A90-42357

a circular disk at rest and under forced vibrations

with the wake behind an airfoil

revolution at high angles of attack

# UPPER SURFACE BLOWING

Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740

#### **URBAN TRANSPORTATION**

Hydrogen in future energy and propulsion technology p 692 A90-41736 .Adaptive control of a system with periodic dynamics:

p 642 A90-40166 p 647 A90-42496 EH101 vibration control

The interaction of a supersonic streamwise vortex and a normal shock wave p 633 N90-24241	WIN
a normal shock wave p 633 N90-24241 Ground evaluation of seeding an in-flight wingtip vortex	wir
using infrared imaging flow visualization technique	
p 635 N90-25035	wir
Generation of circumferential velocity contours	
associated with pulsed point suction on a rotating disk	ins
p 691 N90-25065	(IL
VORTICITY	WIN
Relationship between velocity circulation around a wing profile and vorticity dispersion in a boundary layer	ı
p 620 A90-39539	[N
Navier-Stokes solutions for vortical flows over a	WIN
tangent-ogive cylinder p 620 A90-39780	AF
Vorticity distribution of vortex street in the wake of a	se
circular cylinder p 623 A90-41751	[N
Computation of flow through a centrifugal impeller with	WIN
tip leakage	,
[AIAA PAPER 90-2021] p 684 A90-41987	pa
VULNERABILITY Aviation security: Corrective actions underway, but better	A] Wini
inspection guidance still needed. Report to the	141141
Chairwoman, Government Activities and Transportation	bo
Subcommittee, Committee on Government Operations,	-
House of Representatives	air
[GAO/RCED-88-160] p 635 N90-23367	ı
'	
W	
	1
WAKES	rot
Preliminary characterization of parachute wake	, (૦
recontact p 622 A90-40681	wir
Coherent vortex structures in the wake of a sphere and	""
a circular disk at rest and under forced vibrations p 623 · A90-40749	7
A visualization study of the interaction of a free vortex	aire
with the wake behind an airfoil p 623 A90-41119	7
Viscous-inviscid interaction method for calculating the	pai
flow in compressor cascade blade passages and wake	
with separation	and
[AIAA PAPER 90-2125] p 624 A90-42032	[A]
WALL FLOW	- 1
New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel	sta
[AD-A220933] p 674 N90-24278	an [Al
WALL PRESSURE	,,,
Experimental investigation of terminal shock sensors in	NA
mixed-compression inlets [AIAA PAPER 90-1931] p 681 A90-40560	
[AIAA PAPER 90-1931] p 681 A90-40560 WARNING SYSTEMS	ext
Obstacle warning system for helicopters	wir
p 653 A90-41114	Ϊ.
Development of the stall warning/stick pusher system	var
for the Boeing/de Havilland Dash 8 Series 300	L
p 645 A90-42420	wa
WATER VAPOR Transonic flow around airfoils with relaxation and energy	(FI
supply by homogeneous condensation	mo
p 620 A90-39782	[N.
WAVE EXCITATION	
Wave structure of artificial perturbations in a supersonic	AH
boundary layer on a plate p 619 A90-39518	Set (N
WAVEGUIDE ANTENNAS  Applications of slotted cable antennas in the instrument	.,4
landing system p 639 A90-41708	inv
WEAR	wir
Evaluation of brush seals for limited-life engines	[N
[AIAA PAPER 90-2140] p 685 A90-42040	
WEATHER Inclement weather induced aircraft engine power loss	cha ogi
[AIAA PAPER 90-2169] p 662 A90-42055	[N
	į. v
WEATHER FORECASTING	
A comparison of lightning network data with surface	[N
A comparison of lightning network data with surface weather observations	
A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832	(N) <b>WINI</b> S
A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832 WEIGHT REDUCTION	(N) <b>WINI</b> Stu
A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832 WEIGHT REDUCTION  Optimum design of composite wing structures subjected	(N/ <b>WINI</b> S Stu
A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832 WEIGHT REDUCTION	(N/) <b>WINI</b> Stu Stu Hig
A comparison of lightning network data with surface weather observations [AD-A22003] p 692 N90-23832 WEIGHT REDUCTION Optimum design of composite wing structures subjected to displacement constraints p 680 A90-39276 WESTLAND AIRCRAFT Usage monitoring of military helicopters	(N/ <b>WINI</b> Stu Stu Hig Tra
A comparison of lightning network data with surface weather observations [AD-A22003] p 692 N90-23832 WEIGHT REDUCTION  Optimum design of composite wing structures subjected to displacement constraints p 680 A90-39276 WESTLAND AIRCRAFT  Usage monitoring of military helicopters p 651 A90-39984	(N/ <b>WINI</b> Stu Stu Hig Tra
A comparison of lightning network data with surface weather observations [AD-A22003] p 692 N90-23832 WEIGHT REDUCTION Optimum design of composite wing structures subjected to displacement constraints p 680 A90-39276 WESTLAND AIRCRAFT  Usage monitoring of military helicopters p 651 A90-39984 WILDERNESS	(N/ <b>WINI</b> Stu Stu Hig Tra
A comparison of lightning network data with surface weather observations [AD-A22003] p 692 N90-23832 WEIGHT REDUCTION  Optimum design of composite wing structures subjected to displacement constraints p 680 A90-39276 WESTLAND AIRCRAFT  Usage monitoring of military helicopters p 651 A90-39984	[N/ WINI S stu N Hig Tra L wa

Aviation meteorology - Panel report

Wind shear at Pantelleria airport

shear hazard to aircraft

The response of helicopter to dispersed gust p 670 A90-42470 A quantitative technique to estimate microburst wind

WIND SHEAR

p 692 A90-39403

p 692 A90-39702

p 692 N90-25040

D TUNNEL APPARATUS The six component magnetic suspension system for nd tunnel testing p 673 A90-41725 New transonic test sections for the NAE 5ftx5ft trisonic p 630 A90-42431 nd tunnel The University of Toronto-Ryerson Polytechnical stitute hypersonic gun tunnel p 673 A90-4; Test and Measurement Technique in Hypersonics p 673 A90-42432 R-MITT-225(1989)] p 618 N90-24225 D TUNNEL CALIBRATION Flow unsteadiness effects on boundary layers ASA-CR-186067] p 690 N90-24557 D TUNNEL MODELS Aerodynamic performance of a 0.27-scale model of an 1-64 helicopter with baseline and alternate rotor blade ASA-TM-4201] p 632 N90-24237 D TUNNEL STABILITY TESTS Wind tunnel tests of a 20-gore disk-gap-band rachute D-A221326) p 634 N90-24251 D TUNNEL TESTS Wave structure of artificial perturbations in a supersonic undary layer on a plate p 619 A90-39518 The cryogenic wind tunnel as a testing tool for frame/propulsion systems p 672 A90-40400 Investigation of the near wake of a propfan p 622 A90-40686 Experimental windtunnel studies for EFA p 672 A90-41113 Wind-tunnel measurement of noise emitted by helicopter ors at high speed NERA, TP NO. 1990-28] p 695 A90-41207 The six component magnetic suspension system for p 673 A90-41725 p 673 A90-41726 nd tunnel testina Cryogenic wind tunnels A new noise certification method for 'light propeller craft' in testing p 635 A90-41728 of control-surface compensation The influence rameters on the hinge moment characteristics p 643 A90-41737 Design and analysis of a large-plug inlet ADP nacelle d pylon --- Advanced Ducted Prop AA PAPER 90-2015] p 673 A90-41986 nvestigation of unsteady flow through a transonic turbine ge. II - Data/prediction comparison for time-averaged d phase-resolved pressure data AA PAPER 90-24091 p 626 A90-42162 Vind tunnel results and numerical computations for the E deHavilland series of natural laminar flow airfoils p 628 A90-42403 Measurements of aerodynamic forces on aircraft ternal stores in the NAE trisonic blowdown p 629 A90-42419 d-tunnel mproving tilt rotor aircraft performance p 646 A90-42445 iable-diameter rotors ow speed testing of a laminar flow airfoil in an adaptive A-TN-1989-081 FA-TN-1989-08] p 632 N90-23363 Experimental performance and acoustic investigation of dern, counterrotating blade concepts ASA-CR-185158] p 649 N90-23393 Aerodynamic performance of a 0.27-scale model of an -64 helicopter with baseline and alternate rotor blade ASA-TM-42011 p 632 N90-24237 Static wind-tunnel and radio-controlled flight test estigation of a remotely piloted vehicle having a delta na planform ASA-TM-4200] p 632 N90-24238 Subsonic sting interference on the aerodynamic aracteristics of a family of slanted-base ve-cvlinders ASA-CR-4299] p 633 N90-24242 low unsteadiness effects on boundary layers p 690 N90-24557 ASA-CR-1860671 D TUNNEL WALLS Sidewall boundary-layer removal and wall adaptation p 672 A90-40680 Wind tunnel wall interference investigations in NAE/NRC h Reynolds Number 2D Facility and NASA Langley 0.3m p 628 A90-42404 Insonic Cryogenic Tunnel ow speed testing of a laminar flow airfoil in an adaptive Il wind tunnel FA-TN-1989-08] p 632 N90-23363 D TUNNELS Langley aerospace test highlights, 1989 [NASA-TM-102631] p 69

p 699 N90-24221

p 673 N90-24227

p 689 N90-23762

The gun tunnel of the Brunswick Institute for Fluid

Nondestructive measurement of residual stresses in

Mechanics: Current development status

WINDSHIELDS

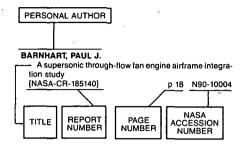
[AD-A218680]

aircraft transparencies

WING CAMBER Aerodynamic development perspective for traffic [DGLR-89-141] p 637 N90-24260 WING LOADING An experimental and analytical investigation of the buffet excitation parameter p 645 A90-42417 Transonic wing charge improvements by passive shock boundary layer interference control: Development status and prospects [ETN-90-96463] p 650 N90-24267 WING NACELLE CONFIGURATIONS Critical review of design philosophies for recent transport WIG effect vehicles - Wing-in Ground p 684 A90-41753 The flow over a wing/nacelle combination in the presence of a propeller slipstream n 629 A90-42415 WING OSCILLATIONS Various sources of wing rock p 622 A90-40679 Flow structure generated by oscillating delta-wing egments p 622 A90-40694 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41 p 623 A90-41203 WING PANELS Impact damage and residual strength analysis of composite panels with bonded stiffeners --- for primary aircraft structures p 642 A90-40130 WING PROFILES Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing p 619 A90-39465 Relationship between velocity circulation around a wing profile and vorticity dispersion in a boundary layer p 620 A90-39539 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740 WING ROOTS Agusta methodology for pitch link loads prediction in p 646 A90-42465 preliminary design phase WING TIP VORTICES Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41 p 623 A90-41203 WING TIPS Ground evaluation of seeding an in-flight wingtip vortex using infrared imaging flow visualization technique p 635 N90-25035 WINGS Optimum design of composite wing structures subjected to displacement constraints WORKSTATIONS p 680 A90-39276 Simulator evaluation of the final approach spacing tool [NASA-TM-102807] p 636 N90-23374 X X-30 VEHICLE The challenge of demonstrating the X-30 p 659 A90-41162 YAW Actuated forebody strakes p 648 N90-23390 [NASA-CASE-LAR-13983-1]

p 617 A90-40648

#### Typical Personal Author **Index Listing**



Listings in this index are arranged alphabetically by personal author. The title of the document provides the user with a brief description of the subject matter. The report number helps to indicate the type of document listed (e.g., NASA report, translation, NASA contractor report). The page and accession numbers are located beneath and to the right of the title. Under any one author's name the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

#### ABDOL-HAMID, KHALED S.

Application of a new adaptive grid for aerodynamic analysis of shock containing single jets

[AIAA PAPER 90-2025] p 624 A90-41988

## ABILEAH, ADI

Performance of full color active-matrix-LCD in the cockpit p 681 A90-40392 environment

#### ABU-HAKIMA, SUHAYYA

Jet Engine Technical Advisor (JETA)

p 693 A90-41184

#### ACAMPORA, G.

EH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489

#### ADAMS, R. J.

Aeronautical decisionmaking for air ambulance program administrators

p 635 N90-23368 (DOT/FAA/DS-88/8)

#### ADAMSON, J. D.

The development of a probabilistic turbine rotor design system p 662 A90-42060

#### [ÁIAA PAPER 90-2176] AFZALI. HOSSEIN

Development and verification of software for flight safety p 694 A90-42454 critical strapdown systems

#### AGARWAL, R.

Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas

p 630 A90-42439

#### AHMED, S. R.

Comparison with experiment of various computational methods of airflow on three helicopter fuselages p 630 A90-42436

## AKINYANJU, TED

Ground evaluation of seeding an in-flight wingtip vortex using infrared imaging flow visualization technique p 635 N90-25035

#### ALAG, GURBUX S.

A proposed Kalman filter algorithm for estimation of unmeasured output variables for an F100 turbofan

[AIAA PAPER 90-1920] p 656 A90-40558

#### ALCORN, CHARLES W.

Subsonic sting interference on the aerodynamic characteristics of a family of slanted-hase ogive-cylinders

p 633 N90-24242 [NASA-CR-4299]

ALI, ALI Y A/F32T-9 large turbo fan engine enclosed noise suppressor system (T-9 NSS), exterior far-field and interior

noise, McConnell AFB, Kansas [AD-A220535] p 665 N90-23402

#### ALLAIRE, P. E.

Digital control of magnetic bearings supporting a p 682 A90-40712 multimass flexible rotor

A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed p 632 N90-23359 [DLC-EST-TN-030]

AMER KENNETH R

A 'new' philosophy of structural reliability, fail safe versus safe life p 688 A90-42490

#### AMBANI AHMED OMAR

Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166 AMTSBERG I

Comparison with experiment of various computational methods of airflow on three helicopter fuselage p 630 A90-42436

#### ANDERSON, J. THOMAS

Airframe/propulsion integration of supersonic cruise vehicles p 644 A90-42047

[AIAA PAPER 90-2151]

## ANDERSON, N. E.

Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274

#### ANDO, SHIGENORI

Critical review of design philosophies for recent transport WIG effect vehicles p 684 A90-41753

ANDRE, PIERRE

Toward total quality in industry p 684 A90-41768 ANDRES, J.

Eurofar - Status of the European tilt-rotor project p 645 A90-42441

## ANDRISANI, DOMINICK

Estimating short-period dynamics using an extended Kalman filter

ANISHCHENKO, P. M.

[NASA-TM-101722] p 648 N90-23392

The development result of SPEKTR automated air traffic control (ATC) system with extended grade of automation p 639 A90-41058 for terminal and hub areas ANJUM, M. I.

Non-steady flow loss mechanisms associated with vaneless diffusers

[AIAA PAPER 90-2508] p 682 A90-40641 ARMSTRONG, HERBERT B.

Automatic speech recognition in air-ground data link p 690 N90-25037

#### ARNETT, ERIC M.

Propulsion control system designs for advanced Navy multimission aircraft

[AIAA PAPER 90-2403] p 663 A90-42160

## ARNOLD, RICHARD

MLS - Keeping pace with the future p 640 A90-41709

## ARONSON, MOSES

Taking a new look at cockpit vertical situation displays p 652 A90-40382

#### ARTLEY, M. E.

The influence of material quality on airframe structuraldurability p 676 A90-41336

Hydraulic accumulators and high pressure bottles in p 688 A90-42493 composite material

#### ARVANITIS, S.

Planet gear sleeve spinning analysis

### ARYA, V. K.

[AIAA PAPER 90-2154] p 681 A90-40613

Finite element analysis of structural components using viscoplastic models with application to a cowl lip

[NASA-CR-185189]

p 690 N90-23769

#### ASAI, KEISUKE

The cryogenic wind tunnel as a testing tool for airframe/propulsion systems p 672 A90-40400

ATAMANCHUK, T. M.

On- and off-design performance analysis of hypersonic detonation wave ramjets

TAIAA PAPER 90-24731 p 664 A90-42188 ATKIN, KEITH N.

The EH101 electronic instrument system p 652 A90-40462

#### ATKINSON, A. STUART

Rationale for determining information associated with aircraft gas turbine engines that is of historical

[AIAA PAPER 90-2754]

AVERBACH, B. L. Initiation of spalling in aircraft gas turbine bearings [AIAA PAPER 90-2291] p 686 A90-42110

AZUMA. AKIRA Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469

## В

#### BAEUMKER, MANFRED

Analytical evaluation of helicopter true air speed and p 647 A90-42499 associated flight tests BAHR D W

Fuel effects on gas turbine combustor dynamics

p 676 A90-40570 [AIAA PAPER 90-1957]

BAILEY, M. W.

Automated aircraft engine costing using artificial intelligence p 660 A90-41981

[AIAA PAPER 90-1887]

BALDWIN, S. F. Flight tests to explore tail rotor limitations in the low p 647 A90-42498 speed envelope

RALLAL, D. R.

Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530

#### BAN, XIANLIN

The application of concentric vortex simulation to calculating the aerodynamic characteristics of bodies of revolution at high angles of attack p 627 A90-42357

BANSOD, PRAKASH Computation of flow through a centrifugal impeller with

tip leakage [AIAA PAPER 90-2021] p 684 A90-41987

# BARAI, AMALESH

Flutter of shaft-supported low aspect-ratio control surfaces p 667 A90-38912

## BARANKIEWICZ, W. S.

A modeling technique for STOVL ejector and volume dynamics

[AIAA PAPER 90-2417] p 663 A90-42168 BARBER, D. J.

## Preliminary design and analysis of propellers

p 645 A90-42407 BARBER, S. A. Evaluation of solid lubricant powder delivery system for

turbine bearing lubrication

[AIAA PAPER 90-2046] p 684 A90-41997

BARBER, T. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system

AIAA PAPER 90-2492] p 658 A90-40637 BARBOT, ANDRE

Developmental tests on the M 88 engine are on track p 660 A90-41761

#### BATTARREE, D. I.

p 647 A90-42496 EH101 vibration control BATTEY, DAVID E.

Holographic combiner design to obtain uniform symbol brightness at head-up display video camera p 652 A90-40394

#### BAUER, JEFFREY E.

Estimating short-period dynamics using an extended Kalman filter

p 648 N90-23392 [NASA-TM-101722]

BEGUIN, DANIEL  Dual cross-polarization planar arrays in the C and bands  p 638 A90-4097  BEHNKE, BERND  Model of a labyrinth seal with flow  p 687 A90-4233	BLOY, ALBERT W.	BRYAN, W. BARRY
BEHNKE, BERND Model of a labyrinth seal with flow		Flow induced forced response of an incompressible
Model of a labyrinth seal with flow	longitudinal stability and control during air to air	radial cascade including profile and incidence effect
	refuelling p 669 A90-41767	[AIAA PAPER 90-2352] p 626 A90-4213
. p 001 A30-1233	BOCIEK, STANISLAW	BUCCI, R. J.  The influence of material quality on airframe structural
BELAN, V. V.	Digital delophot to high discount process	durability p 676 A90-4133
Synthesis of optimal multidimensional digital system	BOGARDUS, SCOTT  High speed civil transport	BUCKNER, RANDY L
for the simulation of the angular motions of a flight vehicle	[NASA-CR-186661] p 649 N90-23396	The collection of usage data to improve structura
under random loading p 669 A90-4195	BOHLMANN, JONATHAN D.	integrity of operational helicopters p 651 A90-3998
BELIAEV, N. M.	Static percelastic tailoring for oblique wing lateral trim	BURCHAM, FRANK W., JR.
Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing	p 667 A90-40689	Propulsion system-flight control integration-flight evaluation and technology transition
p 619 A90-3946	BOHN, HANS EINAR	[AIAA PAPER 90-2280] p 644 A90-4210
BELLMARD, LARRY	An aircraft noise study in Norway p 698 N90-24872	BUREAU, J. L.
Preliminary design of a supersonic Short Takeoff and	BONHAUS, DARYL L	Measurements of aerodynamic forces on aircraft
Vertical Landing (STOVL) fighter aircraft	Strake camber and thickness design procedure for low alpha supersonic flow p 622 A90-40678	external stores in the NAE trisonic blowdown
[NASA-CR-186670] p 649 N90-2339-	alpha supersonic flow p 622 A90-40678  BONIFACIO, R.	wind-tunnel p 629 A90-4241
BELOTSERKOVSKII, SERGEI M.  Mathematical modeling of plane parallel separated flow	and the common to the state of	BURKHARD, ALAN H.  Application of fracture mechanics to microscal
past bodies p 619 A90-3947		phenomena in electronic assemblies
BEN BUEMI, S.	BOOCOCK, RUSS	p 684 A90-4133
Redesign of an electro-optical shroud in		BURSEY, R.
graphite/epoxy p 676 A90-4021	· · · · · · · · · · · · · · · · · · ·	Flight test results of the F-15 SMTD thrus
BENETSCHIK, HANNES	BORCHERS, PAUL	vectoring/thrust reversing exhaust nozzle
Inviscid and viscous flows in transonic and supersonic cascades using an implicit upwind relaxation algorithm		[AIAA PAPER 90-1906] p 660 A90-4198 BURT, E. G. C.
[AIAA PAPER 90-2128] p 625 A90-42034		Hypersonic (T-D) 'pinch' and aerospaceplane
BENNETT, BRADFORD C.	BORGNOLO, F.	propulsion
Calculation of hypersonic forebody/inlet flow fields	EH-101 main rotor hub application of thick carbon fiber	[AIAA PAPER 90-2474] p 675 A90-4218
[AIAA PAPER 90-1493] p 619 A90-39049	unidirectional tension bands p 618 A90-42489	BUSH, ROBERT H.
ENNETT, JOE	BORSHCH, V. L.	Computational modeling of inlet hammershock way
Lightweight fuel pump and metering component fo advanced gas turbine engine control		generation [AIAA PAPER 90-2005] p 621 A90-4059
[AIAA PAPER 90-2032] p 657 A90-40602	of a viscous gas past a concave conical wing p 619 A90-39465	BUSSING, THOMAS R. A.
SENNETT, RICHARD L.	BOTROS, DAVID F.	Transverse fuel-injection model for a scramjet propulsio
Design methodology for multivariable helicopter contro	Feasibility study for a microwave-powered ozone sniffer	system p 659 A90-4092
systems p 669 A90-42461		BUTTLE, D. J.
BENNETT, W. A.  Investigation of unsteady flow through a transonic turbine	[NASA-CR-186660] p 650 N90-23397	Characterisation of fatigue of aluminium alloys b acoustic emission. Part 2: Discrimination between primar
stage. II - Data/prediction comparison for time-averaged		and other emissions
and phase-resolved pressure data	A highly maneuverable helicopter in-light simulator -  Aspects of realization	[AERE-R-13303-PT-2] p 678 N90-2352
[AIAA PAPER 90-2409] p 626 A90-42162		BUYUKATAMAN, KAYAALP
ENNINGTON, DONALD R.	BOUWER, GERHARD	Gearbox system design for ultra-high bypass engine
Real-time simulation clock	ATTHeS - A helicopter in-flight simulator for ACT	[AIAA PAPER 90-2152] p 685 A90-4204
[NASA-CASE-LAR-14056-1] p 689 N90-23713 BENSON, ROBERT L.	, , , , , , , , , , , , , , , , , , ,	BYRD, GREGORY P.  A quantitative technique to estimate microburst wind
Peacetime replacement and crash damage factors for	BOWES, MICHAEL A. SH-2F airframe fatigue test program	shear hazard to aircraft p 692 N90-2504
army aircraft	p 642 A90-39989	
[AD-A218544] p 636 N90-23372		C
BERGER, E.	Supersonic rectangular isothermal shrouded jets	•
Coherent vortex structures in the wake of a sphere and a circular disk at rest and under forced vibrations		CAIN, BRENDAN G.
p 623 A90-40749	BOZZOLA, P.  Use of smart actuators for the tail rotor collective pitch	AIRNET: A real-time comunications network fo
BERNINGER, DANIEL J.	control p 688 A90-42483	aircraft
Flight safety performance of the microwave landing		[NASA-CR-186140] p 690 N90-2451
system p 639 A90-41705	The state of the s	CAIRO, R. R.  Bonded airfoil attachments - A path to rotor structura
ETTNER, J. L. Precurser convertible engine study	techniques p 668 A90-40817	efficiency
[AIAA PAPER 90-2486] p 658 A90-40636	BRANGIER, F.  Applications of Mode S secondary surveillance radar	[AIAA PAPER 90-2177] p 686 A90-4206
BETTNER, JAMES L.	to civil air traffic control - Studies, experiments, and policy	CALMON, JEAN
Component arrangement studies for an 8000 shp	of the French Direction de la Navigation Aerienne	Military engines - Cradle of technology
turboshaft high technology core	p 639 A90-41056	p 660 A90-4175
[AIAA PAPER 90-2398] p 663 A90-42159		CAMERON, C. D.
HATT, VINAY  Multilevel optimization of large-scale structures in a	Numerical modeling of an impinging jet in cross-flow	Symmetry assessment of an air-blast atomizer spray p 682 A90-4093
parallel computing environment p 693 A90-39180		CANNELLA, VINCENT
HUNGALLA, AMAR	Subsonic sting interference on the aerodynamic	Performance of full color active-matrix-LCD in the cocke
Correlation/validation of finite element code analyses		environment p 681 A90-4039
for vibration assessment of avionic equipment	ogive-cylinders	CARDEN, HUEY D.
[AD-A220393] p 654 N90-23398		Unique failure behavior of metal/composite aircra
ICEN, A. F.	BROADBENT, E. G.	structural components under crash type loads
Combustion characteristics of a model can-type		[NASA-TM-102679] p 690 N90-2466
combustor p 676 A90-40479	[AIAA PAPER 90-2474] p 675 A90-42189	CARICO, DEAN
ILLMAN, BARRY R. Position computation without elevation information for	DROUM D	Helicopter controllability [AD-A220078] p 672 N90-2427
computed centerline operations	Measurements of aerodynamic forces on aircraft	CARLSON, LELAND A.
[DOT/FAA/CT-TN89/42] p 640 N90-23379		Determination of aerodynamic sensitivity coefficient
BIRD, VICTOR J.	wind-tunnel p 629 A90-42419	based on the transonic small perturbation formulation
Fiber-optic turbine inlet temperature measurement	New transonic test sections for the NAE 5ftx5ft trisonic wind tunnel p 630 A90-42431	p 622 A90-4068
system (FOTITMS)	New transcapia tost sactions for the NAE 5 ft v 5 ft trisonia	CARONI, L.
[AIAA PAPER 90-2033] p 657 A90-40603	wind tunnel	EH-101 main rotor hub application of thick carbon fibe
BIRMAN, V.	[AD-A220933] n 674 N90-24278	unidirectional tension bands p 618 A90-4248
	BROWN, GERALD V.	CARR, L. W.
Supersonic flutter of shear deformable laminated	experimental evaluation of a tuned electromagnetic	Flow visualization studies of the Mach number effect on dynamic stall of an oscillating airfoil
composite flat panels p 683 A90-41104	damper for vibration control of cryogenic turbopump	p 622 A90-4068
composite flat panels p 683 A90-41104 BISWAS, GAUTAM	rotom	
composite flat panels p 683 A90-41104	101013	CARROLL, B. F.
composite flat panels p 683 A90-41104 BISWAS, GAUTAM Multi-level models for diagnosis of complex		CARROLL, B. F. Computation of multiple normal shock wave/turbuler
composite flat panels p 683 A90-41104  ISWAS, GAUTAM  Multi-level models for diagnosis of complex electro-mechanical systems p 693 A90-38888  BLAKE, DAVID R.  Fire hazards of aerosol cans in aircraft cargo	(NASA-TP-3005) p 665 N90-23403 BROWN, H. A.	Computation of multiple normal shock wave/turbuler boundary layer interactions
composite flat panels p 683 A90-41104 IISWAS, GAUTAM Mutil-level models for diagnosis of complete electro-mechanical systems p 693 A90-38888 BLAKE, DAVID R. Fire hazards of aerosol cans in aircraft cargo compartments	[NASA-TP-3005] p 665 N90-23403  BROWN, H. A.  A comparison of lightning network data with surface weather observations	Computation of multiple normal shock wave/turbulen boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-4203
composite flat panels p 683 A90-41104 ISWAS, GAUTAM Multi-level models for diagnosis of complex p 693 A90-38886 BLAKE, DAVID R. Fire hazards of aerosol cans in aircraft cargo compartments [DOT/FAA/CT-89/32] p 636 N90-23368	[NASA-TP-3005] p 665 N90-23403  BROWN, H. A.  A comparison of lightning network data with surface weather observations [AD-A220003] p 692 N90-23832	Computation of multiple normal shock wave/turbulen boundary layer interactions [AIAP PAPER 90-2133] p 685 A90-4203: CARROTTE, J.
composite flat panels p 683 A90-41104 IISWAS, GAUTAM Mutil-level models for diagnosis of complete electro-mechanical systems p 693 A90-38888 BLAKE, DAVID R. Fire hazards of aerosol cans in aircraft cargo compartments	[NASA-TP-3005] p 665 N90-23403  BROWN, H. A.  A comparison of lightning network data with surface weather observations	Computation of multiple normal shock wave/turbulen boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-4203

CHESNAKAS, CHRISTOPHER J.

compressor

Three-component LDA measurements in an axial-flow

High enthalpy hypersonic wind tunnel F4: General

description and associated instrumentation

p 683 A90-40943

p 673 N90-24228

PERSONAL AUTHOR INDEX		
CARROTTE, J. F.	CHIGIER, NORMAN	CONWAY, JOHN T.
Experimental studies of combustor dilution zone	Laser Doppler velocimetry investigation of swirler	Modelling of bou
aerodynamics. II - Jet development p 659 A90-40947	flowfields p 682 A90-40929	effects for the
CASTRO-LINARES, R.	CHILDS, E. P.  Turbulence model performance in V/STOL flow field	transpiration
Helicopter control design using feedback linearization techniques p 668 A90-40817	simulation	COOPER, G. K. CFD application
techniques p 668 A90-40817 CAVALIERE, M.	[AIAA PAPER 90-2248] p 625 A90-42094	[AIAA PAPER 90-
Problems of internal acoustics in two and three	CHIN, JU SHAN	CORDIER, STEPHA
dimensional cavities with deformable walls using the	Influence of fuel composition on flame radiation in gas	Rotary-Jet thrus
MSC/Nastran code	turbine combustors p 659 A90-40946	riotaly-oet unus
[DLC/STR-INT-TN-004] p 699 N90-24876	CHITTUM, CHARLES B.	CORTELLINI, FRAN
CEBECI, TUNCER	The influence of adjacent seating configurations on	The safety analy
An interactive boundary-layer method for unsteady airfoil	egress through a type 3 emergency exit	
flows. Part 1: Quasi-steady-state model	[AD-A218393] p 636 N90-23371	COSNER, RAYMON
[AD-A221220] p 634 N90-24250	CHO, JINSOO	Computational
CEDOZ, R. W.	Counter-rotating propellant analysis using a frequency domain panel method p 623 A90-40937	generation
Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274	CHOI, GWAN SEUNG	[AIAA PAPER 90-
CELI, ROBERTO	An experimental study of fault propagation in a jet-engine	COSTES, JJ.
Aeroelastic effects on stability and control of hingeless	controller	Coupled aerody
rotor helicopters p 647 A90-42473	[NASA-CR-181335] p 665 N90-23401	a high-aspect-ratio [ONERA, TP NO.
CERBE, T.	CHRISTIANSEN, HOWARD	COTTRELL, CHARL
Influence of ground effect on helicopter takeoff and	Helicopter Airborne Laser Positioning System (HALPS)	Drag reduction
landing performance p 645 A90-42278	[NASA-TM-102814] p 654 N90-23399	stepped afterbodie
Influence of ground effect on helicopter takeoff and	CHRISTOPHE, J.	CRANE, PETER M.
landing performance p 646 A90-42468	High enthalpy hypersonic wind tunnel F4: General	Dynamic FLIR si
CERTAIN, BERNARD	description and associated instrumentation	•
Full Authority Digital Engine Control for the AS 355 N	p 673 N90-24228 CHRYSANTHOU, A.	CRAWFORD, DANII
TM 319 engines . p 665 A90-42486	Identification of multivariable models of jet engines	Real-time simula
CHAMBERLAIN, R. R.  Calculation of three-dimensional jet interaction	[AIAA PAPER 90-1874] p 655 A90-40540	[NASA-CASE-LAR
flowfields	Design of digital self-selecting multivariable controllers	CROSS, C. J.
[AIAA PAPER 90-2099] p 624 A90-42018	for jet engines	Metal matrix co
CHAN, Y. Y.	[AIAA PAPER 90-1875] ρ 655 A90-40541	[AIAA PAPER 90-2 CROSS, JEFFREY
Wind tunnel wall interference investigations in NAE/NRC	CHU, WULI	Helicopter Airbo
High Reynolds Number 2D Facility and NASA Langley 0.3m	An experimental investigation of rotating stall in a	(NASA-TM-102814
Transonic Cryogenic Tunnel p 628 A90-42404	centrifugal compressor with vaneless diffuser	CUCCIO, J.
New transonic test sections for the NAE 5ftx5ft trisonic	p 621 A90-40513	Development of
wind tunnel p 630 A90-42431	CHUNG, Y. L.	turbine component
New transonic test sections for the NAE 5 ft x 5 ft trisonic	Numerical simulations of gas turbine combustor flows	[AIAA PAPÉR 90-2
wind tunnel	[AIAA PAPER 90-2305] p 686 A90-42116 CHUPP, RAYMOND E.	CURTISS, H. C., JR.
[AD-A220933] p 674 N90-24278	Evaluation of brush seals for limited-life engines	Influence of gro
CHAND, SUJEET  Energy based stability analysis of a fuzzy roll controller	[AIAA PAPER 90-2140] p 685 A90-42040	landing performance
design for a flexible aircraft wing p 668 A90-40833	CLARK, JIM A.	Influence of gro
CHANDRA, RAMESH	Modeling gas turbine combustor performance under	landing performand
Estimation of fatigue crack growth in patched cracked	transient conditions	
panels p 684 A90-41335	[AIAA PAPER 90-2161] p 661 A90-42051	
CHANDRASEKHARA, M. S.	CLER, A.	
Flow visualization studies of the Mach number effects	Comparison with experiment of various computational	DABBENE, DANILO
on dynamic stall of an oscillating airfoil	methods of airflow on three helicopter fuselages	Expert system for
p 622 A90-40683	p 630 A90-42436	an intensive protot
CHAPPELL, M. A.	Experimental study of the flow around an helicopter	DAHLEN, HELMUT
Adjusting turbine engine transient performance for the	fuselage - Comparison with three-dimensional boundary	Acoustics of ultra
effects of environmental variances [AIAA PAPER 90-2501] p 658 A90-40639	layer calculations p 630 A90-42438	A new noise c
[AIAA PAPER 90-2501] p 658 A90-40639 CHEATHAM, P. L.	Improving helicopter aerodynamics - A step ahead	aircraft' in testing DANCEY, CLINTON
Computation of vectoring nozzle performance	p 631 A90-42443	Three-componer
[AIAA PAPER 90-2752] p 627 A90-42225	CLOUSER, S.	compressor
CHEESEMAN, IAN C.	Fuel effects on gas turbine combustor dynamics	DANIELSON, ARNO
The place of knowledge based systems in helicopter	[AIAA PAPER 90-1957] p 676 A90-40570	Inverse heat trans
dynamic system condition prognosis	CODY, CHARLOTTE K.	aluminum on TVC
p 618 A90-42475	Feasibility study for a microwave-powered ozone sniffer	(AIAA PAPER 90-1
CHEN, KENNY	aircraft	DARYMOV, IURII P.
NASA/USRA high altitude reconnaissance aircraft	[NASA-CR-186660] p 650 N90;23397	Air traffic control
[NASA-CR-186685] p 650 N90-24266	COHEN, GERALD C. IAPSA 2 small-scale system specification	DAVIDSON, PHILIPF
CHEN, NAIXING	[NASA-CR-182006] p 695 N90-24103	Jet Engine Tech
Numerical solution of 3-D hybrid problems in turbomachinery p 621 A90-40501	• • • • • • • • • • • • • • • • • • • •	DAVIC M H A
turbomachinery p 621 A90-40501 CHEN, REN LIANG	COHEN, J. M. Influences on the uniformity of sprays produced by gas	DAVIS, M. H. A. An image analys
The response of helicopter to dispersed gust	turbine high shear nozzle/swirler assemblies	All illiago alialys
p 670 A90-42470	[AIAA PAPER 90-2193] p 686 A90-42068	DAVIS, THOMAS J.
CHEN, REN-LIANG	COIRO, DOMENICO P.	Simulator evalua
The influence of the inertia coupling on the stability and	A computer code for the prediction of aerodynamic	[NASA-TM-102807
control of the helicopter and the response of helicopter	characteristics of lifting airfoils at transonic speed	DE BRUIN, A. C.
gust p 671 A90-42472	[DLC-EST-TN-030] p 632 N90-23359	Comparison with
CHEN, RUXIAN	Prediction of aerodynamic performance of airfoils in low	methods of airflow
Calculation of viscous-inviscid strong interaction for	Reynolds number flows	
transonic flows over aerofoils p 627 A90-42364	[DLC-EST-TN-031] p 632 N90-23360	DE HOFF, RONALD
CHEN, SHYI-YAUNG	COLEHOUR, J. L.	The application o
Extension of a three-dimensional viscous wing flow	Investigation of very high bypass ratio engines for	tool to aircraft engi
analysis	subsonic transports p 659 A90-40945	[AIAA PAPER 90-2
[NASA-CR-182023] p 631 N90-23348	COLOZZA, ANTHONY J.	DE OLIVEIRA, M. C.
CHEN, WENJUN  Analysis of aeroelastic divergence for the slender flight	Preliminary design of a long-endurance Mars aircraft	Implementation of
vehicles p 680 A90-39298	[AIAA PAPER 90-2000] p 674 A90-40587	DE SAINT-VICTOR,
CHENG, VICTOR H. L.	COLVIN, M. ALEXANDER	Experimental stu
Concept development of automatic guidance for	AIRNET: A real-time comunications network for	fuselage - Compar
rotorcraft obstacle avoidance p 669 A90-41632	aircraft	layer calculations
CHESNAKAS CHRISTOPHER I	[NASA-CR-186140] p 690 N90-24514	DEL AMASANTIERE

COMMON, CHRISTIAN J.

[AIAA PAPER 90-2403]

CONLIFFE, CALVIN H.

Propulsion control system designs for advanced Navy multimission aircraft

Turbofans turn to UHB propulsion p 659 A90-41165

p 663 A90-42160

Modelling of boundary layer and trailing edge thickness ects for the Euler equations using surface nspiration p 629 A90-42412 PER, G. K. CFD applications in an aerospace engine test facility

[AA PAPER 90-2003] p 681 A90-40590 DIER, STEPHANE JEAN Rotary-Jet thrust augmentor with jet-flapped blades p 633 N90-24243 TELLINI, FRANCESCO The safety analysis approach for the EH101 p 635 A90-42456 NER. RAYMOND R. Computational modeling of inlet hammershock wave AA PAPER 90-20051 p 621 A90-40592 ES. J.-J. coupled aerodynamic forces due to unsteady stall on igh-aspect-ratio wing oscillating at high amplitude NERA, TP NO. 1990-24] p 623 A90-41 p 623 A90-41203 RELL, CHARLES J. trag reduction by controlling flow separation using pped afterbodies p 622 A90-40690 ynamic FLIR simulation in flight training research p 681 A90-40109 WFORD, DANIEL J. leal-time simulation clock SA-CASE-LAR-14056-1] p 689 N90-23713 Metal matrix composites structural design experience AA PAPER 90-2175] p 677 A90-42059 p 677 A90-42059 S, JEFFREY lelicopter Airborne Laser Positioning System (HALPS) (SA-TM-102814] p 654 N90-23399 evelopment of impact design methods for ceramic gas ine components A PAPER 90-2413] p 687 A90-42165 188, H. C., JR. ifluence of ground effect on helicopter takeoff and ling performance p 645 A90-42278 ifluence of ground effect on helicopter takeoff and p 646 A90-42468 ding performance D BENE, DANILO xpert system for pilot assistance - The challenge of ntensive prototyping p 693 A90-38909 ntensive prototyping EN, HELMUT coustics of ultralight airplanes p 643 A90-40685 new noise certification method for 'light propeller p 635 A90-41728 EY, CLINTON L. hree-component LDA measurements in an axial-flow p 683 A90-40943 ELSON, ARNOLD O. verse heat transfer studies and the effects of propellant ninum on TVC jet vane heating and erosion p 655 A90-40533 A PAPER 90-18601 MOV, IURII P. p 638 A90-39581 SON, PHILIPPE et Engine Technical Advisor (JETA) p 693 A90-41184 S. M. H. A. n image analysis method for vehicle stabilization p 668 A90-40914 S, THOMAS J. imulator evaluation of the final approach spacing tool SA-TM-102807] p 636 N90-23374 RUIN, A. C. comparison with experiment of various computational hods of airflow on three helicopter fuselages p 630 A90-42436 OFF. RONALD L. he application of an expert maintenance and diagnostic to aircraft engines p 657 A90-40605 LIVEIRA, M. C. F. nplementation of a transputer-based flight controller p 667 A90-38966 AINT-VICTOR, X. xperimental study of the flow around an helicopter elage - Comparison with three-dimensional boundary er calculations p 630 A90-42438 DELAMASANTIERE, CLAUDE Starter systems and auxiliary power units p 660 A90-41760 DELANEUVILLE, R. E. The development of a probabilistic turbine rotor design [AIAA PAPER 90-2176] p 662 A90-42060

FARIOLI, M.
EH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489

Characterization of helicopter turboshaft engine noise p 660 A90-41759

FARRANDO, ALAIN

DELANEY, R. A.	Multiple swirler dome combustor for high temperature	EL-FOULY, M.
Investigation of unsteady flow through transonic turbine	rise applications	Application of 3-D flow analysis to the design of a high
stage. I - Analysis	[AIAA PAPER 90-2159] p 661 A90-42050	work transonic turbine p 628 A90-42395
[AIAA PAPER 90-2408] p 626 A90-42161	DOHRMANN, ULRICH	ELANDS, P. J. M.  Experimental and computational flammability limits in a
Investigation of unsteady flow through a transonic turbine stage. II - Data/prediction comparison for time-averaged	Transonic flow around airfoils with relaxation and energy supply by homogeneous condensation	solid fuel ramjet
and phase-resolved pressure data	. р 620 А90-39782	[AIAA PAPER 90-1964] p 676 A90-40574
[AIAA PAPER 90-2409] p 626 A90-42162	DOLEGA, BOGUSLAW	ELBANNA, HESHAM M.
DEMATTEIS, P. P.	Digital autopilot for light aircraft p 653 A90-41741	Determination of aerodynamic sensitivity coefficients
A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed	DONG, MING	based on the transonic small perturbation formulation p 622 A90-40682
[DLC-EST-TN-030] p 632 N90-23359	Numerical solution of 3-D hybrid problems in turbomachinery p 621 A90-40501	ELIAS DE LOS REYES, DAVO
DENICOLA, CARLO	DONOVAN, JOHN F.	Use of pulse radars for helicopters detection - Design
Prediction of aerodynamic performance of airfoils in low	Experimental investigation of terminal shock sensors in	constraints p 683 A90-41073 ELIAS FUSTE, ANTONI
Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360	mixed-compression inlets	Use of pulse radars for helicopters detection - Design
DEROSA, S.	[AIAA PAPER 90-1931] p 681 A90-40560	constraints p 683 A90-41073
Problems of internal acoustics in two and three	DRESS, DAVID A.	ELLIOTT, D. W.
dimensional cavities with deformable walls using the	Drag measurements on a modified prolate spheroid using a magnetic suspension and balance system	A remote tip-driven fan powered supersonic fighter
MSC/Nastran code [DLC/STR-INT-TN-004] p 699 N90-24876	p 672 A90-40684	concept [AIAA PAPER 90-2415] p 663 A90-42167
[DLC/STR-INT-TN-004] p 699 N90-24876  DESCHAMBAULT, R. L.	DROZDA, THOMAS J.	ELLIOTT, K.
The University of Toronto-Ryerson Polytechnical	Composites applications - The future is now	Correlation of radial-to-axial vaneless turns for
Institute hypersonic gun tunnel p 673 A90-42432	p 678 A90-42372	centrifugal compressors
DETURRIS, D. J.	DRUMMOND, C. K.	[AIAA PAPER 90-1917] p 656 A90-40556
Direct measurements of skin friction in a scramjet combustor	A modeling technique for STOVL ejector and volume dvnamics	ELLIOTT, S. J.  Experiments on the active control of the transmission
[AIAA PAPER 90-2342] p 626 A90-42132	[AIAA PAPER 90-2417] p 663 A90-42168	of sound through a clamped rectangular plate
DEVINE, KIRK	DU VAL, RONALD	p 695 A90-41109
Inclement weather induced aircraft engine power loss	Parameter identification of aeroelastic modes of rotary	ELLIS, F. A.
[AIAA PAPER 90-2169] p 662 A90-42055 DI MARTINO, P.	wings from transient time histories p 642 A90-40166	Measurements of aerodynamic forces on aircraft
Numerical simulation of the behaviour of internal	DUBOST, GERARD	external stores in the NAE trisonic blowdown wind-tunnel p 629 A90-42419
combustion supercharged engines	Dual cross-polarization planar arrays in the C and X bands p 638 A90-40979	ELROD, W. C.
[AIAA PAPER 90-1873] p 655 A90-40539	DUNBAR, L. W.	Electrical analog circuit for heat transfer measurements
DICKERSON, WILLIAM	Turbine configuration impact on advanced IHPTET	on a flat plate simulating turbine vane heat transfer in
When propfans cruise, will LDN 65 fly	engine system mission capabilities	turbulent flow
p 697 N90-24864 DICKINSON, R.	[AIAA PAPER 90-2739] p 664 A90-42221	[AIAA PAPER 90-2412] p 687 A90-42164 EPPEL, JOSEPH C.
Flight test results of the F-15 SMTD thrust	DUNCAN, LARRY B.	Helicopter Airborne Laser Positioning System (HALPS)
vectoring/thrust reversing exhaust nozzle	Application of fracture mechanics to microscale phenomena in electronic assemblies	[NASA-TM-102814] p 654 N90-23399
[AIAA PAPER 90-1906] p 660 A90-41982	p 684 A90-41334	EPPS, J. A.
DIETENBERGER, MARK A.  Analyses of Arrow Air DC-8-63 accident of December	DUNCAN, T. M.	Criteria for coal tar seal coats on airport pavements.  Volume 2: Laboratory and field studies
12, 1985 - Gander, Newfoundland p 635 A90-40687	A daylight stellar sensor using a charge-coupled	[AD-A220167] p 674 N90-24277
DIFTLER, M. A.	device p 637 A90-39002 DUNFORD, P. G.	ERHART, J. J.
UH-60A helicopter stability augmentation study	EH101 development progress p 646 A90-42442	Application of CFD to pitch/yaw thrust vectoring
p 670 A90-42471	DUNN, DAVID A.	spherical convergent flap nozzles
DIJKSTRA, F. Ultrasonic regression rate measurement in solid fuel	HPLC analysis of helicopter rotor blade materials	[AIAA PAPER 90-2023] p 657 A90-40597 ERICSSON, L. E.
ramiets	[AD-A221121] p 650 N90-24270	Various sources of wing rock p 622 A90-40679
[AIAA PAPER 90-1963] p 656 A90-40573	DUNN, M. G. Investigation of unsteady flow through a transonic turbine	ERZBERGER, HEINZ
Experimental and computational flammability limits in a	stage. II - Data/prediction comparison for time-averaged	Analysis of sequencing and scheduling methods for
solid fuel ramjet [AIAA PAPER 90-1964] p 676 A90-40574	and phase-resolved pressure data	arrival traffic [NASA-TM-102795] p 636 N90-23373
DILL, H. D.	[AIAA PAPER 90-2409] p 626 A90-42162	Simulator evaluation of the final approach spacing tool
Certification testing methodology for fighter hybrid	DUONG, L. Planet gear sleeve spinning analysis	[NASA-TM-102807] p 636 N90-23374
structure p 642 A90-40128	[AIAA PAPER 90-2154] p 681 A90-40613	ESCANES, J. C.
DIMICCO, R. G.  The effect of constructive and destructive interference	DUPONT, LEON	Use of pulse radars for helicopters detection - Design constraints p 683 A90-41073
on the downstream development of twin jets in a crossflow.	Dual cross-polarization planar arrays in the C and X	ESCH, PETER
II - Interference effects of angularly displaced jets	bands p 638 A90-40979 DUPRIEZ, F.	Aerodynamic work for Hermes spaceplane
[AIAA PAPER 90-2107] p 684 A90-42020	Design and manufacturing of composite materials blade	p 675 A90-41115
Contribution of anxion investment on and future	models p 618 A90-42492	EVANS, RONALD J.
Contribution of engine improvement on next future rotorcraft p 665 A90-42488	DURVASULA, S.	Dynamic FLIR simulation in flight training research p 681 A90-40109
DIRUSSO, ELISEO	Flutter of shaft-supported low aspect-ratio control	·
DIRUSSO, ELISEO Experimental evaluation of a tuned electromagnetic	surfaces p 667 A90-38912	EWALD, J.
DIRUSSO, ELISEO Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump	surfaces p 667 A90-38912 <b>DUTTON</b> , J. C.	·
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors	surfaces p 667 A90-38912	EWALD, J. Helicopter ground and air resonance dynamics p 646 A90-42457 EXLEY, T.
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent	EWALD, J. Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T. Correlation of radial-to-axial vaneless turns for
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors
Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556 Numerical analysis of the flows in annular slinger
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L  CFD propels NASP propulsion progress p 683 A90-41163	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors
Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L CFD propels NASP propulsion progress	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L  CFD propels NASP propulsion progress p 683 A90-41163	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.  II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind  p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions  [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P.	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.  II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind  p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions  [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P.  Active control of helicopter cabin noise	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556 Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind  p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective  [AIAA PAPER 90-2278] p 644 A90-42105	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions  [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P.	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective  [AIAA PAPER 90-2278] p 644 A90-42105  DOBRZYNSKI, WERNER	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions  [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P.  Active control of helicopter cabin noise p 645 A90-42434  ECKSTROM, CLINTON V.  Static aeroelastic tailoring for oblique wing lateral trim	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets
DIRUSSO, ELISEO  Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors  [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets  [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind  p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective  [AIAA PAPER 90-2278] p 644 A90-42105	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P. Active control of helicopter cabin noise p 645 A90-42434  ECKSTROM, CLINTON V.  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020
Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective  [AIAA PAPER 90-2278] p 644 A90-42105  DOBRZYNSKI, WERNER  A coustics of ultralight airplanes p 643 A90-40685 A new noise certification method for 'light propeller aircraft' in testing p 635 A90-41728	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions  [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L.  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P.  Active control of helicopter cabin noise p 645 A90-42434  ECKSTROM, CLINTON V.  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689  EDWARDS, THOMAS A.	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets
Experimental evaluation of a tuned electromagnetic damper for vibration control of cryogenic turbopump rotors [NASA-TP-3005] p 665 N90-23403  DISIMILE, P. J.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow.  II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020  DIX, DONALD M.  Aircraft engine technology gets a second wind p 659 A90-41166  DOANE, PAUL  Integrated air vehicle/propulsion technology for a multirole fighter - A MCAIR perspective [AIAA PAPER 90-2278] p 644 A90-42105  DOBRZYNSKI, WERNER  Acoustics of ultralight airplanes p 643 A90-40685 A new noise certification method for 'light propeller'	surfaces p 667 A90-38912  DUTTON, J. C. Investigation of supersonic mixing layers p 623 A90-40926  Computation of multiple normal shock wave/turbulent boundary layer interactions [AIAA PAPER 90-2133] p 685 A90-42037  DWOYER, DOUGLAS L  CFD propels NASP propulsion progress p 683 A90-41163  E  EATWELL, G. P. Active control of helicopter cabin noise p 645 A90-42434  ECKSTROM, CLINTON V.  Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689	EWALD, J.  Helicopter ground and air resonance dynamics p 646 A90-42457  EXLEY, T.  Correlation of radial-to-axial vaneless turns for centrifugal compressors [AIAA PAPER 90-1917] p 656 A90-40556  Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052  F  FABRIS, D.  The effect of constructive and destructive interference on the downstream development of twin jets in a crossflow. II - Interference effects of angularly displaced jets [AIAA PAPER 90-2107] p 684 A90-42020  FALEMPIN, G.

Wind tunnel results and numerical computations for the NAE deHavilland series of natural laminar flow airfoils

Fighter agility metrics, research, and test [NASA-CR-186118] p 648

EGGOLD, DAVID P.

p 628 A90-42403

p 648 N90-23386

to muzzle blast effects

DODDS, W. J.

DOBYNS, A. L.
The analysis and testing of composite panels subject

Fuel effects on gas turbine combustor dynamics [AIAA PAPER 90-1957] p 676 A90-

p 675 A90-39991

p 676 A90-40570

FAUGHNAN, BRIAN W. FRIEDMANN P P GINERIS DENISE J Polysilicon active-matrix liquid crystal displays for cockpit A model for active control of helicopter air resonance Synthetic aperture radar imagery of airports and p 681 A90-40393 p 670 A90-42462 applications in hover and forward flight surrounding areas: Denver Stapleton International FEDERSPIEL JOHN Airport [NASA-CR-4305] Dual cross-polarization planar arrays in the C and X o 637 N90-24257 Three dimensional transonic and supersonic flow p 638 A90-40979 hands GIORDANENGO, PATRIZIA prediction in axi-vectored nozzles using a finite volume FUGEDY, JOHN Expert system for pilot assistance - The challenge of Control system validation in the autonomous elicopter 2 667 A90-38908 [AIAA PAPER 90-2026] p 624 A90-41989 an intensive prototyping p 693 A90-38909 FEDOROV ROMAN M heliconter GIRARD, A. FUKAL I. Mathematical modeling of plane parallel separated flows High enthalpy hypersonic wind tunnel F4: General Simulation of the reduction characteristics of scattering past bodies p 619 A90-39475 description and associated instrumentation from an aircraft coated with a thin-type absorber by the FELKER, FORT F. p 673 N90-24228 p 638 A90-39855 spatial network method GJESTLAND, TRULS T. A review of tilt rotor download research FUKUDA, KIZUKI p 630 A90-42437 An aircraft noise study in Norway p 698 N90-24872 Calculation of stability derivatives for slender bodies FERNANDO, M. S. U. K. using boundary element method p 620 A90-40181 Application of the moving surface boundary layer control Experimental study of the flow around an helicopter FURMAN, PETER J. fuselage - Comparison with three-dimensional boundary to a two dimensional airfoil p 628 A90-42405 Potential application of automotive fatigue technology rotorcraft design p 681 A90-39987 p 630 A90-42438 layer calculations FERTIG. TIM M. in rotorcraft design Redesign of an electro-optical GOEBEL, S. G. shroud p 676 A90-40215 graphite/epoxy Investigation of supersonic mixing layers G p 623 A90-40926 FIEBIG, DAVID A. GOIKHENBERG, M. M. Full authority digital electronic engine control system GALLO, PAOLO The investigation of heat transfer in cooled blades of provides needed reliability Expert system for pilot assistance - The challenge of [AIAA PAPER 90-2037] p 658 A90-40606 an intensive prototyping p 693 A90-38909 [AIAA PAPER 90-2144] p 685 A90-42043 GALLUS, HEINZ E. GOMER CHARLIE The effects of toughening stresses on liquid impact Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft Inviscid and viscous flows in transonic and supersonic induced fracture n 692 A90-41315 cascades using an implicit upwind relaxation algorithm FIELDS, JAMES M. p 625 A90-42034 [AIAA PAPER 90-2128] [NASA-CR-186670] p 649 N90-23394 Social survey findings on en route noise annoyance GALPERIN, F. A. p 698 N90-24868 iceupe GOODCHILD, PETER J. Fracture control via DRM-Algorithm The modular HUM system p 618 A90-42476 FISHER, DIANA C. p 694 A90-41343 GOODYER, M. J. Design and analysis aid for evaluating aircraft tructures p 694 A90-41188 GALWAY, R. D. structures The six component magnetic suspension system for New transonic test sections for the NAE 5ftx5ft trisonic wind tunnel testing p 673 A90-41725 FLEETER, SANFORD p 630 A90-42431 wind tunnel GORELOV, V. A. Aerodynamic detuning for control of supersonic rotor New transpric test sections for the NAE 5 ft x 5 ft trisonic The investigation of heat transfer in cooled blades of forced response gas turbines [AIAA PAPER 90-2018] p 621 A90-40596 AD-A2209331 p 674 N90-24278 [AIAA PAPER 90-2144] p 685 A90-42043 Flow induced forced response of an incompressible GOTO, S.

Development of the jet-swirl high loading combustor page 20-2451 p 658 A90-40633 GAMACHE, R. N. cascade including profile and incidence effects Reverse flow in multistage axial compressors [AIAA PAPER 90-2352] p 626 A90-42136 p 623 A90-40942 FLEMING, P. J. GAO, HAO GOULD, WARREN P. Implementation of a transputer-based flight controller A new simplification method for analysing the rapid Preliminary airworthiness evaluation of the RC-12K rolling stability of aircraft p 667 A90-38966 p 669 A90-42367 [AD-A219545] p 648 N90-23387 GAO. JINGMAN FLOWERS, GEORGE T. GOUNET, H. Application of leaned blades to an aeroengine Experimental study of the effects of nonlinearities on Directivity of the noise radiation emitted from the inlet p 643 A90-40172 p 654 A90-40503 ground resonance duct of a turboshaft helicopter engine GARBELL, MAURICE A. FLUGSTAD, T. H. [ONERA, TP NO. 1990-26] p 695 A90-41205 Proposed definition of the term en route in en route High Mach exhaust system concept scale model test GRANDT, A. F., JR. p 696 N90-24854 requite The effect on fatigue crack growth under spectrum The effect of noise-abatement profiles on noise [AIAA PAPER 90-1905] n 655 A90-40552 loading of an imposed placard 'G' limit immissions and human annoyance underneath a FODALE, ROBERT p 643 A90-41339 subsequent climbpath p 698 N90-24865 Miniaturization of flight deflection measurement GRATZER, LOUIS B. GARBER, DONALD P. Conceptual design for aerospace vehicles PTA en route noise measurements [NASA-CASE-LAR-13628-1] p 651 N90-25043 p 689 N90-23707 p 696 N90-24855 FÖRDEN, NOAH P. GRAY, DAVID E. GARCIA-NOCETTI. F. Feasibility study for a microwave-powered ozone sniffer Turbofans turn to UHB propulsion p 659 A90-41165 Implementation of a transputer-based flight controller GREEN, JOHN W. aircraft p 667 A90-38966 [NASA-CR-186660] o 650 N90-23397 Modeling gas turbine combustor performance under GARDINER, M. STROUP FORSYTH, GRAHAM F. transient conditions Criteria for coal tar seal coats on airport pavements. Concept demonstration of the use of interactive fault [AIAA PAPER 90-2161] p 661 A90-42051 Volume 2: Laboratory and field studies diagnosis and isolation for TF30 engines GREEN, MICHAEL J. [AD-A220167] p 674 N90-24277 p 617 A90-41177 CFD propels NASP propulsion progress GARG, SANJAY p 683 A90-41163 FOUQUES, B. Analysis of airframe/engine interactions - An integrated GREEN, PETER F. Preliminary flight evaluation of the SA 365 Panther control perspective
[AIAA PAPER 90-1918] helicopter in air-to-air combat manoeuvres Equilibrium swelling of elastomeric materials in solvent p 667 A90-40557 p 647 A90-42494 environments GARRIS, C. A. FOWLER, D. K. p 678 N90-24430 Non-steady flow loss mechanisms associated with Engineering design models for ramjet efficiency and lean GREEN, STEVEN M. vaneless diffusers Simulator evaluation of the final approach spacing tool blowoff AIAA PAPER 90-2508] p 682 A90-40641 [NASA-TM-102807] p 636 N90-23374 [AIAA PAPER 90-2453] p 663 A90-42176 GAVALI, SHARAD FRADENBURGH, EVAN A. GŘEENE. J. B. Supercomputer applications in gas turbine flowfield Nonflammable hydraulic power system for tactical Improving tilt rotor aircraft performance with variable-diameter rotors p 646 A90-42445 p 620 A90-40495 p 646 A90-42445 aircraft. Volume 1: Aircraft system definition, design and GENGO, JOSEPH T. FRANKE, M. E. Confined jet thrust vector control nozzle studies
[AIAA PAPER 90-2027] p 657 A90 Application of neural networks to the F/A-18 engine [AD-A218493] p 671 N90-23409 condition monitoring system p 657 A90-40598 GREITZER, E. M. [AD-A219820] p 666 N90-24271 FRATELLO, DAVID J. Reverse flow in multistage axial compressors GEOFFROY, P. p 623 A90-40942 Static wind-tunnel and radio-controlled flight test Design and manufacturing of composite materials blade investigation of a remotely piloted vehicle having a delta GRIDLEY, M. C. p 618 A90-42492 models Computation of vectoring nozzle performance [AIAA PAPER 90-2752] p 627 A wing planform GILMORE, JOHN F. p 627 A90-42225 [NASA-TM-4200] p 632 N90-24238 Control system validation in the autonomous FRENGLEY, MICHAEL C. GROMOV, GENNADII N. p 667 A90-38908 helicopter Retirement lives of rolling element bearings Differential-geometrical technique of transformation and estimation of position, rate and acceleration parameters using supplementary data GILYARD, GLENN B. p 680 A90-39980 A proposed Kalman filter algorithm for estimation of FRENSTER, JEFF

unmeasured output variables for an F100 turbofan

A preliminary evaluation of an F100 engine parameter

p 656 A90-40558

p 656 A90-40559

p 644 A90-42106

integration-flight

[AIAA PAPER 90-1920]

[AIAA PAPER 90-1921]

[AIAA PAPER 90-2280]

estimation process using flight data

evaluation and technology transition

Propulsion system-flight control

The application of an expert maintenance and diagnostic

Confined jet thrust vector control nozzle studies [AIAA PAPER 90-2027] p 657 A90

Control system validation in the

p 657 A90-40605

p 657 A90-40598

p 667 A90-38908

autonomous

tool to aircraft engines [AIAA PAPER 90-2036]

FRIDDELL, J. H.

helicopter

FRIEDEL, THOMAS

p 638 A90-41004

p 655 A90-40526

p 653 A90-41741

p 653 A90-41742

The SEPR 844 reusable liquid rocket engine for Mirage

Onboard digital recording system for flight tests

GROSDEMANGE, HERVE

[AIAA PAPER 90-1835]

Digital autopilot for light aircraft

combat aircraft

GRZYBOWSKI, JOZEF

GUDINO, JUAN	HARRISON, SCOTT RUSSELL	HERTEL, JOHANN
NASA/USRA high altitude reconnaissance aircraft	Throughput and delay characteristics for a slow-frequency hopped aircraft-to-aircraft packet radio	A study of the influence of a helicopter rotor blade on
[NASA-CR-186685] p 650 N90-24266 GUERIN, G.	network	the following blades using Euler equations p 630 A90-42435
Digital map reader for helicopters p 653 A90-42448	[AD-A220525] p 688 N90-23609	HESHMAT, H.
GUETTIER, MICHEL	HARTMAN, P.	High temperature powder lubricated dampers for gas
Experiments on Mode S secondary surveillance radar	Viscous flow analysis for advanced inlet particle	turbine engines
The participation of the French Direction de la Navigation	separators	[AIAA PAPER 90-2048] p 684 A90-41999
Aerienne in the European effort p 639 A90-41057 GUILE, R. N.	[AIAA PAPER 90-2136] p 661 A90-42038	HESSELINK, LAMBERTUS  Three-dimensional measurement, display, and
Hydrocarbon-fueled scramjet combustor investigation	HARTMANN, LAWRENCE	interpretation of fluid flow datasets p 679 A90-38854
[AIAA PAPER 90-2337] p 658 A90-40622	Preliminary thoughts on an acoustic metric for the wilderness aircraft overflight study p 697 N90-24862	HGUYEN, TU D.
GUNSALLUS, C. T.	HARTWICH, PETER-M.	Design and analysis aid for evaluating aircraft
Rotating system load monitoring using minimum fixed	Navier-Stokes solutions for vortical flows over a	structures p 694 A90-41188
system instrumentation p 651 A90-39982	tangent-ogive cylinder p 620 A90-39780	HIERGEIST, KARL
GUO, WEN	HARTZHEIM, WOLFGANG	Eight years of flight operations with composite rotorblades p 635 A90-42481
A novel synthetic method for studying nonlinear flight stability p 645 A90-42355	Development and application of an optimization	HILBIG, R.
GUPTA, K. K.	procedure for space and aircraft structures	Aerodynamic development perspective for traffic
STARS: An integrated general-purpose finite element	p 679 A90-39186	aeroplanes
structural, aeroelastic, and aeroservoelastic analysis	HASEGAWA, GIZO	[DGLR-89-141] p 637 N90-24260
computer program	Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations	HILLER, M.
[NASA-TM-101709] p 689 N90-23768	p 646 A90-42464	Computer-aided analysis of three-dimensional multiloop
GUPTA, ROOP M.	HASEL, K. L.	mechanisms p 669 A90-42328 HINDASH, ISMAIL O.
Low-density flow effects for hypervelocity vehicles, phase 2	Ultra high bypass turbofan technologies for the	Computational modeling of inlet hammershock wave
[AD-A221034] p 634 N90-24249	twenty-first century	generation
GUTMARK, E.	[AIAA PAPER 90-2397] p 662 A90-42158	[AIAA PAPER 90-2005] p 621 A90-40592
Supersonic rectangular isothermal shrouded jets	HASHIM, S. M.	HINKLE, A. J.
[AIAA PAPER 90-2028] p 621 A90-40599	New transonic test sections for the NAE 5ftx5ft trisonic	The influence of material quality on airframe structural
Multistep dump combustor design to reduce combustion	wind tunnel p 630 A90-42431	durability p 676 A90-41336 HIROSE, TAKEICHIRYO
instabilities p 659 A90-40934	New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel	Aeroelastic response characteristics of a rotor executing
11	[AD-A220933] p 674 N90-24278	arbitrary harmonic blade pitch variations
H	HASHINO, R.	p 646 A90-42464
	Application of 3-D Navier-Stokes computation to bowed	HIRSCHKRON, R.
HAGNAUER, GARY L.	stacking turbine vane design	Convertible engine system for high speed rotorcraft
HPLC analysis of helicopter rotor blade materials [AD-A221121] p 650 N90-24270	[AIAA PAPER 90-2129] p 625 A90-42035	[AIAA PAPER 90-2512] p 658 A90-40643 HOCKENBROCK, RICHARD
HALASZ, MIKE	HASSAN, A. A.	Multifunction displays optimized for viewability
Jet Engine Technical Advisor (JETA)	Rotorcraft computational fluid dynamics - Recent	p 652 A90-40398
p 693 A90-41184	developments at McDonnell Douglas p 630 A90-42439	New technology advances for brighter color CRT
HALL, R. M.	HASSENPFLUG, WOLFGANG	displays p 652 A90-40399
Navier-Stokes solutions for vortical flows over a	System concept and performance criteria of modern	HOFF, G. E.
tangent-ogive cylinder p 620 A90-39780	helicopter navigation p 640 A90-42452	Experimental performance and acoustic investigation of modern, counterrotating blade concepts
HALPERN, M. E.	Development and verification of software for flight safety	[NASA-CR-185158] p 649 N90-23393
Application of optimal tracking methods to aircraft terrain following	critical strapdown systems p 694 A90-42454	HÖLLE, G. F.
[AD-A221099] p 641 N90-24264	Analytical evaluation of helicopter true air speed and	Gas turbine engine brush seal applications
HALSTEAD, D. E.	associated flight tests p 647 A90-42499	[AIAA PAPER 90-2142] p 685 A90-42041
Boundary-layer transition and separation on a turbine	HAWBOLDT, R. J.	HOLMBERG, ANDERS
blade in a plane cascade .	The University of Toronto-Ryerson Polytechnical Institute hypersonic gun tunnel p 673 A90-42432	Euler code predicted separation at the airfoil trailing edge
[AIAA PAPER 90-2263] p 625 A90-42102	HE, CHENGJIAN	[FFA-TN-1989-30] p 632 N90-23364
HAM, NORMAN D.	Helicopter stability and control modeling improvements	HOOPER, STEVEN J.
Active control of tiltrotor blade in-plane loads during maneuvers p 670 A90-42463	and verification on two helicopters p 671 A90-42474	Development of a finite element based delamination
maneuvers p 670 A90-42463 HAMPTON, HERBERT R.	HE, XIONG	analysis for laminates subject to extension, bending, and
Miniaturization of flight deflection measurement	A new simplification method for analysing the rapid	torsion p 679 N90-25049 HORLEBEIN, A.
system	rolling stability of aircraft p 669 A90-42367	The Franco-German helicopter programme HAP,
[NASA-CASE-LAR-13628-1] p 689 N90-23707	HE, ZHIDAI	PAH-2/HAC p 618 A90-42478
HANAGUD, S.	A novel synthetic method for studying nonlinear flight stability p 645 A90-42355	HOSKINS, P. D.
Kane's methods in rotorblade dynamics	HELD, WOLF	A remote tip-driven fan powered supersonic fighter
p 646 A90-42458	En route noise of turboprop aircraft and their	concept
HAND, R. J.	acceptability: Report of tests p 697 N90-24858	[AIAA PAPER 90-2415] p 663 A90-42167 HOUGHTON, P. D.
The effects of toughening stresses on liquid impact induced fracture p 692 A90-41315	HELLBAUM, R. F.	SMAS - An expert system for configuring a research
HANDLEY, C. S.	Direct measurements of skin friction in a scramjet	flight simulator p 694 A90-41191
Flight tests to explore tail rotor limitations in the low	combustor	HOUWINK, R.
speed envelope p 647 A90-42498	[AIAA PAPER 90-2342] p 626 A90-42132	Computation of viscous aerodynamic characteristics of
HANSEN, STEVE	HELLER, HANNO Acoustics of ultralight airplanes p 643 A90-40685	2-D airfoils for helicopter applications
Energy based stability analysis of a fuzzy roll controller	A new noise certification method for 'light propeller	p 631 A90-42440
design for a flexible aircraft wing p 668 A90-40833	aircraft' in testing p 635 A90-41728	HSU, K. C.  The influence of swirl on velocity, temperature and
HANSON, D. B.	HELSING, MARTIN A.	species characteristics in a can combustor
Investigation of the near wake of a propfan	Feasibility study for a microwave-powered ozone sniffer	[AIAA PAPER 90-2454] p 664 A90-42177
HARDERSEN, CHARLES P.	aircraft	HSU, YU-KAO
SH-2F airframe fatigue test program	[NASA-CR-186660] p 650 N90-23397	An analytic study of nonsteady two-phase laminar
p 642 A90-39989	HEMSCH, MICHAEL J.	boundary layer around an airfoil p 691 N90-25051
HARDY, GORDON H.	Comparison of high-angle-of-attack slender-body theory and exact solutions for potential flow over an ellipsoid	HU, H. X.
Lateral-directional stability and control characteristics of	p 622 A90-40692	Guaranteed cost control via optimal parametric LQ
the Quiet Short-Haul Research Aircraft (QSRA)	HENCKELS, A.	design p 693 A90-40810
[NASA-TM-102250] p 671 N90-23413	Infrared thermography at hypersonic channel H2K	HUA, JUN A transonic airfoil design method and examples
HARMON, A. O.  Nonflammable hydraulic power system for tactical	p 674 N90-24235	p 627 A90-42351
aircraft. Volume 1: Aircraft system definition, design and	HENDERSON, DEAN	HUANG, CHUANQI
analysis	Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft	Optimum design of composite wing structures subjected
[AD-A218493] p 671 N90-23409	[NASA-CR-186670] p 649 N90-23394	to displacement constraints p 680 A90-39276
HARRIS, DAVID O.		LUIEDNED C
Application of fracture mechanics to microscale	HENEGHAN, S. P.	HUEBNER, S.
•	Acoustic characteristics of a research step combustor	Numerical analysis of the flows in annular slinger
phenomena in electronic assemblies	Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530	Numerical analysis of the flows in annular slinger combustors
p 684 A90-41334	Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530 HERBER, ANDREAS	Numerical analysis of the flows in annular slinger combustors [AIAA PAPER 90-2164] p 685 A90-42052
	Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530	Numerical analysis of the flows in annular slinger combustors

p 622 A90-40690

HUGHES, I. J.

Active control of helicopter cabin noise

p 645 - A90-42434

A new Lagrangian method for steady supersonic flow p 631 A90-42506 computation. I - Godunov scheme HULL P. R.

Convertible engine system for high speed rotorcraft p 658 A90-40643 [AIAA PAPER 90-2512]

HUMMEL, D. The gun tunnel of the Brunswick Institute for Fluid Mechanics: Current development status

p 673 N90-24227

**HURST, LORI E.** 

SH-2F airframe fatigue test program p 642 A90-39989

ı

IPRI, ALFRED C.

Polysilicon active-matrix liquid crystal displays for cockpit p 681 A90-40393 applications

JACAZIO, G.

Use of smart actuators for the tail rotor collective pitch p 688 A90-42483 control

JACOBS, TAVIS

Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft

p 649 N90-23394 [NASA-CR-186670] JANAKIRAM, R. D.

Rotorcraft computational fluid dynamics - Recent developments at McDonnell Douglas

p 630 A90-42439

JANG, HONG-MING

An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model p 634 N90-24250

[AD-A221220] JEFFREY, J. R.

Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and

analysis [AD-A218493] p 671 N90-23409

JENKEL, S. D.

Bonded airfoil attachments - A path to rotor structural efficiency

[AIAA PAPER 90-2177] p 686 A90-42061

JENKINS, S. W.

Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies

p 674 N90-24277 [AD-A220167]

JESKE, JAMES A.

Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA) p 671 N90-23413 [NASA-TM-102250]

JIANG. TONG

An experimental investigation of rotating stall in a centrifugal compressor with vaneless diffuser

p 621 A90-40513

JIANG, W. T.

Numerical simulations of gas turbine combustor flows [AIAA PAPER 90-2305] p 686 A90-42116 JOHNSON, STEVEN A.

A simple dynamic engine model for use in a real-time aircraft simulation with thrust vectoring p 662 A90-42054 [AIAA PAPER 90-2166]

JOHNSTON, G. W.

approximations Higher-order boundary-layer interactive airfoil calculations p 628 A90-42402 Nonlinear unsteady airfoil response studies

p 628 A90-42406

JONES, A. H.

Identification of multivariable models of jet engines p 655 A90-40540 [AIAA PAPER 90-1874] Design of digital self-selecting multivariable controllers for iet engines

[AIAA PAPER 90-1875] n 655 A90-40541

JONES, C. M.

Implementation of a transputer-based flight controller p 667 A90-38966

JONES, D. J.

Wind tunnel results and numerical computations for the NAE deHavilland series of natural laminar flow airfoils p 628 A90-42403

JONES, JESSE D.

MLS mathematical model validation study using airborne MLS data from Midway Airport engineering flight tests, August 1988

[DOT/FAA/CT-TN90/2] p 640 N90-23378 JONES, T.

Development of high temperature actuation systems for advanced aircraft engines

[AIAA PAPER 90-2031] p 660 A90-41990 JOUAILLEC, F.

Recent propeller development and studies conducted at ONERA [ONERA, TP NO. 1990-16] p 683 A90-41201

JOZWIAK, ROBERT

The influence of control-surface compensation parameters on the hinge moment characteristics p 643 A90-41737

Influence of some geometrical and design parameters on the hinge moment characteristics of rudders

p 643 A90-41739 Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its p 623 A90-41740 aerodynamic characteristics

JUGGINS, P. T. W. A comprehensive approach to coupled rotor-fuselage p 646 A90-42460 dynamics

JUTRAS, THOMAS H.

Feasibility study for a microwave-powered ozone sniffer aircraft p 650 N90-23397 [NASA-CR-186660]

K

KADAR, IVAN

Neural networks for adaptive shape tracking p 638 A90-39959

Application of the KTRAN transonic small disturbance code to the complete CF-18 aircraft with stores

p 629 A90-42416

KALLIS, JAMES M.

Application of fracture mechanics to microscale phenomena in electronic assemblies p 684 A90-41334

Boundary-element shape optimization system for aircraft structural components p 680 A90-39786

KANNINEN, MELVIN F. Application of fracture mechanics to microscale phenomena in electronic assemblies

p 684 A90-41334

KASHIWA, T.

Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by th spatial network method p 638 A90-39855 KAUTZ, E. F.

Certification testing methodology for fighter hybrid structure p 642 A90-40128

KAWACHI, KEIJI

Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469

KAY, I. W. Hydrocarbon-fueled scramjet combustor investigation p 658 A90-40622 [AIAA PAPER 90-2337]

KEE, YEHO Initial flight test of half-scale unmanned air vehicle [AD-A219584] p 648 N90-23388

KEITH, F. J.

Digital control of magnetic bearings supporting p 682 A90-40712 multimass flexible rotor

KELAITA, PAUL

Supercomputer applications in gas turbine flowfield p 620 A90-40495

KELLEY, HENRY L.

Aerodynamic performance of a 0.27-scale model of an AH-64 helicopter with baseline and alternate rotor blade

p 632 N90-24237 [NASA-TM-4201]

KELLY, R. J.

MLS - A total system approach

KENNEDY, ARTHUR E. Flight testing and application of a Peripheral Vision p 652 A90-40381

p 640 A90-41710

KEYVANI, ANOOSH

NASA/USRA high altitude reconnaissance aircraft p 650 N90-24266

[NASA-CR-186685] KHADJAVI, F.

Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel [FFA-TN-1989-08] p 632 N90-23363

KHALID. M.

Wind tunnel results and numerical computations for the NAE deHavilland series of natural laminar flow airfoils

p 628 A90-42403 New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel

[AD-A220933] p 674 N90-24278 KHOSLA, P. K.

Composite reduced Navier Stokes procedures for flow roblems with strong pressure interactions

p 689 N90-23687 [AD-A219621] KIDD JAMES A Drag reduction by controlling flow separation using

stepped afterbodies

Helicopter surveillance - A look at current and proposed future programs p 642 A90-39986

KIESSLING, FRITZ

On simplified analytical flutter clearance procedures for (DLR-FB-89-56) p 672 N90-24276

KIHM, K. D.

Laser Doppler velocimetry investigation of swirler flowfields p 682 A90-40929

KIKER, R. JFS190 turbine engine performance optimized using

Taguchi methods [AIAA PAPER 90-2419]

p 663 A90-42169

KILFORD, R. I. A study of the technology required for advanced vertical take-off aircraft

[ETN-90-96786] p 650 N90-24268

KILGORE, ROBERT A. Cryogenic wind tunnels

p 673 A90-41726 KILGORE, W. ALLEN Subsonic sting interference on the aerodynamic

of a family characteristics slanted-base of ogive-cylinders INASA-CR-42991 p 633 N90-24242

KILLINGSWORTH, E. C., JR.

Requirements for business jet aircraft

[AIAA PAPER 90-2038] p 644 A90-41991

KIM. DOHOON

Feasibility study for a microwave-powered ozone sniffer aircraft [NASA-CR-186660] p 650 N90-23397

Viscous flow around a propeller-shaft configuration with infinite-pitch rectangular blades p 683 A90-40938

KING, E. W.

Application of CFD to pitch/yaw thrust vectoring spherical convergent flap nozzles p 657 A90-40597

[AIAA PAPER 90-2023] KING, P. I.

Electrical analog circuit for heat transfer measurements on a flat plate simulating turbine vane heat transfer in turbulent flow

[AIAA PAPER 90-2412] p 687 A90-42164

KINGTON, H.

Development of impact design methods for ceramic gas turbine components p 687 A90-42165

[AIAA PAPER 90-2413]

KIRBY, PETER J.

Fiber-optic turbine inlet temperature measurement system (FOTITMS) [AIAA PAPER 90-2033]

p 657 A90-40603

KIRK, R. GORDON

Analysis of thermal gradient effects in oil ring seals p 682 A90-40716

KISSINGER, R. DOHN

The challenge of demonstrating the X-30

p 659 A90-41162 The evaluation of flight recorders p 653 A90-41729

KLEMBOWSKI, WIESLAW Design of new Polish primary radars AVIA DM/CM p 638 A90-41035

KNEPPE. GUENTER

Development and application of an optimization procedure for space and aircraft structures p 679 A90-39186

KNOSPE, CARL RICHARD

Adaptive control of a system with periodic dynamics: Application of an impulse response method to the helicopter vibration problem p 694 N90-23990

KNOWLES, K. Numerical modeling of an impinging jet in cross-flow

[AIAA PAPER 90-2246] p 686 A90-42093 KOCHIN, V. A. Relationship between velocity circulation around a wing

profile and vorticity dispersion in a boundary layer

KOENIG. KLAUS Short time Force and moment measurement System for shock tubes (SFS) for measuring times less than 10

KOHIYAR, F. A.

Aerodynamics of store separation p 629 A90-42418 KOMERATH N. M. Numerical simulation of the growth of instabilities in

supersonic free shear layers p 623 A90-40941

p 620 A90-39539

p 674 N90-24233

KOMURO, T.		
Some governing parameters igniter/flameholder in a scramjet co		asma torch
[AIAA PAPER 90-2098]		A90-42017
KOOP, W. E.		
Metal matrix composites structu [AlAA PAPER 90-2175]		n experience A90-42059
Metal matrix composite fan blade		
[AIAA PAPER 90-2178]		A90-42062
KORS, DAVID L		
The challenge of demonstrating t	ne X-30 p 659	A90-41162
KORTING, P. A. O. G.	p 038	A30-41102
Ultrasonic regression rate meas	urement	in solid fuel
ramjets		****
[AIAA PAPER 90-1963] KOSINOV, A. D.	p 656	A90-40573
Wave structure of artificial perturb	ations in	a supersonic
boundary layer on a plate		A90-39518
KOSMATKA, J. B.	0-	.:_4 \//-
Analysis of composite rotor blade solutions		nt Venant's A90-42491
Extension-torsion coupling be		
composite tilt-rotor blades	p 651	N90-25057
KOTOVSKII, VLADIMIR N.		
Mathematical modeling of plane pa past bodies		arated flows A90-39475
KOURTIDES, DEMETRIUS A.	POIS	A30-33473
Some 1-(diorganooxyphospho	nyl)meth	yl-2,4- and
-2,6-dinitro-benzenes		
[NASA-CASE-ARC-11425-3]	p 678	N90-23475
KOZLOV, L. F.  Vortex theory for the screw prope	ller with :	a hub
Torick theory for the serent prope		A90-39538
Relationship between velocity circ	ulation ar	ound a wing
profile and vorticity dispersion in a b		
KRAEMER, EWALD	p 620	A90-39539
A study of the influence of a heli	copter ro	tor blade on
the following blades using Euler equ		
KDACHOWCKI BOODAN D	p 630	A90-42435
KRASNOWSKI, BOGDAN R.  Designing rotorcraft dynamic con	Inanante	to reliability
requirements		
requirements KRAVETS, V. V.	p 641	A90-39978
KRAVETS, V. V.  Numerical solution of the problem	p 641 n of sup	A90-39978 ersonic flow
KRAVETS, V. V.	p 641 n of sup- nical wing	A90-39978 ersonic flow
KRAVETS, V. V.  Numerical solution of the problem	p 641 n of sup- nical wing	A90-39978 ersonic flow
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave con  KRAWCZYK, PETER A.  Fatigue crack growth investigation	p 641 m of suprical wing p 619 of a Ti-6/	A90-39978 ersonic flow 3 A90-39465 Al-4V forging
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading condition	p 641 m of suprical wing p 619 of a Ti-6/	A90-39978 ersonic flow 3 A90-39465 Al-4V forging
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con  KRAWCZYK, PETER A.  Fatigue crack growth investigation  under complex loading condition  supplemental engine disk program	p 641 m of sup- nical wing p 619 of a Ti-6/ ons: NA	A90-39978 ersonic flow 3 A90-39465 AI-4V forging TO/AGARD
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading condition	p 641 m of sup- nical wing p 619 of a Ti-6/ ons: NA	A90-39978 ersonic flow 3 A90-39465 Al-4V forging
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditic supplemental engine disk program (AD-A220239)  KRESS, E. J.  Multiple swirler dome combustor	p 641 m of suprinical wing p 619 of a Ti-6/ ons: NA	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditic supplemental engine disk program [AD-A220239]  KRESS, E. J.  Multiple swirler dome combustor rise applications	p 641 m of supriced wing p 619 of a Ti-64 ons: NA p 678 for high	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave concave concave concave.  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditions supplemental engine disk program [AD-A220239]  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]	p 641 m of supriced wing p 619 of a Ti-64 ons: NA p 678 for high	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditic supplemental engine disk program [AD-A220239]  KRESS, E. J.  Multiple swirler dome combustor rise applications	p 641 m of supnical wing p 619 of a Ti-6/ ons: NA p 678 for high	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave concave concave concave. The stigue crack growth investigation under complex loading conditions supplemental engine disk program [AD-A220239]  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]  KRIER, H.  Investigation of supersonic mixing	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave concave concave concave.  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditions supplemental engine disk program [AD-A220239]  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]  KRIER, H.  Investigation of supersonic mixing KRISHNAN, M. R.	p 641 m of supplication of a Ti-6/ons: NA p 678 for high p 661 layers p 623	A90-39978 ersonic flow 3 A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave concave concave.  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditic supplemental engine disk program (AD-A220239)  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]  KRIER, H.  Investigation of supersonic mixing KRISHNAN, M. R.  Gas turbine engine brush seal applications of supersonic mixing krishnan, M. R.	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave conc	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications	A90-39978 ersonic flow 3 A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave concave concave.  KRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditic supplemental engine disk program (AD-A220239)  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]  KRIER, H.  Investigation of supersonic mixing KRISHNAN, M. R.  Gas turbine engine brush seal applications of supersonic mixing krishnan, M. R.	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot a viscous gas past a concave cot a viscous gas past a concave cot kRAWCZYK, PETER A.  Fatigue crack growth investigation under complex loading conditions (AD-A220239)  KRESS, E. J.  Multiple swirler dome combustor rise applications [AIAA PAPER 90-2159]  KRIER, H.  Investigation of supersonic mixing KRISHNAN, M. R.  Gas turbine engine brush seal applications (AIAA PAPER 90-2142)  KRYZHANOVSKII, GEORGII A.  Air traffic control KUDOU, K.	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685 p 638	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave conc	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 blications p 685 p 638 of pla	A90-39978 ersonic flow 3 A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave conc	p 641 m of suppnical wing p 619 of a Ti-6/ nns: NA p 678 for high p 661 layers p 623 blications p 685 p 638 of pla mbustor	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave conc	p 641 m of suppnical wing p 619 of a Ti-6/ nns: NA p 678 for high p 661 layers p 623 blications p 685 p 638 of pla mbustor	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a condition of a viscous gas past past gas past gas past gas	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 blications p 685 p 638 of pla mbustor p 661 processin	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave co of a viscous gas past a concave c	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 blications p 685 p 638 of pla mbustor p 661 processin	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-42041 A90-39581 sma torch A90-42017
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave con a viscous gas past a concave con a viscous gas past a concave con the problet of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas problem of supersonic mixing the problem of	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685 p 638 of pla mbustor p 661 processin p 638	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-39581 sma torch A90-42017 g applied to A90-41034
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave con a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a condition of the problem of the probl	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685 p 638 of pla mbustor p 661 processin p 638 ement co	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave con a viscous gas past a concave con a viscous gas past a concave con the problet of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas past a concave con the problem of a viscous gas problem of supersonic mixing the problem of	p 641 m of suppnical wing p 619 of a Ti-6/ ons: NA p 678 for high p 661 layers p 623 odications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipment	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave cooker of a viscous gas past a viscous gas past a viscous gas past gas	p 641 m of suppnical wing p 619 of a Ti-6/ ons: NA p 678 for high p 661 layers p 623 odications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipment	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the probler of a viscous gas past a concave cooker of a viscous gas past a viscous gas past a viscous gas past gas	p 641 m of suppnical wing p 619 of a Ti-6/ ons: NA p 678 for high p 661 layers p 623 odications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipment	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot concave cot a viscous gas past a concave cot concave cot concave cot gas past a viscous gas past a concave cot gas past gas pas	p 641 m of suppnical wing p 619 of a Ti-6/ ons: NA p 678 for high p 661 layers p 623 odications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipment	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot concave cot a viscous gas past a concave cot concave cot concave cot gas past a viscous gas past a concave cot gas past gas pas	p 641 m of suppnical wing p 619 of a Ti-6/ ons: NA p 678 for high p 661 layers p 623 odications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipment	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot a viscous gas past a concave cot a viscous gas past a concave cot concave cot a viscous gas past a concave cot concave cot concave cot concave c	p 641 m of suppnical wing p 619 of a Ti-6/ nns: NA p 678 for high p 661 layers p 623 oblications p 685 p 638 of pla mbustor p 661 processin p 638 ement coequipmen p 654	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses t N90-23398
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot concave cot a viscous gas past a concave cot concave cot concave cot concave cot a viscous gas past a concave cot	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipmen p 654	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses th N90-23398
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cook and a viscous gas past a concave cook and a viscous gas past a viscous gas past g	p 641 m of suppnical wing p 619 of a Ti-6/ons: NA p 678 for high p 661 layers p 623 olications p 685 p 638 of pla mbustor p 661 orocessin p 638 ement coequipmen p 654	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses th N90-23398
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cot a viscous gas past a concave cot a viscous gas past a concave cot concave cot a viscous gas past a concave cot	p 641 m of suppnical wing p 619 of a Ti-6/ nns: NA p 678 for high p 661 layers p 623 oblications p 685 p 638 of pla mbustor p 661 processin p 638 ement co- equipmen p 654	A90-39978 ersonic flow A90-39465 Al-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses t N90-23398 A90-39702 ezone sniffer
KRAVETS, V. V.  Numerical solution of the problet of a viscous gas past a concave cook and a viscous gas past a concave cook and a viscous gas past a viscous gas past g	p 641 m of suppnical wing p 619 of a Ti-6/ nns: NA p 678 for high p 661 layers p 623 oblications p 685 p 638 of pla mbustor p 661 processin p 638 ement co- equipmen p 654	A90-39978 ersonic flow A90-39465 AI-4V forging TO/AGARD N90-23538 temperature A90-42050 A90-40926 A90-42041 A90-39581 sma torch A90-42017 g applied to A90-41034 de analyses th N90-23398

Direct drive servovalves: Why and how - The Magnaghi p 688 A90-42484 A preliminary evaluation of an F100 engine parameter

LINDSEY, STEVEN W. LAMBORN, LYNDON Stress concentration factors - Comparison of theory with Prediction of longitudinal pilot induced oscillations using p 680 A90-39979 fatique test data the optimal control model [AD-A220593] p 671 N90-23412 LAMBORN, LYNDON C. Certification plan for an all-composite main rotor A new Lagrangian method for steady supersonic flow flexbeam computation. 1 - Godunov scheme LANTZ, EDWARD p 631 A90-42506 Accelerators and decelerators for large, hypersonic Guaranteed cost control via optimal parametric LQ aircraft [AIAA PAPER 90-1986] p 674 A90-40582 desian p 693 A90-40810 LOHE, S. N. LAPIN. B. A. Nonflammable hydraulic power system for tactical The development result of SPEKTR automated air traffic aircraft. Volume 1: Aircraft system definition, design and control (ATC) system with extended grade of automation p 639 A90-41058 for terminal and hub areas analysis LARKIN, MICHAEL D. AD-A2184931 p 671 N90-23409 LOPER, BRENT Concept demonstration of the use of interactive fault High speed civil transport diagnosis and isolation for TF30 engines [NASA-CR-186661] p 617 A90-41177 p 649 N90-23396 LAUERMANN, H.-D. LORD, W. K. Navier-Stokes analysis of an elector and mixer-elector Unsteady deformations of elastic rotor blades operating at pressure ratios in the range 2-4 p 687 A90-42341 p 626 A90-42218 LAUZON, M. [AIAA PAPER 90-2730] LOWEY, H. E. 5DOF dynamic loads on a jet vane p 675 A90-42147 [AIAA PAPER 90-2382] GE's CF34 engine for business and regional jets [AIAA PAPER 90-2041] LAWSON, TODD p 661 A90-41992 Preliminary design of a supersonic Short Takeoff and LU. H. Y. Fuselage boundary-layer effects on sound propagation Vertical Landing (STOVL) fighter aircraft and scattering [NASA-CR-186670] p 649 N90-23394 p 695 A90-39781 LUDTKE, WILLIAM P. LAWTON, J. Wind tunnel tests of a 20-gore disk-gap-band Development of a heavy fuel engine for an unmanned parachute air vehicle [AIAA PAPER 90-2170] [AD-A221326] p 634 N90-24251 p 662 A90-42056 LUERS, JAMES K. LEE, B. H. K. Analyses of Arrow Air DC-8-63 accident of December Flow separation on a supercritical airfoil 12, 1985 - Gander, Newfoundland p 635 A90-40687 p 627 A90-42394 LUISE, FEDERICA Expert system for pilot assistance - The challenge of Numerical simulations of gas turbine combustor flows an intensive prototyping p 693 A90-38909 AIAA PAPER 90-2305] p 686 A90-42116 LUONG, TAI NASA/USRA high altitude reconnaissance aircraft Finite element analysis of composite panel flutter p 681 A90-40032 [NASA-CR-186685] p 650 N90-24266 LEFEBVRE, ARTHUR H. Influence of fuel composition on flame radiation in gas М p 659 A90-40946 turbine combustors LEHRA, HEINRICH MA, ZHIHENG Aerodynamic work for Hermes spaceplane A study on the application of controllability and p 675 A90-41115 observability concepts in the design of flight control LENORT, FRANCISZEK systems p 693 A90-39303 Discrete Fourier transform with high resolution for low MACCORMACK, ROBERT W. frequencies applied to the modal analysis of aircraft Modeling supersonic combustion using a fully-implicit p 679 A90-38975 numerical method LESMERISES, A. L. [AIAA PAPER 90-2307] p 677 A90-42117 Acoustic characteristics of a research step combustor MACE, JAMES [AIAA PAPER 90-1851] p 655 A90-40530 Integrated air vehicle/propulsion technology for a LEVIN. K. multirole fighter - A MCAIR perspective Damage tolerance of carbon fibre reinforced plastic [AIAA PAPER 90-2278] p 644 A90-42105 sandwich panel p 675 A90-40047 MÀCHA, J. MICHAEL LEVINE, WILLIAM S. Preliminary characterization of parachute wake Digital controller design for the pitch axis of the F-14 recontact p 622 A90-40681 using an H(infinity) method p 668 A90-40912 MACKIN, CLIFFORD W. LEWY, S. An evaluation of the accuracy of a microwave landing Directivity of the noise radiation emitted from the inlet system area navigation system at Miami/Tamiami Florida duct of a turboshaft helicopter engine Airport [ONERA, TP NO. 1990-26] p 695 A90-41205 [DOT/FAA/CT-TN89/40] p 640 N90-23377 Noise-source measurements by thin-film pressure MADAN, RAM C. transducers in a subsonic turbofan model Impact damage and residual strength analysis of p 659 A90-41212 [ONERA, TP NO. 1990-36] composite panels with bonded stiffeners LEWY, SERGE p 642 A90-40130 Characterization of helicopter turboshaft engine noise MADAVAN, NATERI K. p 660 A90-41759 Supercomputer applications in gas turbine flowfield LIASJO, KARE H. p 620 A90-40495 An aircraft noise study in Norway p 698 N90-24872 MAGLIERI, DOMENIC J. LIBRESCU. L. Summary of sonic boom rise times observed during FAA Supersonic flutter of shear deformable laminated community response studies over a 6-month period in the composite flat panels p 683 A90-41104 Oklahoma City area LICEAGA-CASTRO, E. [NASA-CR-4277] p 696 N90-24852 Helicopter control design using feedback linearization MAGNESS, C. techniques p 668 A90-40817 Flow visualization via laser-induced reflection from LIDSTONE, GARY L bubble sheets p 680 A90-39784 Transverse fuel-injection model for a scramjet propulsion MAGNUSEN, P. E. p 659 A90-40927 system The influence of material quality on airframe structural LIEFER, RANDALL K. durability p 676 A90-41336 Fighter agility metrics, research, and test [NASA-CR-186118] p 648 MAINE, TRINDEL A. p 648 N90-23386 A preliminary evaluation of an F100 engine parameter LIESE, HUBERT estimation process using flight data Technological preparations of civil aircraft programs [AIAA PAPER 90-1921] p 656 A90-40559 p 617 A90-41110 MAKOWIEC, GEORGE M. LILLEY, ROBERT W. Static wind-tunnel and radio-controlled flight test Demonstration of MLS advanced approach techniques p 640 A90-41711 investigation of a remotely piloted vehicle having a delta wing planform [NASA-TM-4200] Measurements of turbulent dual-jet interaction p 632 N90-24238 MALAK, M. F. [AIAA PAPER 90-2105] p 624 A90-42019 LINDEN, STEFAN JFS190 turbine engine performance optimized using

Taguchi methods

[AIAA PAPER 90-2419]

p 663 A90-42169

Multilevel optimization of large-scale structures in a

p 693 A90-39180

parallel computing environment

LAFFRANCHI, D.

Milano answer

LAMBERT, HEATHER H.

[AIAA PAPER 90-1921]

estimation process using flight data

p 656 A90-40559

PERSONAL AUTHOR INDEX MCFARLAND, RICHARD H. MOKRY, MIROSLAV MALECKI, R. E. Navier-Stokes analysis of an ejector and mixer-ejector ILS - A safe bet for your future landings p 639 A90-41707 operating at pressure ratios in the range 2-4 [AIAA PAPER 90-2730] p 626 A90-42218 MCINTYRE, MICHAEL E. Direct lift STOVL engine integration [AIAA PAPER 90-2274] MALEK, A. p 644 A90-42103 New transonic test sections for the NAE 5 ft x 5 ft trisonic MCKAMEY, R. S. wind tunnel [AD-A220933] p 674 N90-24278 Adjusting turbine engine transient performance for the MONGIA, H. C. effects of environmental variances MÄLKOV, V. A. The investigation of heat transfer in cooled blades of [AIAA PAPER 90-2501] p 658 A90-40639 injectors of different concepts [AIAA PAPER 90-2190] gas turbines MEAR, MARK E. Modeling growth of fatigue cracks which originate at [AIAA PAPER 90-2144] p 685 A90-42043 MONTEIL, F. p 691 N90-25060 rivet holes MÂNG, JOYCE M. MEHTA, JAYESH M. Redesign of an electro-optical Fuel effects on gas turbine combustor dynamics p 676 A90-40215 graphite/epoxy [AIAA PAPER 90-1957] p 676 A90-40570 MANNESS, M. A. MELCONIAN, JERRY O. A technique for the tuning of helicopter flight control Introducing the VRT gas turbine combustor p 670 A90-42467 evstems [NASA-TM-103176] p 688 N90-23591 MANNING, CLARKE O. Development of a least squares time response MELLOR A M MORRIS, MARTIN J. Engineering design models for ramiet efficiency and lean lower-order equivalent systems technique [AD-A220527] p 648 N90-23389 [AIAA PAPER 90-2453] mixed-compression inlets p 663 A90-42176 MAPES, D. E. [AIAA PAPER 90-1931]. MELZER, JAMES E. Ultra high bypass turbofan technologies for the MOSS, DAVID twenty-first century
[AIAA PAPER 90-2397] Holographic combiner design to obtain uniform symbol p 662 A90-42158 brightness at head-up display video camera [AIAA PAPER 90-2522] p 652 A90-40394 MARTIN, N. F., JR. MOSTAFA, A. MERRILL, B. J. Nonlinear finite-element analysis to predict fan-blade p 683 A90-40939 Three-dimensional analysis on flow and temperature damage due to soft-body impact distributions for aircraft fuel thermal stability separators MASLOV. A. A. AD-A2196511 p 678 N90-23571 [AIAA PAPER 90-2136] Wave structure of artificial perturbations in a supersonic p 619 A90-39518 MERTENS, JOSEF boundary layer on a plate MOSTAFA, ABDU A. Short time Force and moment measurement System MASSARO. C. Introducing the VRT gas turbine combustor [NASA-TM-103176] p 688 Co-development of CT7-6 engines - A continued tradition for shock tubes (SFS) for measuring times less than 10 p 674 N90-24233 technology and reliability p 665 A90-42485 MOUSTAPHA, H. MESSERSMITH, N. L. MASUYA, G. Investigation of supersonic mixing layers Some governing parameters of plasma torch igniter/flameholder in a scramjet combustor work transonic turbine p 623 A90-40926 MUELLER, K. p 661 A90-42017 METWALLY, OMAR M. [AIAA PAPER 90-2098] The interaction of a supersonic streamwise vortex and MATSUL TATSUYA overflight elevations a normal shock wave p 633 N90-24241 Vorticity distribution of vortex street in the wake of a MUNDEN, RICHARD C. MEYER, THOMAS J. p 623 A90-41751 circular cylinder Additive evaluation criteria for aircraft noise MATSUNAGA, K. monitoring p 698 N90-24867 Application of 3-D Navier-Stokes computation to bowed MUNGUR. P. MICKLOW, GERALD J. stacking turbine vane design Viscous-inviscid interaction method for calculating the p 625 A90-42035 [AIAA PAPER 90-2129] [AIAA PAPER 90-1957] flow in compressor cascade blade passages and wake MÀULL, D. J. MURAKAMI, A. An experimental and analytical investigation of the buffet with separation [AIAA PAPER 90-2125] p 624 A90-42032 p 645 A90-42417 excitation parameter MIESS, JOSEPH C. [AIAA PAPER 90-2098] Preliminary airworthiness evaluation of the RC-12K Infrared thermography at hypersonic channel H2K AD-A219545] p 648 N90-23387 MURCH, JERRY p 674 N90-24235 MIKROYANNIDIS, JOHN A. MAUTER, GEORGE A. Aircraft drawings index Some 1-(diorganooxyphosphonyl)methyl-2,4- and p 618 N90-23340 MAVRIPLIS, D. J. 2,6-dinitro-benzenes MURRAY-SMITH, D. J. Euler and Navier-Stokes computations for airfoil [NASA-CASE-ARC-11425-3] p 678 N90-23475 MILLER, DAVID G. geometries using unstructured meshes systems Active control of tiltrotor blade in-plane loads during p 630 A90-42425 MURRI, DANIEL G. p 670 A90-42463 maneuvers Actuated forebody strakes MILLER, LAWRENCE Application of 3-D Navier-Stokes computation to bowed [NASA-CASE-LAR-13983-1] The application of an expert maintenance and diagnostic stacking turbine vane design MURTHY, A. V. tool to aircraft engines p 625 A90-42035 [AIAA PAPER 90-2036] MÀYBECK, PETER S. p 657 A90-40605 studies MILLER, R. F. Multiple model adaptive controller for the STOL F-15 MURTHY, SREEDHARA V. ith sensor/actuator failures p 668 A90-40878 A remote tip-driven fan powered supersonic fighter Flow unsteadiness effects on boundary layers MAYFIELD, WILLIAM INASA-CR-1860671 [AIAA PAPER 90-2415] p 663 A90-42167 AVION: A detailed report on the preliminary design of MUSSI, F. a 79-passenger, high-efficiency, commercial transport MINECK. R. E. EH101 development progress Wind tunnel wall interference investigations in NAE/NRC

[NASA-CR-186663] p 649 N90-23395

MCARDLE, JACK G. Analysis of internal flow in a ventral nozzle for STOVL aircraft

[NASA-TM-103123] p 666 N90-23404 Experimental and analytical study of close-coupled ventral nozzles for ASTOVL aircraft [NASA-TM-103170] p 666 N90-24273

MCAULAY, ALASTAIR

Neural networks for adaptive shape tracking p 638 A90-39959 MCCANN, G. L.

CFE738 - A case for joint engine development [AIAA PAPER 90-2522] p 664 A90 p 664 A90-42197 MCCARTHY, D. K.

The analysis and testing of composite panels subject to muzzle blast effects p 675 A90-39991 MCCONKEY, E. D.

Aeronautical decisionmaking for air ambulance program administrators [DOT/FAA/DS-88/8] p 635 N90-23368

MCCURDY, DAVID A. En route noise annoyance laboratory test: Preliminary p 698 N90-24870 MCDONNELL, V. G.

Symmetry assessment of an air-blast atomizer spray p 682 A90-40930 MINTZ, FRED When propfans cruise, will LDN 65 fly

p 697 N90-24864 MIRZA-BAIG, F. S.

High Reynolds Number 2D Facility and NASA Langley 0.3m Transonic Cryogenic Tunnel p 628 A90-42404

On and off-design performance prediction of single spool turbojets using gasdynamics

[AIAA PAPER 90-2393] p 662 A90-42155 MITYAS, S. J. Navier-Stokes analysis of an ejector and mixer-ejector

operating at pressure ratios in the range 2-4 [AIAA PAPER 90-2730] p 626 A90-42218 MODI, V. J.

Application of the moving surface boundary layer control to a two dimensional airfoil D 628 A90-42405 MOELLER, M.

Computer-aided analysis of three-dimensional multiloop p 669 A90-42328 mechanisms MOKHTARIAN, F.

Application of the moving surface boundary layer control p 628 A90-42405 to a two dimensional airfoil

New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel IAD-A2209331 p 674 N90-24278

Finite volume solutions of two-dimensional Euler equations on adapted structured meshes p 629 A90-42413

The University of Toronto-Ryerson Polytechnical Institute hypersonic gun tunnel p 673 A90-42432

Further validation of a semi-analytical approach for fuel

p 686 A90-42067

Applications of Mode S secondary surveillance radar

to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056

Eurofar - Status of the European tilt-rotor project

p 645 A90-42441

Experimental investigation of terminal shock sensors in

p 681 A90-40560

CFE738 - A case for joint engine development p 664 A90-42197

Viscous flow analysis for advanced inlet particle

p 661 A90-42038

p 688 N90-23591

Application of 3-D flow analysis to the design of a high p 628 A90-42395

Noise measurements of turboprop airplanes at different

p 697 N90-24860

New systems for helicopter and aircraft vibration p 653 A90-42477

Fuel effects on gas turbine combustor dynamics p 676 A90-40570

Some governing parameters of plasma torch igniter/flameholder in a scramjet combustor

p 661 A90-42017

Multifunction displays optimized for viewability p 652 A90-40398

A technique for the tuning of helicopter flight control p 670 A90-42467

Sidewall boundary-layer removal and wall adaptation

p 648 N90-23390

p 672 A90-40680

p 690 N90-24557

p 646 A90-42442 MYERS, JAMES W. Forward canopy feasibility and Thru-The-Canopy (TTC)

ejection system study (AD-A2203601 p 637 N90-24258

MYERS, LAWRENCE P. Propulsion system-flight control integration-flight evaluation and technology transition

[AIAA PAPER 90-2280] p 644 A90-42106

NABITY, JAMES A.

Metallized fuel particle size study in a solid fuel ramjet AD-A220079] p 679 N90-24451

NAGAR, ARVIND

Recent advances in fatigue life analysis methods for erospace applications p 677 A90-41338

aerospace applications NAGASHIMA, TOMOARI

Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations

p 646 A90-42464

NAGY, EDWARD G.

SH-2F airframe fatigue test program p 642 A90-39989 NAIK, DINESH A.

3-D Euler calculations for aft-propfan integration [AIAA PAPER 90-2147] p 625 A90-42044 NANNONI, FABIO

Agusta methodology for pitch link loads prediction in preliminary design phase p 646 A90-42465

NAUMAN, CHRIS

High speed civil transport p 649 N90-23396 NAYANI, SUDHEER N.

Low-density flow effects for hypervelocity vehicles, phase 2

[AD-A221034] p 634 N90-24249

NEKOHASHI, TOSHIFUMI

Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations

p 646 A90-42464

NELSON, P. A.

Experiments on the active control of the transmission of sound through a clamped rectangular plate p 695 A90-41109

NELSON, PAUL Evaluation of brush seals for limited-life engines [AIAA PAPER 90-2140] p 685 A90-42040 NEMOUCHI, ZOUBIR

The computation of turbulent thin shear flows associated with flow around multiplement aerofoils p 633 N90-24240

**NEUMAN, FRANK** 

Analysis of sequencing and scheduling methods for arrival traffic

[NASA-TM-102795] p 636 N90-23373 NÈWBERG. I. L.

Reduced insertion loss of X-band RF fiber optic links p 695 A90-41240

NEWCOMB, D. E.

Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies

p 674 N90-24277 (AD-A220167)

NĞUYEN, HUNĞ LEE Introducing the VRT gas turbine combustor

[NASA-TM-103176] p 688 N90-23591 NISHIMURA, Y.

Wind tunnel wall interference investigations in NAE/NRC High Reynolds Number 2D Facility and NASA Langley 0.3m Transonic Cryogenic Tunnel p 628 A90-42404 NISHT, MIKHAIL I.

Mathematical modeling of plane parallel separated flows p 619 A90-39475 past bodies

NITSCHE, W. Test and Measurement Technique in Hypersonics

p 618 N90-24225 NIXON, DAVID

A study of supermanuever aerodynamics

p 631 N90-23349 [AD-A218378] NOETINGER, JACQUES

The Airbus . . . a challenge launched twenty years ago p 699 A90-41769

NOONAN, KEVIN W.

Aerodynamic characteristics of two rotorcraft airfoils designed for application to the inboard region of a main rotor blade

[NASA-TP-3009] p 633 N90-24239

#### 0

O'BRIEN, T. KEVIN

Towards a damage tolerance philosophy for composite materials and structures p 675 A90-40127 OBATA, M.

Development of the jet-swirl high loading combustor AIAA PAPER 90-2451] p 658 A90-40633 [AIAA PAPER 90-2451] ODIN, ETHAN M.

Feasibility study for a microwave-powered ozone sniffer aircraft

[NASA-CR-186660] p 650 N90-23397

OH, C. H.

Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability p 678 N90-23571 [AD-A219651]

OHMAN, L. H.

New transonic test sections for the NAE 5ftx5ft trisonic rind tunnel p 630 A90-42431

New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel

p 674 N90-24278 [AD-A220933]

OKIISHI, T. H.

Boundary-layer transition and separation on a turbine blade in a plane cascade

[AIAA PAPER 90-2263] p 625 A90-42102

OKIISHI, THEODORE H.

Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting

[AIAA PAPER 90-1912] p 656 A90-40554

OKUDE, MUNESHIGE

Vorticity distribution of vortex street in the wake of a circular cylinder . p 623 A90-41751

OKUNO, YOSHINORI

Analytical study of dynamic response of helicopter in p 670 A90-42469 autorotative flight

ONSTOTT, ROBERT G.

ORLOV. V. N.

Synthetic aperture radar imagery of airports and surrounding areas: Denver Stapleton International Airport [NASA-CR-4305] p 637 N90-24257

Experimental turbofan using liquid hydrogen and liquid natural gas as fuel

[AIAA PAPER 90-2421]

p 663 A90-42170 OSSL R. R. A hydrodynamic turbo-fan/shaft convertible engine

OVERSTREET, MARK A.

Lightweight fuel pump and metering component for advanced gas turbine engine control p 657 A90-40602

[AIAA PAPER 90-2032] OVERTON, K. S.

Automated aircraft engine costing using artificial

intelligence [AIAA PAPER 90-1887]

p 660 A90-41981

p 665 A90-42487

OWENS, R. E. Ultra high bypass turbofan technologies for the twenty-first century

[AIAA PAPER 90-2397] p 662 A90-42158

PADFIELD, GARETH

Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497

Hypersonic (T-D) 'pinch' and aerospaceplane propulsion [AIAA PAPER 90-2474] p 675 A90-42189

PAGE, JEFF

High speed civil transport [NASA-CR-186661] p 649 N90-23396

PAIGE, ALLAN B.

Development of the stall warning/stick pusher system for the Boeing/de Havilland Dash 8 Series 300 p 645 A90-42420

PALUCH, B.

Design and manufacturing of composite materials blade p 618 A90-42492 PAO. S. PAUL

Application of a new adaptive grid for aerodynamic nalysis of shock containing single jets p 624 A90-41988 [AIAA PAPER 90-2025]

PAPANICOLOPOULOS, ALECK

Aircraft applications of advanced composite fiber/metal pressure vessels [AIAA PAPER 90-2344] p 686 A90-42133

PARASCHIVOIU, I.

Finite element simulation of unsteady two-dimensional incompressible viscous flows p 629 A90-42423 PARMENTER, K.

Applying qualitative knowledge to aircraft engine system p 694 A90-41189 desian

PARRIS, RUSTY

High speed civil transport [NASA-CR-186661]

p 649 N90-23396

Reconstitution of crack growth from fractographic observations after flight simulation loading

p 682 A90-40650 Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simulation loading p 689 N90-23760 (LR-592)

PASQUALE, LINDA

MLS mathematical model validation study using airborne MLS data from Midway Airport engineering flight tests, August 1988

[DOT/FAA/CT-TN90/2] p 640 N90-23378 PATEL B. R.

Turbulence model performance in V/STOL flow field simulation p 625 · A90-42094

[AIAA PAPER 90-2248] PATRICK, W. P.

Investigation of the near wake of a propfan p 622 A90-40686

PAUSDER, H.-J.

A highly maneuverable helicopter in-flight simulator -Aspects of realization p 670 A90-42466

[AIAA PAPER 88-4607] PAUSDER, HEINZ-JUERGEN

ATTHeS - A helicopter in-flight simulator for ACT p 643 A90-41727

PEARSON, P. K. Initiation of spalling in aircraft gas turbine bearings [AIAA PAPER 90-2291] p 686 A90-42110 PERKINS, BRETT

AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

[NASA-CR-186663]

p 649 N90-23395

PESCHKA, WALTER Hydrogen in future energy and propulsion technology p 692 A90-41736

PESCHKE, W. T.

Hydrocarbon-fueled scramjet combustor investigation AIAA PAPER 90-2337] p 658 A90-40622

PETERS, D. A.

Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474 PETERSON, ERIC

Preliminary design of a supersonic Short Takeoff and Vertical Landing (STOVL) fighter aircraft p 649 N90-23394 [NASA-CR-186670]

PETOT. D.

Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24]

PETTY, JAMES S.

Aircraft engine technology gets a second wind

p 659 A90-41166

PETZEL H.

The gun tunnel of the Brunswick Institute for Fluid Mechanics: Current development status

n 673 N90-24227

PEZZELLA. G.

High temperature solid lubricant requirements for advanced high performance gas turbine engines [AIAA PAPER 90-2042] p 661 A90-41993

PHAM DUC. T.

The all glass helicopter cockpit p 653 A90-42447

PHAN, SIEU

Jet Engine Technical Advisor (JETA) p 693 A90-41184

PHARES, W. J.

CFD applications in an aerospace engine test facility [AIAA PAPER 90-2003] p 681 A90-40590

PHILLIPS, R. E.

Applying qualitative knowledge to aircraft engine system p 694 A90-41189 design PIERCE, N. J.

Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and analysis p 671 N90-23409

[AD-A218493]

PIKIELNY, JERZY Design of new Polish primary radars AVIA DM/CM p 638 A90-41035

PIPERNI P

Application of the KTRAN transonic small disturbance code to the complete CF-18 aircraft with stores

p 629 A90-42416

PIRAT. JEAN LOUIS

Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056

PITTMAN, JAMES L.

Strake camber and thickness design procedure for low alpha supersonic flow p 622 A90-40678

POENSGEN, C.

Calculation of the aeroelastic blade stabilization with linearized process [MITT-87-01] p 666 N90-24272

POGODA, DONALD L

Multiple model adaptive controller for the STOL F-15 with sensor/actuator failures p 668 A90-40878 PORTER, B.

Identification of multivariable models of jet engines AIAA PAPER 90-1874] p 655 A90-40540 [AIAA PAPER 90-1874] Design of digital self-selecting multivariable controllers

for let engines [AIAA PAPER 90-1875]

POSTLETHWAITE, I. Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965

POVINELLI, LOUIS A.

CFD propels NASP propulsion progress p 683 A90-41163

POWELL, CLEMANS A. FAA/NASA En Route Noise Symposium

INASA-CP-30671

PRASAD, J. V. R. Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474

Wind-tunnel measurement of noise emitted by helicopter rotors at high speed

[ONERA, TP NO. 1990-28]

p 695 A90-41207

p 696 N90-24853

p 655 A90-40541

On and off-design performance prediction of single spool turbojets using gasdynamics
[AIAA PAPER 90-2393] p 662 A90-42155

	<u> </u>	
PRIOR, R. C.	RHIE, CHAE M.	ROSFJORD, T. J.
Engineering design models for ramjet efficiency and lean	Computation of flow through a centrifugal impeller with	Influences on the uniformity of sprays produced by gas
blowaff	tip leakage	turbine high shear nozzle/swirler assemblies
[AIAA PAPER 90-2453] p 663 A90-42176	[AIAA PAPER 90-2021] p 684 A90-41987	[AIAA PAPER 90-2193] p 686 A90-42068
PROKOPIUK, ANDRZEJ	RICHARDS, MARVIN KENT	ROSS, TWEED, III
Application of mathematical modeling to the study of	Operational effects on crashworthy seat attenuators	Preliminary design of a supersonic Short Takeoff and
rigid helicopter rotors p 643 A90-41738	[AD-A221148] p 637 N90-24259	Vertical Landing (STOVL) fighter aircraft
PRZYBYLKO, STEPHEN J.	RICHARDSON, MICHAEL	[NASA-CR-186670] p 649 N90-23394
High-temperature electronics for aircraft engines	NASA/USRA high altitude reconnaissance aircraft	ROSSI, O.
[AIAA PAPER 90-2035] p 657 A90-40604	[NASA-CR-186685] p 650 N90-24266	EH-101 main rotor hub application of thick carbon fiber
PULLIAM, THOMAS H.	RICKLEY, E. J.	unidirectional tension bands p 618 A90-42489
An introduction to chaos theory in CFD	En route noise: NASA propfan test aircraft (corrected	ROUGIER, PIERRE
[AIAA PAPER 90-1440] p 680 A90-39725	data - simplified procedure)	Full Authority Digital Engine Control for the AS 355 N
PURCELL, TIMOTHY W.	[DOT-TSC-FA953-LR4] p 696 N90-24856	TM 319 engines p 665 A90-42486
CFD and transonic helicopter sound	En route noise: NASA propfan test aircraft (calculated	ROUT, R. K.
p 696 A90-42433	Source noise	Three dimensional transonic and supersonic flow
<b>,</b>	[DOT-TSC-FA953-LR5] p 697 N90-24857	prediction in axi-vectored nozzles using a finite volume
_	RIEGER, HERBERT	method
. <b>Q</b>	Aerodynamic work for Hermes spaceplane	[AIAA PAPER 90-2026] p 624 A90-41989
	p 675 A90-41115	ROWAN, S.
QIAN, BOSHUN	RILEY, JOHN	Composite electronic enclosures for engine-mounted
Linear dynamics of supersonic ramjet	Estimation of rotor blade incidence and blade	environments
p 655 A90-40519	deformation from the measurement of pressures and	[AIAA PAPER 90-2030] p 657 A90-40601
QIAO, XIN	strains in flight - p 647 A90-42497	ROWE, R. K.
Optimum design of composite wing structures subjected	RIOCHE, S.	Three dimensional transonic and supersonic flow
to displacement constraints p 680 A90-39276	Main characteristics of an integrated flight and display	prediction in axi-vectored nozzles using a finite volume
QIAO, ZHIDE	system for AS MKII Super-Puma p 653 A90-42450	method
A transonic airfoil design method and examples	RISSMILLER, RALPH W., JR.	[AIAA PAPER 90-2026] p 624 A90-41989
p 627 A90-42351	Microwave landing system - A pilot's point of view	RUBIN. S. G.
p 021 700-42001	p 640 A90-41712	Composite reduced Navier Stokes procedures for flow
(c) ★	RIZK, N. K.	problems with strong pressure interactions
R	Further validation of a semi-analytical approach for fuel	[AD-A219621] p 689 N90-23687
••	injectors of different concepts	· ·
DADWOWITZ I	[AIAA PAPER 90-2190] p 686 A90-42067	RUIZ-CALAVERA, LUIS PABLO
RABINOWITZ, J.	ROACH, J. M.	A time-marching method to calculate unsteady airloads
Problems related to aircraft noise in Switzerland p 698 N90-24871	Nonflammable hydraulic power system for tactical	on three-dimensional wings. Part 1: Linearized
	aircraft. Volume 1: Aircraft system definition, design and	formulation [DLR-FB-89-58] p 634 N90-24254
RAGSDELL, K. M.	analysis	
Multilevel optimization of large-scale structures in a	[AD-A218493] p 671 N90-23409	A time-marching method for calculating unsteady
parallel computing environment p 693 A90-39180	ROACH, W. RONALD	airloads on three-dimentional wings. Part 2: Full-potential
RAJAGOPAL, P.	Polysilicon active-matrix liquid crystal displays for cockpit	formulation [DLR-FB-89-59] p 635 N90-24255
Aeroelastic analysis of a low aspect ratio wing	applications p 681 A90-40393	- · ·
p 619 A90-38915	ROBBINS, ROBERT D.	RUKAVINA, JOHN P.
RAJU, B. BASAVA	Preliminary airworthiness evaluation of the RC-12K	Stall margin improvement in axial-flow compressors by circumferential variation of stationary blade setting
Nondestructive measurement of residual stresses in aircraft transparencies	[AD-A219545] p 648 N90-23387	angles
[AD-A218680] p 689 N90-23762	ROBELEN, DAVID B.	[AIAA PAPER 90-1912] p 656 A90-40554
	Static wind-tunnel and radio-controlled flight test	RUSCHAU, JOHN J.
RAMANI, T. S.	investigation of a remotely piloted vehicle having a delta	Fatigue crack growth investigation of a Ti-6Al-4V forging
Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915	wing planform	under complex loading conditions: NATO/AGARD
•	[NASA-TM-4200] p 632 N90-24238	supplemental engine disk program
RAO, K. V. Investigation of unsteady flow through transonic turbine	ROBERTS, JACK C.	[AD-A220239] p 678 N90-23538
stage, I - Analysis	Redesign of an electro-optical shroud in	RYZHOV, O. S.
[AIAA PAPER 90-2408] p 626 A90-42161	graphite/epoxy p 676 A90-40215	Boundary layer stability in the case of transonic external
Investigation of unsteady flow through a transonic turbine	ROCH, J. L.	flow p 619 A90-39514
stage. II - Data/prediction comparison for time-averaged	Modern strapdown system for helicopter	
and phase-resolved pressure data	p 653 A90-42451	S
[AIAA PAPER 90-2409] p 626 A90-42162	ROCKWELL, D.	•
- · · · · · · · · · · · · · · · · · · ·	Flow visualization via laser-induced reflection from	SAIGAL SUNIL
RASMUSSEN, PAUL G.	bubble sheets p 680 A90-39784	
The influence of adjacent seating configurations on	ROCKWELL, DONALD	Boundary-element shape optimization system for aircraft structural components p 680 A90-39786
egress through a type 3 emergency exit	Flow structure generated by oscillating delta-wing	structural components p 680 A90-39786 SAITO. S.
[AD-A218393] p 636 N90-23371	segments p 622 A90-40694	Application of the moving surface boundary layer control
RAVENHALL, R.  Metal matrix composite fan blade development	ROCKWELL, R. K.	to a two dimensional airfoil p 628 A90-42405
[AIAA PAPER 90-2178] p 677 A90-42062	Electrical analog circuit for heat transfer measurements	SAITO, SHIGERU
RAY, E. J.	on a flat plate simulating turbine vane heat transfer in	Analytical study of dynamic response of helicopter in
Sidewall boundary-layer removal and wall adaptation	turbulent flow	autorotative flight p 670 A90-42469
studies p 672 A90-40680	[AIAA PAPER 90-2412] p 687 A90-42164	SAJBEN, MIKLOS
RAYMOND, ROBERT E.	RODGERS, C.	Experimental investigation of terminal shock sensors in
Propulsion control system designs for advanced Navy	Review of mixed flow and radial turbine options	mixed-compression inlets
multimission aircraft	[AIAA PAPER 90-2414] p 687 A90-42166	[AIAA PAPER 90-1931] p 681 A90-40560
[AIAA PAPER 90-2403] p 663 A90-42160	RODMAN, LAURA C.	SALAMA, E. E.
RAZZAQ, ZIA	A study of supermanuever aerodynamics	Advanced gearbox technology
Flexural fatigue life prediction of closed hat-section using	[AD-A218378] p 631 N90-23349	[NASA-CR-179625] p 666 N90-24274
materially nonlinear axial fatigue characteristics	- ·	SAMUELSEN. G. S.
p 691 N90-25062	RODRIGUEZ, E. S., III	Symmetry assessment of an air-blast atomizer spray
REEDY, STEVEN W.	Planet gear sleeve spinning analysis	p 682 A90-40930
Analysis of thermal gradient effects in oil ring seals	[AIAA PAPER 90-2154] p 681 A90-40613	SANDLER, SCOTT B.
p 682 A90-40716	ROEPCKE, FRANK	Feasibility study for a microwave-powered ozone sniffer
REICHERT, G.	ILS - Past and present p 639 A90-41706	aircraft
Influence of ground effect on helicopter takeoff and		
	ROGAN, WILLIAM	[NASA-CR-186660] n 650 N90-23397
	AVION: A detailed report on the preliminary design of	[NASA-CR-186660] p 650 N90-23397 SANGER, K. B.
landing performance p 645 A90-42278	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport	SANGER, K. B.
	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft	
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395	SANGER, K. B. Certification testing methodology for fighter hybrid
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L.	SANGER, K. B.  Certification testing methodology for fighter hybrid structure p 642 A90-40128
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P.	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L. The influence of material quality on airframe structural	SANGER, K. B.  Certification testing methodology for fighter hybrid structure p 642 A90-40128  SANGIOVANNI, J. J.  The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P. Investigation of supersonic mixing layers	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L  The influence of material quality on airframe structural durability p 676 A90-41336	SANGER, K. B. Certification testing methodology for fighter hybrid structure p 642 A90-40128 SANGIOVANNI, J. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system [AIAA PAPER 90-2492] p 658 A90-40637
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-422457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P. Investigation of supersonic mixing layers p 623 A90-40926	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L.  The influence of material quality on airframe structural durability p 676 A90-41336 ROMINE, B. M.	SANGER, K. B. Certification testing methodology for fighter hybrid structure p 642 A90-40128 SANGIOVANNI, J. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system [AIAA PAPER 90-2492] p 658 A90-40637 SANKAR, L. N.
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P. Investigation of supersonic mixing layers p 623 A90-40926 RENNA, JAMES P.	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L.  The influence of material quality on airframe structural durability p 676 A90-41336 ROMINE, B. M.  High Mach exhaust system concept scale model test	SANGER, K. B. Certification testing methodology for fighter hybrid structure p 642 A90-40128 SANGIOVANNI, J. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system [AIAA PAPER 90-2492] p 658 A90-40637 SANKAR, L. N. Numerical simulation of the growth of instabilities in
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P. Investigation of supersonic mixing layers p 623 A90-40926 RENNA, JAMES P. Improvements to the fatigue substantiation of the H-60	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L.  The influence of material quality on airframe structural durability p 676 A90-41336 ROMINE, B. M.  High Mach exhaust system concept scale model test results	SANGER, K. B. Certification testing methodology for fighter hybrid structure p 642 A90-40128 SANGIOVANNI, J. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system [AIAA PAPER 90-2492] p 658 A90-40637 SANKAR, L. N. Numerical simulation of the growth of instabilities in supersonic free shear layers p 623 A90-40941
landing performance p 645 A90-42278 Helicopter ground and air resonance dynamics p 646 A90-42457 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 RENIE, J. P. Investigation of supersonic mixing layers p 623 A90-40926 RENNA, JAMES P.	AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport aircraft [NASA-CR-186663] p 649 N90-23395 ROLF, R. L.  The influence of material quality on airframe structural durability p 676 A90-41336 ROMINE, B. M.  High Mach exhaust system concept scale model test	SANGER, K. B. Certification testing methodology for fighter hybrid structure p 642 A90-40128 SANGIOVANNI, J. J. The role of hydrogen/air chemistry in nozzle performance for a hypersonic propulsion system [AIAA PAPER 90-2492] p 658 A90-40637 SANKAR, L. N. Numerical simulation of the growth of instabilities in

p 652 A90-40462

system for AS MKII Super-Puma

Main characteristics of an integrated flight and display

p 653 A90-42450

The EH101 electronic instrument system

SARKAR, S.

Kane's methods in rotorblade dynamics

p 646 A90-42458

SAVENKOV, I. V. Boundary layer stability in the case of transonic external

p 619 A90-39514

SAWYER, R. STEVEN

Lift response of a rectangular wing undergoing a step change in forward speed p 620 A90-39801

Co-development of CT7-6 engines - A continued tradition p 665 A90-42485 in technology and reliability SCHADOW, K. C.

Supersonic rectangular isothermal shrouded jets (AIAA PAPER 90-2028) p 621 A90-40599

Multistep dump combustor design to reduce combustion p 659 A90-40934 instabilitie SCHAFFFFR GUY

The SEPR 844 reusable liquid rocket engine for Mirage combat aircraft

[AIAA PAPER 90-1835] p 655 A90-40526

SCHAFER, R. M.

Digital control of magnetic bearings supporting a multimass flexible rotor p 682 A90-40712 SCHAUWECKER, LUDWIG

Experimental windtunnel studies for EFA

p 672 A90-41113

SCHETZ, J. A. Direct measurements of skin friction in a scramjet combustor

[AIAA PAPER 90-2342] p 626 A90-42132

SCHIERMAN, JOHN D.

Analysis of airframe/engine interactions - An integrated control perspective

[AIAA PAPER 90-1918] p 667 A90-40557

SCHIJVE, J. Reconstitution of crack growth from fractographic

observations after flight simulation loading p 682 A90-40650

Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simulation loading p 689 N90-23760 II R-5921

SCHMIDT, DAVID K.

Analysis of airframe/engine interactions - An integrated control perspective p 667 A90-40557

[AIAA PAPER 90-1918] SCHNEIDER, WILLIAM E.

UV spectroradiometric output of an F404 turbojet aircraft engine p 652 A90-40195

SCHNERR, GUENTER H.

Transonic flow around airfoils with relaxation and energy supply by homogeneous condensation

p 620 A90-39782

SCHOLZ, D. Coherent vortex structures in the wake of a sphere and

a circular disk at rest and under forced vibrations p 623 A90-40749

SCHOMER, PAUL D.

Human response research update

p 699 N90-24873 SCHRAGE, D. P.

Helicopter stability and control modeling improvements and verification on two helicopters p 671 A90-42474

SCHUESSLER, RANDALL AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

INASA-CR-1866631 p 649 N90-23395

SCHUMM, M.

Coherent vortex structures in the wake of a sphere and a circular disk at rest and under forced vibrations p 623 A90-40749

SCOTT WILLIAM R

YF-23A previews design features of future fighters p 643 A90-40344

Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary and other emissions

[AERE-R-13303-PT-2] p 678 N90-23523

SEHRA, A.

Viscous flow analysis for advanced inlet particle

[AIAA PAPER 90-2136] p 661 A90-42038

SELBY, GREGORY V.

Generation of circumferential velocity contours associated with pulsed point suction on a rotating disk p 691 N90-25065

SEMENOV, N. V.

Wave structure of artificial perturbations in a supersonic boundary layer on a plate p 619 A90-39518

SHAMROTH, STEPHEN J.

Extension of a three-dimensional viscous wing flow

[NASA-CR-182023] p 631 N90-23348 SHEHAN, J. J.

Nonflammable hydraulic power system for tactical aircraft. Volume 1: Aircraft system definition, design and

[AD-A218493] p 671 N90-23409 SHEU. M. J.

Measurements of turbulent dual-jet interaction

[AIAA PAPER 90-2105] p 624 A90-42019

SHEVEL'KOV, S. G.

Wave structure of artificial perturbations in a supersonic boundary layer on a plate p 619 A90-39518 SHIAU, L. C.

Finite element analysis of composite panel flutter p 681 A90-40032

SHIGEMATSU, JUNJI

A numerical investigation of supersonic inlet using implicit TVD scheme

p 621 A90-40612 [AIAA PAPER 90-2135] SHIRAISHI, KAZUO

A numerical investigation of supersonic inlet using implicit TVD scheme

[AIAA PAPER 90-2135] p 621 A90-40612 SHOOK, J. E.

Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies

[AD-A220167] p 674 N90-24277

SHUART, MARK J.

Impact damage and residual strength analysis of composite panels with bonded stiffeners

p 642 A90-40130 SICLARI, MICHAEL J.

Strake camber and thickness design procedure for low p 622 A90-40678 alpha supersonic flow SICRE, J. L.

The all glass helicopter cockpit p 653 A90-42447 SIDOROV, A. V.

p 638 A90-39581 Air traffic control SILVER, W.

A captive store flight vibration simulation project

p 672 A90-40476

A remote tip-driven fan powered supersonic fighter concept

(AIAA PAPER 90-2415) p 663 A90-42167 SIMONCIC, ROBERT

AIRNET: A real-time comunications network for aircraft p 690 N90-24514 [NASA-CR-1861401

SIMPSON, CAROL A.

Evaluation of speech recognizers for use in advanced combat helicopter crew station research and development [NASA-CR-177547] p 650 N90-24265

SINGH, SAHJENDRA N. Ultimate boundedness control of uncertain systems with

application to roll coupled aircraft maneuver p 668 A90-40886

SISKIND, KENNETH S.

Glass-ceramic matrix composites for advanced gas turhines [AIAA PAPER 90-2014] p 676 A90-40594 SISLIAN, J. P.

On- and off-design performance analysis of hypersonic detonation wave ramiets

[AIAA PAPER 90-2473] p 664 A90-42188

SMITH, BRUCE A. W.

The flow over a wing/nacelle combination in the presence of a propeller slipstream p 629 A90-42415

Mixing characteristics of dilution jets in small gas turbine combustors

[AIAA PAPER 90-2728] p 664 A90-42217 SMITH, C. FREDERIC

Analysis of internal flow in a ventral nozzle for STOVL [NASA-TM-103123] n 666 N90-23404

Experimental and analytical study of close-coupled entral nozzles for ASTOVL aircraft

p 666 N90-24273 FNASA-TM-1031701

SMITH, CHRISTOPHER J.

The promise of advanced materials for a 21st century URF

[AIAA PAPER 90-2396] p 662 A90-42157 SMITH. JANE

Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497 SMITH, JOHN A.

Multi-level models for diagnosis

of complex electro-mechanical systems p 693 A90-38888 SMITH, R. A.

instabilities

Supersonic rectangular isothermal shrouded iets [AIAA PAPER 90-2028] p 621 A90-40599 Multistep dump combustor design to reduce combustion p 659 A90-40934 SNODGRASS, FARON BRITT

Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS)

[AD-A220106] p 654 N90-23400 SNYDER, STEVEN P.

Exploration of concepts for multi-role fighters

[AIAA PAPER 90-2276] p 644 A90-42104 SOBEL, KENNETH M.

Flight control application of eigenstructure assignment with optimization of robustness to structured state space p 693 A90-40885 uncertainty SOMMERS, JOHN D.

An experimental investigation of support strut interference on a three-percent fighter model at high angles

p 631 N90-23353 [AD-A219793]

SONG, J.

Development of impact design methods for ceramic gas turbine components [AIAA PAPER 90-2413] p 687 A90-42165

SOSOUNOV, V. A.

Experimental turbofan using liquid hydrogen and liquid natural gas as fuel

[AIAA PAPER 90-2421] SOTHCOTT, VICTOR E.

Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area

p 663 A90-42170

p 646 A90-42465

p 695 A90-41240

[NASA-CR-4277] p 696 N90-24852

SPABERG, GORDON H.

UV spectroradiometric output of an F404 turbojet aircraft engine p 652 A90-40195

SPARA, KAREN M.

Aerodynamic detuning for control of supersonic rotor forced response

[AIAA PAPER 90-2018] p 621 A90-40596 SPIGEL, BARRY S.

Considerations of reliability design for rotorcraft

p 680 A90-39977 SPINTZYK, JOHANNES

Euromant - The European aviation research and technology program

p 617 A90-41112 STABELLINI, ALESSANDRO Agusta methodology for pitch link loads prediction in

preliminary design phase STARR. K. K.

Failure analysis handbook p 689 N90-23752

[AD-A219747] STEINBACH, GREG

High speed civil transport [NASA-CR-186661] p 649 N90-23396

STEINER, A. L. Design and analysis of a large-plug inlet ADP nacelle

and pylon [AIAA PAPER 90-2015] p 673 A90-41986

STEPHENSON, JACK D.

Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA)

[NASA-TM-102250] p 671 N90-23413 STERN, F.

Viscous flow around a propeller-shaft configuration with p 683 A90-40938 infinite-pitch rectangular blades STERN, G. J. Reduced insertion loss of X-band RF fiber optic links

STETSON, KENNETH F. Comments on 'Effect of nose bluntness and cone angle p 620 A90-39814 on slender-vehicle transition'

STEVENS, S. J. Experimental studies of combustor dilution zone aerodynamics. II - Jet development p 659 A90-40947 The performance of a combustor pre-diffuser

incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053

STEWART, MARK E. M.

Automated generation two-dimensional non-overlapping structured grids for multiple element p 629 A90-42422 airfoils with Euler solutions

STEWART, ROGER G.

Polysilicon active-matrix liquid crystal displays for cockpit p 681 A90-40393 applications

STEWART, WILBER C.

Polysilicon active-matrix liquid crystal displays for cockpit applications p 681 A90-40393 STIELER, BERNHARD Measurement of angles and angle characteristics with

accelerometers and gyroscopes p 653 A90-41730 STOCKERT, JOE AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

[NASA-CR-1866631 p 649 N90-23395

implicit TVD scheme [AIAA PAPER 90-2135]

TANG, N.

wind tunnel [AD-A220933]

STOW, P. Simulation of inviscid blade-row interaction using a	TANG, W.  Numerical simulation of the growth of instabilities in	TREFNY, CHARLES J.  On the use of external burning to reduce aerospace
linearised potential code	supersonic free shear layers p 623 A90-40941	vehicle transonic drag
[AIAA PAPER 90-1916] p 621 A90-40555	TANI, K.	[AIAA PAPER 90-1935] p 656 A90-4056.
STRICKLAND, JAMES H.	Some governing parameters of plasma torch igniter/flameholder in a scramjet combustor	TREMBLAY, M.
Preliminary characterization of parachute wake recontact p 622 A90-40681	[AIAA PAPER 90-2098] p 661 A90-42017	Helicopter store separation - Predictive techniques and flight testing p 647 A90-4249:
STUMPF, W. F.	TAO, ALBERT C. C.	TROCHALIDIS, VASSILIOS
Helicopter stability and control modeling improvements	Structure analysis of burning liquid-fueled spray in a	Large receiver aircraft - The performance and
and verification on two helicopters p 671 A90-42474	confined combustor [AIAA PAPER 90-2444] p 677 A90-42174	longitudinal stability and control during air to ai
STURGESS, G. J.	TAPE, ROBERT F.	refuelling p 669 A90-4176
Acoustic characteristics of a research step combustor [AIAA PAPER 90-1851] p 655 A90-40530	Direct lift STOVL engine integration	TSAY, D. H.  Finite element analysis of composite panel flutter
SU, JICHAO	[AIAA PAPER 90-2274] p 644 A90-42103	p 681 A90-4003
Calculation of the complete transonic unsteady small	Advanced material applications for direct lift engines [AIAA PAPER 90-2753] p 664 A90-42226	TSAY, S. B.
disturbance equation by ADI method	TAUBER, MICHAEL E.	The influence of swirl on velocity, temperature and
p 627 A90-42353	Hypervelocity, minimum-radii, coordinated turns	species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-4217
SUDDHOO, A.  Simulation of inviscid blade-row interaction using a	p 667 A90-40691	TSE, D. G. N.
linearised potential code	TAYLOR, J. R.	Combustion characteristics of a model can-type
[AIAA PAPER 90-1916] p 621 A90-40555	Multiple swirler dome combustor for high temperature rise applications	combustor p 676 A90-40479
SULLIVAN, J. P.	[AIAA PAPER 90-2159] p 661 A90-42050	TSEPLIAEV, IU. F.
Design and performance of a small, high speed axial	TCHON, K. F.	Air traffic control p 638 A90-3958
compressor [AIAA PAPER 90-1911] p 624 A90-41983	Finite element simulation of unsteady two-dimensional	TSUEI, Y. M.  Numerical simulations of gas turbine combustor flows
SULLIVAN, JOHN P.	incompressible viscous flows p 629 A90-42423	[AIAA PAPER 90-2305] p 686 A90-42110
Lift response of a rectangular wing undergoing a step	TEAGUE, CHARLES J.  Lightweight fuel pump and metering component for	TU, XING
change in forward speed p 620 A90-39801	advanced gas turbine engine control	The application of concentric vortex simulation to
SULLIVAN, P. A.	[AIAA PAPER 90-2032] p 657 A90-40602	calculating the aerodynamic characteristics of bodies of
The University of Toronto-Ryerson Polytechnical Institute hypersonic gun tunnel p 673 A90-42432	TEN HAVE, A. A.	revolution at high angles of attack p 627 A90-4235
SUN. FRANK	Usage monitoring of military helicopters	TUNIK, A. A.  Synthesis of optimal multidimensional digital systems
Laser Doppler velocimetry investigation of swirler	p 651 A90-39984	for the simulation of the angular motions of a flight vehicle
flowfields p 682 A90-40929	TEREKHOVA, N. M.  Perturbations of higher modes in a supersonic jet	under random loading p 669 A90-4195
SUNDARARAJAN, S.	p 619 A90-39516	TYNER, T. M.
Finite-element analysis of large spur and helical gear	THAIN, J.	Design and performance of a small, high speed axia
systems p 683 A90-40940 SUNDER, R.	New transonic test sections for the NAE 5 ft x 5 ft trisonic	compressor [AIAA PAPER 90-1911] p 624 A90-4198;
Estimation of fatigue crack growth in patched cracked	wind tunnel [AD-A220933] p 674 N90-24278	[
panels p 684 A90-41335	THIEDE. P.	U
SUTHERLAND, LOUIS C.	Transonic wing charge improvements by passive shock	U .
Sound propagation elements in evaluation of en route noise of advanced turbofan aircraft p 697 N90-24861	boundary layer interference control: Development status	UGOLINI, B.
SUZUKI, SHINJI	and prospects	Aerodynamics of store separation p 629 A90-42418
Calculation of stability derivatives for slender bodies	[ETN-90-96463] p 650 N90-24267	UTSCH, T.
using boundary element method p 620 A90-40181	THOMAS, D. R.  Experiments on the active control of the transmission	Flow visualization via laser-induced reflection from
SWEENEY, PATRICK C.  Fiber-optic turbine inlet temperature measurement	of sound through a clamped rectangular plate	bubble sheets p 680 A90-39784
system (FOTITMS)	p 695 A90-41109	UTSCH, THOMAS
[AIAA PAPER 90-2033] p 657 A90-40603	THOMPSON, H. A.	Flow structure generated by oscillating delta-wing segments p 622 A90-40694
SWIRYDCZUK, J.	Implementation of a transputer-based flight controller p 667 A90-38966	F 122 1.00
A visualization study of the interaction of a free vortex with the wake behind an airfoil p 623 A90-41119	THOREN, STEPHEN J.	V
SYED, S. A.	Extension of a three-dimensional viscous wing flow	<b>V</b>
Application of CFD to pitch/yaw thrust vectoring	analysis	VAISSIERE, A.
spherical convergent flap nozzles [AIAA PAPER 90-2023] p 657 A90-40597	[NASA-CR-182023] p 631 N90-23348	The Super Puma MKII automatic flight control system
The role of hydrogen/air chemistry in nozzle	TOH, H.  Development of the jet-swirl high loading combustor	p 669 A90-42449
performance for a hypersonic propulsion system	[AIAA PAPER 90-2451] p 658 A90-40633	VALASEK, JOHN
[AIAA PAPER 90-2492] p 658 A90-40637	TOMCZYK, ANDRZEJ	Fighter agility metrics, research, and test [NASA-CR-186118] p 648 N90-23386
SZODRUCH, J. Test and Measurement Technique in Hypersonics	Digital autopilot for light aircraft p 653 A90-41741	VALDES, LC.
[ILR-MITT-225(1989)] p 618 N90-24225	Onboard digital recording system for flight tests	Interaction between a high-level steady acoustic field
Aerodynamic development perspective for traffic	p 653 A90-41742	and a ducted turbulent flow
aeroplanes	TONGUE, BENSON H.  Experimental study of the effects of nonlinearities on	[ONERA, TP NO. 1990-27] p 695 A90-41206 VAN DEN BERG, R. P.
[DGLR-89-141] p 637 N90-24260 SZYMKOWIAK, E. A.	ground resonance p 643 A90-40172	Ultrasonic regression rate measurement in solid fue
A captive store flight vibration simulation project	TORELLA, G.	ramjets
p 672 A90-40476	Numerical simulation of the behaviour of internal	[AIAA PAPER 90-1963] p 656 A90-40573
•	combustion supercharged engines [AIAA PAPER 90-1873] p 655 A90-40539	VAN EGMOND, J. A.  Computation of viscous aerodynamic characteristics o
T	Trend analysis and diagnostics codes for training	2-D airfoils for helicopter applications
·	purposes	p 631 A90-42440
TAKAHASHI, M. D.	[AIAA PAPER 90-2394] p 617 A90-42156	VAN GELDER, P. A.
A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462	TORKELSON, THOMAS C.	Computation of viscous aerodynamic characteristics of
TAKALLU, M. A.	IAPSA 2 small-scale system specification [NASA-CR-182006] p 695 N90-24103	2-D airfoils for helicopter applications p 631 A90-4244(
Unsteady potential flow past a propeller blade section	[NASA-CR-182006] p 695 N90-24103 TORNABENE, ROBERT	VAN PELT, S. G.
[NASA-CR-4307] p 634 N90-24246	Lightweight fuel pump and metering component for	Initiation of spalling in aircraft gas turbine bearings
TAKEUCHI, H.	advanced gas turbine engine control	[AIAA PAPER 90-2291] p 686 A90-42110
Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design		VANGSNESS, M. D.
	[AIAA PAPER 90-2032] p 657 A90-40602	Acoustic characteristics of a research sten combusto
[AIAA PAPER 90-2129] p 625 A90-42035	TORRES, M.	
[AIAA PAPER 90-2129] p 625 A90-42035 TANAKA, A.	TORRES, M. Improving helicopter aerodynamics - A step ahead	[AIAA PAPER 90-1851] p 655 A90-40530 VENN, G. J.
[AIAA PAPER 90-2129] p 625 A90-42035 TANAKA, A. Application of 3-D Navier-Stokes computation to bowed	TORRES, M. Improving helicopter aerodynamics - A step ahead p 631 A90-42443	[AIAA PAPER 90-1851] p 655 A90-40530 <b>VENN, G. J.</b> EH101 vibration control p 647 A90-42496
[AIAA PAPER 90-2129] p 625 A90-42035  TANAKA, A.  Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design	TORRES, M. Improving helicopter aerodynamics - A step ahead	[AIAA PAPER 90-1851] p 655 A90-40530 VENN, G. J. EH101 vibration control p 647 A90-42496 VERDON, JOSEPH M.
[AIAA PAPER 90-2129] p 625 A90-42035 TANAKA, A. Application of 3-D Navier-Stokes computation to bowed	TORRES, M. Improving helicopter aerodynamics - A step ahead p 631 A90-42443  TOTAH, JOSEPH Helicopter Airborne Laser Positioning System (HALPS) [NASA-TM-102814] p 654 N90-23399	VENN, G. J. EH101 vibration control p 647 A90-42496
[AIAA PAPER 90-2129] p 625 A90-42035  TANAKA, A.  Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design [AIAA PAPER 90-2129] p 625 A90-42035	TORRES, M. Improving helicopter aerodynamics - A step ahead p 631 A90-42443  TOTAH, JOSEPH Helicopter Airborne Laser Positioning System (HALPS)	[AIAA PAPER 90-1851] p 655 A90-40530 VENN, G. J. EH101 vibration control p 647 A90-42496 VERDON, JOSEPH M. Linearized unsteady aerodynamics for turbomachinen

p 621 A90-40612

p 674 N90-24278

New transonic test sections for the NAE 5 ft x 5 ft trisonic

Dual cross-polarization planar arrays in the C and X bands p 638 A90-40979

aerospaceplane

p 675 A90-42189

TOWNEND, L. H.
Hypersonic (T-D) 'pinch' and

propulsion [AIAA PAPER 90-2474]

p 647 A90-42496

Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings
[AIAA PAPER 90-2126] p 625 A90-42033

VEUILLOT, J.-P.

VIGNATI, G.
EH101 vibration control

VITTALA, N. G. V. Aeroelastic analysis of a low aspect ratio wing p 619 A90-38915 VIZZINI, RUSSELL W. Propulsion control system designs for advanced Navy multimission aircraft [AIAA PAPER 90-2403] p 663 A90-42160 VON GRUENHAGEN, W. A highly maneuverable helicopter in-flight simulator -Aspects of realization [AIAA PAPER 88-4607] p 670 A90-42466 VON GRUENHAGEN, WOLFGANG ATTHeS - A helicopter in-flight simulator for ACT p 643 A90-41727 VOROB'EV, N. F. The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges p 620 A90-39519 VUILLEZ, C.

Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings TAIAA PAPER 90-21261 p 625 A90-42033 VYRIOTES, P. Preliminary design and analysis of propellers p 645 A90-42407 WADKINS, R. P. Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability p 678 N90-23571 [AD-A219651] WAGNER, BERNHARD Aerodynamic work for Hermes spaceplane p 675 A90-41115 WAGNER, D. A. Advanced gearbox technology [NASA-CR-179625] p 666 N90-24274 WAGNER, SIEGFRIED A study of the influence of a helicopter rotor blade on the following blades using Euler equations p 630 A90-42435 WALKER, C. R. Failure analysis handbook [AD-A219747] p 689 N90-23752 WALKER, K. The effect on fatigue crack growth under spectrum loading of an imposed placard 'G' limit p 643 A90-41339 WALKER, S. H. Twin jet screech suppression concepts tested for 4.7 percent axisymmetric and two-dimensional nozzle configurations [AIAA PAPER 90-2150] p 696 A90-42046 Computation of vectoring nozzle performance [AIAA PAPER 90-2752] p 627 AS p 627 A90-42225 WALLE, GERARDO Tests for integrating measurement of gas pressures in flight propellers p 634 N90-24253 WALSH, MICHAEL J. Effect of detailed surface geometry on riblet drag reduction performance p 622 A90-40693 WALTON, J. F. High temperature powder lubricated dampers for gas turbine engines [AIAA PAPER 90-2048] p 684 A90-41999 WANG, BAOGUO Numerical analysis of viscous-inviscid interaction in transonic flow p 627 A90-42363 WANG. M. R. The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177 WÀNG, PEISHEN A transonic airfoil design method and examples p 627 A90-42351 WANG, XUEYU Partial similarity and a real-time model of twin-spool gas p 654 A90-40512 turbine WANTUCK, PAUL J. Radio frequency (RF) heated supersonic flow laboratory [AIAA PAPER 90-2469] p 673 A90-42186 WARNER, PAUL A. High temperature solid lubricant requirements for advanced high performance gas turbine engines [AIAA PAPER 90-2042] p 661 A9 p 661 A90-41993 WATANABE, HARRY H.

Radio frequency (RF) heated supersonic flow

Applications of slotted cable antennas in the instrument

p 673 A90-42186

p 639 A90-41708

WEAVER, ALFRED C.

WILSON, K. J.

inetahilitiae

WILSON, W. W.

WINDECK, THEO

WILTON, STEPHEN A.

AIAA PAPER 90-2152]

Supersonic rectangular isothermal shrouded jets [AIAA PAPER 90-2028] p 621 A90-

Experimental windtunnel studies for EFA

Gearbox system design for ultra-high bypass engines

p 685 A90-42048

p 672 A90-41113

uncertainty

H(infinity)-optimisation

AIRNET: A real-time comunications network for blade in a plane cascade aircraft [AIAA PAPER 90-2263] [NASA-CR-186140] WEI, LIXIN WLEZIEN, RICHARD W. An improvement on upwinding technique used in the Galerkin finite element method for the computation of inviscid transonic flow with shock waves (AIAA PAPER 90-2149) WOLF, CHRISTOPHER J. p 627 A90-42361 computed centerline operations An experimental investigation of turbine rotor wakes for [DOT/FAA/CT-TN89/42] the development of a fiber optic pressure sensor WOLZ, R. R. [AIAA PAPER 90-2411] WEINBERG, BERNARD C. [AIAA PAPER 90-2038] Extension of a three-dimensional viscous wing flow WRAY, A. P. analysis [NASA-CR-182023] p 631 N90-23348 WEISSHAAR, TERRENCE A. [AIAA PAPER 90-2165] Static aeroelastic tailoring for oblique wing lateral trim WU, GIIN YUAN p 667 A90-40689 WENNERSTROM, ARTHUR J. confined combustor Stall margin improvement in axial-flow compressors by [AIAA PAPER 90-2444] circumferential variation of stationary blade setting WYBIERALA, MICHEL [AIAA PAPER 90-1912] p 656 A90-40554 Mode S WERLEY, CRAIG J. Fatigue evaluation of C/MH-53E main rotor damper X threaded joints p 642 A90-39988 WERNER, WINFRIED XU, LIPING Structural components of fiber-reinforced p 676 A90-41111 thermoplastics WESLER, JOHN Sound propagation elements in evaluation of en route XU, XIN YU noise of advanced turbofan aircraft p 697 N90-24861 WEST, BLAINE S. Nondestructive measurement of residual stresses in aircraft transparencies [AD-A218680] p 689 N90-23762 WHELESS, K. JFS190 turbine engine performance optimized using Taguchi methods [AIAA PAPER 90-2419] p 663 A90-42169 WHITELAW, J. H. Combustion characteristics of a model can-type YAMAKAWA, GEORGE M. p 676 A90-40479 combustor WHITTAKER, R. W. (AD-A2195451 High Mach exhaust system concept scale model test YAMAMOTO, KAZUOMI results p 655 A90-40552 [AIAA PAPER 90-1905] implicit TVD scheme WIELDT, J. A. [AIAA PAPER 90-2135] Nonflammable hydraulic power system for tactical YANG, JIANN-SHIOU aircraft. Volume 1: Aircraft system definition, design and analysis using an H(infinity) method [AD-A218493] p 671 N90-23409 YANIV. ZVI WIKOFF, DENNIS Drag reduction by controlling flow separation using environment p 622 A90-40690 stepped afterbodies YEH, C, L, WILKERSON, DAVE NASA/USRA high altitude reconnaissance aircraft [AIAA PAPER 90-2305] [NASA-CR-186685] p 650 N90-24266 YIP. LONG P. WILLIAMS, MARC H. Counter-rotating propellant analysis using a frequency omain panel method p 623 A90-40937 domain panel method wing planform WILLIAMS, R. D. [NASA-TM-4200] Digital control of magnetic bearings supporting a p 682 A90-40712 YODA, MINAMI multimass flexible rotor WILLSHIRE, WILLIAM L., JR. PTA en route noise measurements YOKOMIZO, T. p 696 N90-24855 WILSON, ALAN J. to a two dimensional airfoil The safety analysis approach for the EH101 YONEZAWA, Y. p 635 A90-42456 WILSON, GREGORY J. [AIAA PAPER 90-2451] Modeling supersonic combustion using a fully-implicit YOSHIDA, N. numerical method [AIAA PAPER 90-2307] p 677 A90-42117 WILSON, JAMES Aviation meteorology - Panel report

PERSONAL AUTHOR INDEX WISLER, D. C. Boundary-layer transition and separation on a turbine p 625 A90-42102 The sensitivity of near-field acoustics to the orientation of twin two-dimensional supersonic nozzles p 625 A90-42045 Position computation without elevation information for p 640 N90-23379 Requirements for business jet aircraft p 644 A90-41991 The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes p 661 A90-42053 Structure analysis of burning liquid-fueled spray in a p 677 A90-42174 Performances and new surveillance possibilities in SSR p 639 A90-41036 The influence of the inlet Mach number on the boundary layer development on turbomachinery blade surfaces p 621 A90-40504 The response of helicopter to dispersed gust p 670 A90-42470 The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter p 671 A90-42472 Preliminary airworthiness evaluation of the RC-12K p 648 N90-23387 A numerical investigation of supersonic inlet using p 621 A90-40612 Digital controller design for the pitch axis of the F-14 p 668 A90-40912 Performance of full color active-matrix-LCD in the cockpit p 681 A90-40392 Numerical simulations of gas turbine combustor flows p 686 A90-42116 Static wind-tunnel and radio-controlled flight test investigation of a remotely piloted vehicle having a delta p 632 N90-24238 Three-dimensional measurement. display. interpretation of fluid flow datasets p 679 A90-38854 Application of the moving surface boundary layer control p 628 A90-42405 Development of the jet-swirl high loading combustor p 658 A90-40633 Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the spatial network method p 638 A90-39855 YOUNG, B. G. p 692 A90-39403 Finite-element analysis of large spur and helical gear p 683 A90-40940 systems YU. SHOUQIN p 621 A90-40599 An improvement on upwinding technique used in the Multistep dump combustor design to reduce combustion Galerkin finite element method for the computation of p 659 A90-40934 inviscid transonic flow with shock waves p 627 A90-42361 Applying qualitative knowledge to aircraft engine system YU. WANGLING p 694 A90-41189

Flight control application of eigenstructure assignment

Improvement of helicopter handling qualities using

p 693 A90-40885

p 667 A90-38965

with optimization of robustness to structured state space

laboratory

WATTS, C. B., JR.

landing system

[AIAA PAPER 90-2469]

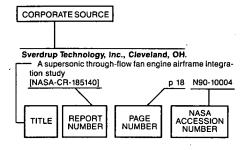
. <b>4</b>	
ZAKEM, STEVEN B.	
Lightweight fuel pump and metering component for	
advanced gas turbine engine control	
[AIAA PAPER 90-2032] p 657 A90-40602	
ZAN, S. J.	•
An experimental and analytical investigation of the buffet	
excitation parameter p 645 A90-42417	
ZANDBERGEN, B. T. C.	
Experimental and computational flammability limits in a	
solid fuel ramjet	
[AIAA PAPER 90-1964] p 676 A90-40574	
ZATONSKII, VIKTOR M. Air traffic control p 638 A90-39581	
ZEBROWSKI, ANTHONY E.	
The GE solid state air detence/ATC radar	
p 639 A90-41062	
ZEDAN, M.	
Viscous flow analysis for advanced inlet particle	
separators	
[AIAA PAPER 90-2136] p 661 A90-42038	
ZENG, QINGFU	
Linear dynamics of supersonic ramjet p 655 A90-40519	
ZHANG, JIALIN	
Numerical solution of 3-D hybrid problems in	
turbornachinery p 621 A90-40501	
ZHANG, QINGBING	
An improvement on upwinding technique used in the	
Galerkin finite element method for the computation of	
inviscid transonic flow with shock waves	
p 627 A90-42361	
ZHANG, ZHONGYIN A transonic airfoil design method and examples	
p 627 A90-42351	
ZHELTUKHIN, N. A.	
Perturbations of higher modes in a supersonic jet	
p 619 A90-39516	
ZHU, NIANGUÕ	
The influence of the inlet Mach number on the boundary	
layer development on turbomachinery blade surfaces	
p 621 A90-40504	
ZHU, XINGJIAN	
Partial similarity and a real-time model of twin-spool gas turbine p 654 A90-40512	
ZILZ, DAVID E.	
The sensitivity of near-field acoustics to the orientation	
of twin two-dimensional supersonic nozzles	
[AIAA PAPER 90-2149] p 625 A90-42045	
ZIMBRICK, R. A.	
Investigation of very high bypass ratio engines for	
subsonic transports p 659 A90-40945	
ZIMMERMANN, GEORG	
Development and application of an optimization	
procedure for space and aircraft structures p 679 A90-39186	
ZINGG, D. W.	
Higher-order boundary-layer approximations in	
interactive airfoil calculations p 628 A90-42402	
Nonlinear unsteady airfoil response studies	
n 630 A00 40406	

ZOU, CHONGQING

The mechanisms and benefits of aeroelastic tailoring p 641 A90-39286

ZUCKER, M. S.
An image analysis method for vehicle stabilization p 668 A90-40914

#### **Typical Corporate Source** Index Listing



Listings in this index are arranged alphabetically by corporate source. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document.

## Advanced Rotorcraft Technology, Inc., Mountain View,

Parameter identification of aeroelastic modes of rotary wings from transient time histories p 642 A90-40166

Aeronautical Research Inst. of Sweden, Stockholm.

Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel

p 632 N90-23363 [FFA-TN-1989-08]

Euler code predicted separation at the airfoil trailing p 632 N90-23364 (FFA-TN-1989-30)

Aeronautical Research Labs., Melbourne (Australia). Application of optimal tracking methods to aircraft terrain

[AD-A221099] p 641 N90-24264

## Air Force Geophysics Lab., Hanscom AFB, MA.

A comparison of lightning network data with surface weather observations p 692 N90-23832 [AD-A220003]

Force Inst. of Tech., Wright-Patterson AFB, OH. Development of a least squares time response lower-order equivalent systems technique

p 648 N90-23389

Continued development and analysis of a new extended Kalman filter for the Completely Integrated Reference Instrumentation System (CIRIS)

p 654 N90-23400 [AD-A220106]

Prediction of longitudinal pilot induced oscillations using the optimal control model

[AD-A220593] p 671 N90-23412

Throughput and delay characteristics slow-frequency hopped aircraft-to-aircraft packet radio network

[AD-A220525] p 688 N90-23609

#### Air Force Occupational and Environmental Health Lab., Brooks AFB, TX.

A/F32T-9 large turbo fan engine enclosed noise suppressor system (T-9 NSS), exterior far-field and interior noise, McConnell AFB, Kansas [AD-A220535] p 665 N90-23402

Allied-Signal Aerospace Co., Phoenix, AZ.

Development of impact design methods for ceramic gas turbine components

[AIAA PAPER 90-2413]

p 687 A90-42165 Amdahi Corp., Sunnyvale, CA.

Supercomputer applications in gas turbine flowfield

p 620 A90-40495 Analytical Services and Materials, Inc., Hampton, VA. Application of a new adaptive grid for aerodynamic

analysis of shock containing single jets [AIAA PAPER 90-2025] p 624 A90-41988

ARE, Inc., Riverdale, MD.

Criteria for coal tar seal coats on airport pavements. Volume 2: Laboratory and field studies p 674 N90-24277 [AD-A220167]

Arizona State Univ., Tempe.

Analysis of airframe/engine interactions - An integrated control perspective [AIAA PAPER 90-1918] p 667 A90-40557

Army Aerostructures Directorate, Hampton, VA.

Towards a damage tolerance philosophy for composite p 675 A90-40127 materials and structures

Army Aviation Engineering Flight Activity, Edwards AFB, CA.

Preliminary airworthiness evaluation of the RC-12K p 648 N90-23387 [AD-A219545]

Army Aviation Systems Command, Moffett Field, CA. CFD and transonic helicopter sound

p 696 A90-42433 Evaluation of speech recognizers for use in advanced combat helicopter crew station

development

p 650 N90-24265 [NASA-CR-177547] Army Aviation Systems Command, Saint Louis, MO. Peacetime replacement and crash damage factors for army aircraft

[AD-A218544] p 636 N90-23372

Army Construction Engineering Research Lab., Champaign, IL.

Human response research update

p 699 N90-24873

Army Materials Technology Lab., Watertown, MA.

HPLC analysis of helicopter rotor blade materials p 650 N90-24270 [AD-A221121]

Auburn Univ., AL

AVION: A detailed report on the preliminary design of a 79-passenger, high-efficiency, commercial transport

[NASA-CR-186663] p 649 N90-23395

High speed civil transport [NASA-CR-186661] p 649 N90-23396

#### В

#### Boeing Advanced Systems Co., Seattle, WA. IAPSA 2 small-scale system specification

[NASA-CR-182006] p 695 N90-24103

Boeing Helicopter Co., Philadelphia, PA.

Active control of tiltrotor blade in-plane loads during p 670 A90-42463 maneuvers

# California State Polytechnic Univ., Pomona. NASA/USRA high altitude reconnaissance aircraft

[NASA-CR-186685] p 650 N90-24266

California Univ., Irvine.

Symmetry assessment of an air-blast atomizer spray p 682 A90-40930

#### California Univ., Los Angeles.

A model for active control of helicopter air resonance in hover and forward flight p 670 A90-42462

# Centro Italiano Ricerche Aerospaziali, Naples. A computer code for the prediction of aerodynamic

characteristics of lifting airfoils at transonic speed p 632 N90-23359 (DLC-EST-TN-030)

Prediction of aerodynamic performance of airfoils in low

Reynolds number flows [DLC-EST-TN-031] p 632 N90-23360

Problems of internal acoustics in two and three dimensional cavities with deformable walls using the MSC/Nastran code

[DLC/STR-INT-TN-004] p 699 N90-24876

Cincinnati Univ., OH.

Composite reduced Navier Stokes procedures for flow problems with strong pressure interactions p 689 N90-23687 [AD-A219621]

Civil Aeromedical Inst., Oklahoma City, OK.

The influence of adjacent seating configurations on egress through a type 3 emergency exit

p 636 N90-23371 (AD-A218393)

#### D

#### Dayton Univ., OH.

Fatigue crack growth investigation of a Ti-6Al-4V forging under complex loading conditions: NATO/AGARD supplemental engine disk program

p 678 N90-23538 [AD-A220239] Nondestructive measurement of residual stresses in

aircraft transparencies [AD-A218680] p 689 N90-23762

Deutsche Forschungsanstalt fuer Luft- und Raumfahrt,

Brunswick (Germany, F.R.).

En route noise of two turboprop aircraft p 697 N90-24859 [DLR-MITT-89-18]

Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

Infrared thermography at hypersonic channel H2K p 674 N90-24235

Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).

A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized

formulation [DLR-FB-89-58] p 634 N90-24254

A time-marching method for calculating unsteady airloads on three-dimentional wings. Part 2: Full-potential formulation [DLR-FB-89-59] p 635 N90-24255

On simplified analytical flutter clearance procedures for light aircraft [DLR-FB-89-56] p 672 N90-24276

Deutsche Lufthansa A.G., Hamburg (Germany, F.R.). The 30th Airlines International Electronics Meeting Proceedings

[ETN-90-96973] p 637 N90-24261 Douglas Aircraft Co., Inc., Long Beach, CA.

Impact damage and residual strength analysis of composite panels with bonded stiffeners p 642 A90-40130

An interactive boundary-layer method for unsteady airfoil flows. Part 1: Quasi-steady-state model

p 634 N90-24250 [AD-A221220]

## Eagle Engineering, Inc., Hampton, VA.

٠.

Summary of sonic boom rise times observed during FAA community response studies over a 6-month period in the Oklahoma City area p 696 N90-24852 INASA-CR-42771

Edgerton, Germeshausen and Grier, Inc., Idaho Falls,

ID.

Three-dimensional analysis on flow and temperature distributions for aircraft fuel thermal stability p 678 N90-23571 [AD-A219651]

Environmental Protection Agency, Washington, DC. When propfans cruise, will LDN 65 fly

p 697 N90-24864

Analysis of sequencing and scheduling methods for Environmental Research Inst. of Michigan, Ann Arbor. Synthetic aperture radar imagery of airports and [NASA-TM-102795] p 636 N90-23373 surrounding areas: Denver Stapleton International Landesanstalt fuer Umweltschutz, Simulator evaluation of the final approach spacing tool Airnort Baden-Wuerttemberg (Germany, F.R.). [NASA-CR-4305] p 636 N90-23374 p 637 N90-24257 [NASA-TM-102807] Noise measurements of turboprop airplanes at different Helicopter Airborne Laser Positioning System (HALPS) overflight elevations p 697 N90-24860 (NASA-TM-102814) p 654 N90-23399 Lockheed Engineering and Sciences Co., Hampton, Lateral-directional stability and control characteristics of the Quiet Short-Haul Research Aircraft (QSRA) Comparison of high-angle-of-attack slender-body theory Federal Aviation Administration, Atlantic City, NJ. [NASA-TM-102250] n 671 N90-23413 and exact solutions for potential flow over an ellipsoid Fire hazards of aerosol cans in aircraft cargo Some 1-(diorganooxyphosphonyl)methyl-2,4- and p 622 A90-40692 compartments -2,6-dinitro-benzenes [NASA-CASE-ARC-11425-3] Unsteady potential flow past a propeller blade section [DOT/FAA/CT-89/32] p 636 N90-23369 p 678 N90-23475 p 634 N90-24246 [NASA-CR-4307] An evaluation of the accuracy of a microwave landing National Aeronautics and Space Administration. Flight system area navigation system at Miami/Tamiami Florida Research Center, Edwards, CA. Propulsion system-flight control integration-flight p 640 N90-23377 [DOT/FAA/CT-TN89/40] evaluation and technology transition MLS mathematical model validation study using airborne p 644 A90-42106 [AIAA PAPER 90-2280] MLS data from Midway Airport engineering flight tests, MAG Consultants, Inc., San Francisco, CA. National Aeronautics and Space Administration. Hugh Proposed definition of the term en route in en route August 1988 L. Dryden Flight Research Facility, Edwards, CA. p 696 N90-24854 [DOT/FAA/CT-TN90/2] p 640 N90-23378 A proposed Kalman filter algorithm for estimation of Position computation without elevation information for The effect of noise-abatement profiles on noise unmeasured output variables for an F100 turbofan computed centerline operations immissions and human annoyance underneath a p 698 N90-24865 (DOT/FAA/CT-TN89/42) p 640 N90-23379 subsequent climboath p 656 A90-40558 [AIAA PAPER 90-1920] Federal Aviation Administration, Washington, DC. Maine Univ., Orono. A preliminary evaluation of an F100 engine parameter IFR aircraft handled forecast by air route traffic control An analytic study of nonsteady two-phase laminar estimation process using flight data p 691 N90-25051 p 656 A90-40559 center: Fiscal years 1990 to 2005 boundary layer around an airfoil [AIAA PAPER 90-1921] [AD-A220312] p 641 N90-24263 Manchester Univ. (England). A simple dynamic engine model for use in a real-time Fields (James M.), Silver Spring, MD. The computation of turbulent thin shear flows associated aircraft simulation with thrust vectoring Social survey findings on en route noise annoyance [AIAA PAPER 90-2166] p 662 A90-42054 with flow around multielement aerofoils p 698 N90-24868 p 633 N90-24240 Estimating short-period dynamics using an extended Forest Service, San Dimas, CA. Marytand Univ., College Park. Kalman filter Preliminary thoughts on an acoustic metric for the [NASA-TM-101722] p 648 N90-23392 Aeroelastic effects on stability and control of hingeless wilderness aircraft overflight study p 697 N90-24862 STARS: An integrated general-purpose finite element rotor helicopters p 647 A90-42473 Massachusetts Inst. of Tech., Cambridge. structural, aeroelastic, and aeroservoelastic analysis computer program G Active control of tiltrotor blade in-plane loads during [NASA-TM-101709] p 689 N90-23768 maneuvers p 670 A90-42463 National Aeronautics and Space Administration. General Accounting Office, Washington, DC. Mauter (George A.), Huntington Station, NY. Langley Research Center, Hampton, VA. Aircraft drawings index p 618 N90-23340 Aviation security: Corrective actions underway, but better Navier-Stokes solutions for vortical flows inspection guidance still needed. Report to the McDonnell Aircraft Co., Saint Louis, MO. tangent-ogive cylinder p 620 A90-39780 Chairwoman, Government Activities and Transportation Nonflammable hydraulic power system for tactical Towards a damage tolerance philosophy for composite Subcommittee, Committee on Government Operations, aircraft. Volume 1: Aircraft system definition, design and p 675 A90-40127 materials and structures House of Representatives Impact damage and residual strength analysis of p 635 N90-23367 [GAO/RCED-88-160] [AD-A218493] composite panels with bonded stiffeners General Electric Co., Cincinnati, OH.

Experimental performance and acoustic investigation of McDonnell-Douglas Research Labs., Saint Louis, MO. p 642 A90-40130 Experimental investigation of terminal shock sensors in Strake camber and thickness design procedure for low modern, counterrotating blade concepts mixed-compression inlets alpha supersonic flow p 622 A90-40678 p 649 N90-23393 [NASA-CR-185158] [AIAA PAPER 90-1931] p 681 A90-40560 Sidewall boundary-layer removal and wall adaptation General Electric Co., Lynn, MA. Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen tudies p 672 A90-40680 Drag measurements on a modified prolate spheroid Convertible engine system for high speed rotorcraft [AIAA PAPER 90-2512] p 658 A90-40643 (Germany, F.R.). Short time Force and moment measurement System using a magnetic suspension and balance system General Motors Corp., Indianapolis, IN. p 672 A90-40684 for shock tubes (SFS) for measuring times less than 10 Advanced gearbox technology [NASA-CR-179625] p 674 N90-24233 Static aeroelastic tailoring for oblique wing lateral trim p 666 N90-24274 Aerodynamic development perspective for traffic p 667 A90-40689 Geneva Univ. (Switzerland). Effect of detailed surface geometry on riblet drag Problems related to aircraft noise in Switzerland [DGLR-89-141] p 637 N90-24260 p 622 A90-40693 reduction performance p 698 N90-24871 CFD propels NASP propulsion progress Transonic wing charge improvements by passive shock George Washington Univ., Washington, DC. p 683 A90-41163 boundary layer interference control: Development status Rotary-Jet thrust augmentor with jet-flapped blades Cryogenic wind tunnels p 673 A90-41726 and prospects p 633 N90-24243 Application of a new adaptive grid for aerodynamic [ETN-90-96463] p 650 N90-24267 Georgia Inst. of Tech., Atlanta. analysis of shock containing single jets Meyer (Thomas J.), Hamburg (Germany, F.R.). Helicopter stability and control modeling improvements [AIAA PAPER 90-2025] p 624 A90-41988 Additive evaluation criteria for aircraft noise and verification on two helicopters p 671 A90-42474 Direct measurements of skin friction in a scramjet p 698 N90-24867 Grumman Aerospace Corp., Bethpage, NY. combustor Strake camber and thickness design procedure for low [AIAA PAPER 90-2342] p 626 A90-42132 p 622 A90-40678 alpha supersonic flow Wind tunnel wall interference investigations in NAE/NRC High Reynolds Number 2D Facility and NASA Langley 0.3m Transonic Cryogenic Tunnel p 628 A90-42404 National Aeronautical Establishment, Ottawa (Ontario) Euler and Navier-Stokes computations for airfoil Wind tunnel wall interference investigations in NAE/NRC Hampton Univ., VA. High Reynolds Number 2D Facility and NASA Langley 0.3m geometries using unstructured meshes p 630 A90-42425 Automatic speech recognition in air-ground data link Transonic Cryogenic Tunnel p 628 A90-42404 New transonic test sections for the NAE 5 ft x 5 ft trisonic Actuated forebody strakes p 690 N90-25037 Hessian Ministry for Economics and Technology, [NASA-CASE-LAR-13983-1] p 648 N90-23390 Frankfurt (Germany, F.R.).

En route noise of turboprop aircraft and their Miniaturization of flight deflection measurement [AD-A220933] n 674 N90-24278 National Aeronautics and Space Administration. Ames [NASA-CASE-LAR-13628-1] p 689 N90-23707 acceptability: Report of tests p 697 N90-24858 Research Center, Moffett Field, CA. Calculation of hypersonic forebody/inlet flow fields [AIAA PAPER 90-1493] p 619 A90-39049 Real-time simulation clock [NASA-CASE-LAR-14056-1] p 689 N90-23713 Langley aerospace test highlights, 1989 [NASA-TM-102631] p 69 An introduction to chaos theory in CFD p 699 N90-24221 [AIAA PAPER 90-1440] p 680 A90-39725 (lilnois Univ., Urbana-Champaign. Aerodynamic performance of a 0.27-scale model of an Supercomputer applications in gas turbine flowfield An experimental study of fault propagation in a jet-engine p 620 A90-40495 AH-64 helicopter with baseline and alternate rotor blade Flow visualization studies of the Mach number effects [NASA-CR-1813351 p 665 N90-23401 [NASA-TM-4201] p 632 N90-24237 on dynamic stall of an oscillating airfoil p 622 A90-40683 Static wind-tunnel and radio-controlled flight test Hypervelocity, minimum-radii, coordinated turns investigation of a remotely piloted vehicle having a delta p 667 A90-40691 p 632 N90-24238 CFD propels NASP propulsion progress [NASA-TM-4200] Kansas Univ., Lawrence. p 683 A90-41163 Aerodynamic characteristics of two rotorcraft airfoils Preliminary design of a supersonic Short Takeoff and designed for application to the inboard region of a main Concept development of automatic guidance for otorcraft obstacle avoidance p 669 A90-41632 Vertical Landing (STOVL) fighter aircraft [NASA-CR-186670] p.6 rotorcraft obstacle avoidance p 649 N90-23394 [NASA-TP-30091 p 633 N90-24239 CFD and transonic helicopter sound Kansas Univ. Center for Research, Inc., Lawrence. p 696 A90-42433 Unique failure behavior of metal/composite aircraft

A review of tilt rotor download research

p 630 A90-42437

structural components under crash type loads

p 690 N90-24660

[NASA-TM-102679]

[NASA-CR-186118]

Fighter agility metrics, research, and test

p 648 N90-23386

FAA/NASA En Route Noise Symposium	Pratt and Whitney Aircraft, West Palm Beach, FL	Texas A&M Univ., College Station.
(NASA-CP-3067) p 696 N90-24853	Failure analysis handbook [AD-A219747] p 689 N90-23752	Determination of aerodynamic se based on the transonic small perturba
PTA en route noise measurements p 696 N90-24855	PRC Systems Services Co., Edwards, CA.	oaseo on the transonic small perturb
En route noise annoyance laboratory test: Preliminary	A proposed Kalman filter algorithm for estimation of	Texas Univ., Austin.
results p 698 N90-24870	unmeasured output variables for an F100 turbofan	Modeling growth of fatigue cracks
National Aeronautics and Space Administration. Lewis	engine [AIAA PAPER 90-1920] p 656 A90-40558	rivet holes Toledo Univ., OH.
Research Center, Cleveland, OH.	Psycho-Linguistic Research Associates, Woodside,	Finite element analysis of structura
Analysis of airframe/engine interactions - An integrated control perspective	ČA.	viscoplastic models with application
[AIAA PAPER 90-1918] p 667 A90-40557	Evaluation of speech recognizers for use in advanced combat helicopter crew station research and	problem [NASA-CR-185189]
On the use of external burning to reduce aerospace	development dew station research and	Transportation Systems Center, Cam
vehicle transonic drag [AIAA PAPER 90-1935] p 656 A90-40562	[NASA-CR-177547] p 650 N90-24265	En route noise: NASA propfan tes
CFD propels NASP propulsion progress	Purdue Univ., West Lafayette, IN.	data - simplified procedure)
p 683 A90-41163	Static aeroelastic tailoring for oblique wing lateral trim p 667 A90-40689	[DOT-TSC-FA953-LR4] En route noise: NASA propfan tes:
A modeling technique for STOVL ejector and volume	Counter-rotating propellant analysis using a frequency	source noise
dynamics [AIAA PAPER 90-2417] p 663 A90-42168	domain panel method p 623 A90-40937	[DOT-TSC-FA953-LR5]
Experimental evaluation of a tuned electromagnetic	Flow induced forced response of an incompressible radial cascade including profile and incidence effects	
damper for vibration control of cryogenic turbopump	[AIAA PAPER 90-2352] p 626 A90-42136	Ū
rotors [NASA-TP-3005] p 665 N90-23403	<u>.</u>	United Kingdom Atomic Energy Auth
Analysis of internal flow in a ventral nozzle for STOVL	R	(England).
aircraft		Characterisation of fatigue of al
[NASA-TM-103123] p 666 N90-23404 Introducing the VRT gas turbine combustor	Royal Air Force Coll., Cranwell (England).  A study of the technology required for advanced vertical	acoustic emission. Part 2: Discriminati and other emissions
[NASA-TM-103176] p 688 N90-23591	take-off aircraft	[AERE-R-13303-PT-2]
Experimental and analytical study of close-coupled	[ETN-90-96786] p 650 N90-24268	United Technologies Corp., Windsor
ventral nozzles for ASTOVL aircraft [NASA-TM-103170] p 666 N90-24273		Investigation of the near wake of a
National Aerospace Lab., Amsterdam (Netherlands).	S	United Technologies Research Cente
Activities report in aerospace and aerodynamics	Condia National Lake Albuquerus NM	CT.
[ETN-90-96774] p 699 N90-24224 Naval Postgraduate School, Monterey, CA.	Sandia National Labs., Albuquerque, NM.  Equilibrium swelling of elastomeric materials in solvent	Hydrocarbon-fueled scramjet com [AIAA PAPER 90-2337]
Flow visualization studies of the Mach number effects	environments	Investigation of the near wake of a
on dynamic stall of an oscillating airfoil	[DE90-010164] p 678 N90-24430	•
p 622 A90-40683	Scientific Research and Technology, Inc., Hampton, VA.	Linearized unsteady aerodynamics aeroelastic applications
An experimental investigation of support strut interference on a three-percent fighter model at high angles	Low-density flow effects for hypervelocity vehicles,	[AIAA PAPER 90-2355]
of attack	phase 2	University of the Pacific, Stockton, C
[AD-A219793] p 631 N90-23353	(AD-A221034) p 634 N90-24249 Scientific Research Associates, Inc., Glastonbury, CT.	Flow unsteadiness effects on boun
Initial flight test of half-scale unmanned air vehicle [AD-A219584] p 648 N90-23388	Extension of a three-dimensional viscous wing flow	[NASA-CR-186067]
Application of neural networks to the F/A-18 engine	analysis	. <b>V</b>
condition monitoring system	[NASA-CR-182023] p 631 N90-23348 Simula, Inc., Phoenix, AZ.	•
[AD-A219820] p 666 N90-24271 Helicopter controllability	Operational effects on crashworthy seat attenuators	Vigyan Research Associates, Inc., Ha
[AD-A220078] p 672 N90-24275	[AD-A221148] p 637 N90-24259	Navier-Stokes solutions for vort
Metallized fuel particle size study in a solid fuel ramjet	Stanford Univ., CA.  Modeling supersonic combustion using a fully-implicit	tangent-ogive cylinder Sidewall boundary-layer removal a
[AD-A220079] p 679 N90-24451 Naval Surface Warfare Center, Sliver Spring, MD.	numerical method	studies
Wind tunnel tests of a 20-gore disk-gap-band	[AIAA PAPER 90-2307] p 677 A90-42117	3-D Euler calculations for aft-propfa
parachute	State Univ. of New York, Brockport.  A quantitative technique to estimate microburst wind	[AIAA PAPER 90-2147] Virginia Polytechnic Inst. and State
[AD-A221326] p 634 N90-24251 Nielsen Engineering and Research, Inc., Mountain	shear hazard to aircraft p 692 N90-25040	Direct measurements of skin fric
View, CA.	Sterling Federal Systems, Inc., Moffett Field, CA.	combustor
A study of supermanuever aerodynamics	Supercomputer applications in gas turbine flowfield simulation p 620 A90-40495	[AIAA PAPER 90-2342] Extension-torsion coupling beha
[AD-A218378] p 631 N90-23349	simulation p 620 A90-40495 Sverdrup Technology, Inc., Brook Park, OH.	composite tilt-rotor blades
Norfolk State Univ., VA.  Ground evaluation of seeding an in-flight wingtip vortex	Preliminary design of a long-endurance Mars aircraft	Virginia Univ., Charlottesville.
using infrared imaging flow visualization technique	[AIAA PAPER 90-2000] p 674 A90-40587	Adaptive control of a system with
p 635 N90-25035	Sverdrup Technology, Inc., Cleveland, OH.  Analysis of airframe/engine interactions - An integrated	Application of an impulse response helicopter vibration problem
Norges Tekniske Hoegskole, Trondheim.  An aircraft noise study in Norway p 698 N90-24872	control perspective	AIRNET: A real-time comunica
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	[AIAA PAPER 90-1918] p 667 A90-40557	aircraft
0	Systems Control Technology, Inc., Arlington, VA.  Aeronautical decisionmaking for air ambulance program	[NASA-CR-186140]
•	administrators	W
Office National d'Etudes et de Recherches	[DOT/FAA/DS-88/8] p 635 N90-23368	**
Aerospatiales, Toulouse (France). High enthalpy hypersonic wind tunnel F4: General	- · · · · · · · · · · · · · · · · · · ·	Washington Univ., Seattle.
description and associated instrumentation	1	Conceptual design for aerospace v
p 673 N90-24228	Tachricoho Hachashula Asahar (Correcti ED)	Wichita State Univ., KS.
Old Dominion Univ., Norfolk, VA. Subsonic sting interference on the aerodynamic	Technische Hochschule, Aachen (Germany, F.R.).  Calculation of the aeroelastic blade stabilization with	Development of a finite element I
characteristics of a family of slanted-base	linearized process	analysis for laminates subject to exte
ogive-cylinders	[MITT-87-01] p 666 N90-24272	torsion Worcester Polytechnic Inst., MA.
[NASA-CR-4299] p 633 N90-24242 Flexural fatigue life prediction of closed hat-section using	Technische Univ., Berlin (Germany, F.R.).	Feasibility study for a microwave-po
materially nonlinear axial fatigue characteristics	Test and Measurement Technique in Hypersonics {ILR-MITT-225(1989)} p 618 N90-24225	aircraft
p 691 N90-25062	- · · · · · · · · · · · · · · · · · · ·	[NASA-CR-186660]
Generation of circumferential velocity contours	Technische Univ., Brunswick (Germany, F.R.).	Wright Research Development Center

# associated with pulsed point suction on a rotating disk p 691 N90-25065

Pennsylvania State Univ., University Park.

The interaction of a supersonic streamwise vortex and a normal shock wave PPG Industries, Inc., Huntsville, AL. p 633 N90-24241

Forward canopy feasibility and Thru-The-Canopy (TTC) ejection system study [AD-A220360] p 637 N90-24258

Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simulation loading [LR-592] p 689 N90-23760

Results of TCAS-2 simulations in reconstructed

The gun tunnel of the Brunswick Institute for Fluid

Tests for integrating measurement of gas pressures in

p 673 N90-24227

p 634 N90-24253

dangerous encounters (Jul. 1986 to Jun. 1989)
[ETN-90-96474] p 636 N90-23375

Mechanics: Current development status

Technische Univ., Delft (Netherlands).

flight propellers

[ETN-90-96498]

ensitivity coefficients ation formulation p 622 A90-40682

s which originate at p 691 N90-25060

al components using ion to a cowl lip

p 690 N90-23769 nbridge, MA.

st aircraft (corrected

p 696 N90-24856 st aircraft (calculated

p 697 N90-24857

hority, Harwell

luminium alloys by ion between primary

p 678 N90-23523 Locks, CT. propfan

p 622 A90-40686 er, East Hartford,

nbustor investigation p 658 A90-40622 propfan

p 622 A90-40686 for turbomachinery

p 626 A90-42137 À. ndary layers

p 690 N90-24557

ampton, VA.

tical flows over a p 620 A90-39780 and wall adaptation p 672 A90-40680

an integration p 625 A90-42044 Univ., Blacksburg.

tion in a scramjet p 626 A90-42132

avior of advanced p 651 N90-25057

periodic dynamics: se method to the p 694 N90-23990 tions network for p 690 N90-24514

ehicles -

p 651 N90-25043

based delamination ension, bending, and p 679 N90-25049

owered ozone sniffer p 650 N90-23397

Wright Research Development Center,

Wright-Patterson AFB, OH.

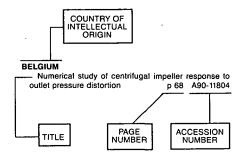
Correlation/validation of finite element code analyses for vibration assessment of avionic equipment p 654 N90-23398 [AD-A220393]

Wyle Labs., Inc., El Segundo, CA.

Sound propagation elements in evaluation of en route noise of advanced turbofan aircraft p 697 N90-24861

# FORE--G N

#### Typical Foreign Technology Index Listing



Listings in this index are arranged alphabetically by country of intellectual origin. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the citation in the abstract section. If applicable, a report number is also included as an aid in identifying the document.

#### **AUSTRALIA**

Concept demonstration of the use of interactive fault diagnosis and isolation for TF30 engines

p 617 A90-41177

The effect on fatigue crack growth under spectrum loading of an imposed placard 'G' limit p 643 A90-41339

Application of optimal tracking methods to aircraft terrain

following [AD-A221099] p 641 N90-24264

#### C

ANADA	
Eliabt	100

Flight testing and application of a Peripheral Vision Display p 652 A90-40381 Planet gear sleeve spinning analysis

p 681 [AIAA PAPER 90-2154] A90-40613 Finite-element analysis of large spur and helical gear A90-40940 p 683 Jet Engine Technical Advisor (JETA)

p 693 A90-41184

Fracture control via DRM-Algorithm p 694

Computation of flow through a centrifugal impeller with tip leakage [AIAA PAPER 90-2021]

p 684 A90-41987 5DOF dynamic loads on a jet vane

[AIAA PAPER 90-2382] p 675 A90-42147 On and off-design performance prediction of single spool turbojets using gasdynamics [AIAA PAPER 90-2393]

p 662 A90-42155 On- and off-design performance analysis of hypersonic detonation wave rami

[AIAA PAPER 90-2473] p 664 A90-42188 Flow separation on a supercritical airfoil

A90-42394 p 627

Application of 3-D flow analysis to the design of a high work transonic turbine p 628 A90-42395 Higher-order boundary-layer approximations interactive airfoil calculations p 628 A90-42402 Wind tunnel results and numerical computations for the NAE deHavilland series of natural laminar flow airfoils p 628 A90-42403

Wind tunnel wall interference investigations in NAE/NRC High Reynolds Number 2D Facility and NASA Langley 0.3m p 628 A90-42404 Transonic Cryogenic Tunnel Application of the moving surface boundary layer control to a two dimensional airfoil p 628 A90-42405 Nonlinear unsteady airfoil response studies

p 628 A90-42406 Preliminary design and analysis of propellers

p 645 A90-42407 Modelling of boundary layer and trailing edge thickness the Euler equations using p 629 transpiration A90-42412 Finite volume solutions of two-dimensional Euler

equations on adapted structured meshes

p 629 · A90-42413 The flow over a wing/nacelle combination in the presence of a propeller slipstream p 629 Application of the KTRAN transonic small disturbance

code to the complete CF-18 aircraft with stores p 629 A90-42416 An experimental and analytical investigation of the buffet A90-42417 excitation parameter p 645 p 629 Aerodynamics of store separation A90-42418 Measurements of aerodynamic forces on aircraft

external stores in the NAE trisonic blowdown p 629 A90-42419 Development of the stall warning/stick pusher system

for the Boeing/de Havilland Dash 8 Series 300 p 645 A90-42420 Finite element simulation of unsteady two-dimensional compressible viscous flows p 629 A90-42423 New transonic test sections for the NAE 5ftx5ft trisonic incompressible viscous flows p 630 A90-42431

The University of Toronto-Ryerson Polytechnical Institute hypersonic gun tunnel p 673 A90-42432 Helicopter store separation - Predictive techniques and p 647 A90-42495 flight testing

A new Lagrangian method for steady supersonic flow computation. I - Godunov scheme 631 A90-42506 New transonic test sections for the NAE 5 ft x 5 ft trisonic wind tunnel

[AD-A220933] p 674 N90-24278

#### CHINA, PEOPLE'S REPUBLIC OF

Optimum design of composite wing structures subjected p 680 A90-39276 to displacement constraints The mechanisms and benefits of aeroelastic tailoring

p 641 A90-39286 Analysis of aeroelastic divergence for the slender flight p 680 A90-39298 vehicles

A study on the application of controllability and observability concepts in the design of flight control n 693 A90-39303 Numerical solution of 3-D hybrid problems in

p 621 A90-40501 turbomachinery Application of leaned blades to an aeroengine p 654 A90-40503

The influence of the inlet Mach number on the boundary layer development on turbomachinery blade surfaces

p 621 A90-40504 Partial similarity and a real-time model of twin-spool gas p 654 A90-40512 turbine

An experimental investigation of rotating stall in a centrifugal compressor with vaneless diffuser

p 621 A90-40513 Linear dynamics of supersonic ramiet

p 655 A90-40519 Influence of fuel composition on flame radiation in gas turbine combustors p 659 A90-40946

A transonic airfoil design method and examples p 627 A90-42351

Calculation of the complete transonic unsteady small disturbance equation by ADI method

p 627 A90-42353 A novel synthetic method for studying nonlinear flight p 645 A90-42355

The application of concentric vortex simulation to calculating the aerodynamic characteristics of bodies of p 627 A90-42357 revolution at high angles of attack

An improvement on upwinding technique used in the Galerkin finite element method for the computation of inviscid transonic flow with shock waves

p 627 A90-42361 Numerical analysis of viscous-inviscid interaction in p 627 A90-42363

Calculation of viscous-inviscid strong interaction for transonic flows over aerofoils p 627 A90-42364

A new simplification method for analysing the rapid rolling stability of aircraft p 669 A90-42367 The response of helicopter to dispersed gust

p 670 A90-42470

The influence of the inertia coupling on the stability and control of the helicopter and the response of helicopter p 671 A90-42472 CZECHOSLOVAKIA

Reconstitution of crack growth from fractographic observations after flight simulation loading

p 682 A90-40650

#### **FRANCE**

The SEPR 844 reusable liquid rocket engine for Mirage

[AIAA PAPER 90-1835] p 655 A90-40526 Dual cross-polarization planar arrays in the C and X p 638 A90-40979

The TVD 900 - A modern signal processing applied to primary civilian ATC radar p 638 A90-41034 Performances and new surveillance possibilities in SSR p 639 A90-41036 - Mode S

Applications of Mode S secondary surveillance radar to civil air traffic control - Studies, experiments, and policy of the French Direction de la Navigation Aerienne p 639 A90-41056

Experiments on Mode S secondary surveillance radar - The participation of the French Direction de la Navigation Aerienne in the European effort p 639 A90-41057 Recent propeller development and studies conducted at ONFRA

[ONERA, TP NO. 1990-16] p 683 A90-41201 Coupled aerodynamic forces due to unsteady stall on a high-aspect-ratio wing oscillating at high amplitude [ONERA, TP NO. 1990-24] p 623 A90-41 p 623 A90-41203

Directivity of the noise radiation emitted from the inlet duct of a turboshaft helicopter engine

p 695 A90-41205 IONERA, TP NO. 1990-261 Interaction between a high-level steady acoustic field and a ducted turbulent flow

IONERA, TP NO. 1990-271 p 695 A90-41206 Wind-tunnel measurement of noise emitted by helicopter rotors at high speed [ONERA, TP NO. 1990-28]

p 695 A90-41207 Noise-source measurements by thin-film pressure transducers in a subsonic turbofan model

p 659 IONERA, TP NO. 1990-361 A90-41212 Military engines - Cradle of technology p 660 A90-41758

Characterization of helicopter turboshaft engine noise p 660 A90-41759

Starter systems and auxiliary power units A90-41760 p 660 Developmental tests on the M 88 engine are on track

p 660 A90-41761 Toward total quality in industry p 684 A90-41768 The Airbus . . . a challenge launched twenty years ago

p 699 A90-41769 Quasi-3D viscous flow computations in subsonic and transonic turbomachinery bladings

[AIAA PAPER 90-2126] p 625 A90-42033 Experimental study of the flow around an helicopter fuselage - Comparison with three-dimensional boundary layer calculations p 630 A90-42438 Eurofar - Status of the European tilt-rotor project

p 645 A90-42441 Improving helicopter aerodynamics - A step ahead p 631 A90-42443

#### **GERMANY, FEDERAL REPUBLIC OF**

The Super Puma MKII automatic flight control system

Main characteristics of an integrated flight and display

The all class helicopter cockoit

Digital map reader for helicopters

p 653 A90-42447

p 653 A90-42448

p 669 A90-42449

system for AS MKII Super-Puma p 653 A90-42450 Modern strapdown system for helicopter p 653 A90-42451 Full Authority Digital Engine Control for the AS 355 N TM 319 engines p 665 A90-42486 Design and manufacturing of composite materials blade p 618 A90-42492 models Preliminary flight evaluation of the SA 365 Panther helicopter in air-to-air combat manoeuvres p 647 A90-42494 GERMANY, FEDERAL REPUBLIC OF Multilevel optimization of large-scale structures in a p 693 A90-39180 parallel computing environment Development and application of an optimization procedure for space and aircraft structures p 679 Transonic flow around airfoils with relaxation and energy supply by homogeneous condensation ρ 620 Acoustics of ultralight airplanes p 643 A90-40685 Coherent vortex structures in the wake of a sphere and a circular disk at rest and under forced vibrations p 623 A90-40749 Technological preparations of civil aircraft programs p 617 A90-41110 Structural of fiber-reinforced components p 676 A90-41111 thermoolastics Euromart - The European aviation research and p 617 A90-41112 technology program Experimental windtunnel studies for EFA p 672 A90-41113 Obstacle warning system for helicopters p 653 A90-41114 Aerodynamic work for Hermes spaceplane p 675 A90-41115 ATTHeS - A helicopter in-flight simulator for ACT testing p 643 A90-41727 A new noise certification method for 'light propeller p 635 A90-41728 p 653 A90-41729 aircraft' in testing
The evaluation of flight recorders p 653 Measurement of angles and angle characteristics with p 653 A90-41730 accelerometers and gyroscopes Hydrogen in future energy and propulsion technology p 692 A90-41736 Inviscid and viscous flows in transonic and supersonic cascades using an implicit upwind relaxation algorithm [AIAA PAPER 90-2128] p 625 A90-42034 Influence of ground effect on helicopter takeoff and landing performance p 645 A90-42278 Computer-aided analysis of three-dimensional multiloop p 669 A90-42328 mechanisms Model of a labyrinth seal with flow p 687 A90-42334 Unsteady deformations of elastic rotor blades p 687 A90-42341 A study of the influence of a helicopter rotor blade on the following blades using Euler equations p 630 Comparison with experiment of various computational methods of airflow on three helicopter fuselages p 630 System concept and performance criteria of modern p 640 A90-42452 helicopter navigation Development and verification of software for flight safety p 694 A90-42454 critical strapdown systems Helicopter ground and air resonance dynamics p 646 A90-42457 A highly maneuverable helicopter in-flight simulator -Aspects of realization [AIAA PAPER 88-4607] p 670 A90-42466 Influence of ground effect on helicopter takeoff and landing performance p 646 A90-42468 The Franco-German helicopter programme HAP, PAH-2/HAC D 618 A90-42478 Eight years of flight operations with composite p 635 A90-424R1 rotorblades Analytical evaluation of helicopter true air speed and associated flight tests p 647 A90-42499 Results of TCAS-2 simulations in reconstructed dangerous encounters (Jul. 1986 to Jun. 1989) [ETN-90-96474] p 636 N90-23375 Test and Measurement Technique in Hypersonics p 618 N90-24225 [ILR-MITT-225(1989)] The gun tunnel of the Brunswick Institute for Fluid Mechanics: Current development status p 673 N90-24227

High enthalpy hypersonic wind tunnel F4: General description and associated instrumentation p 673 N90-24228

Short time Force and moment measurement System for shock tubes (SFS) for measuring times less than 10 ms p 674 N90-24233 Infrared thermography at hypersonic channel H2K

p 674 N90-24235
Tests for integrating measurement of gas pressures in flight propellers
IETN-90-964981 p 634 N90-24253

A time-marching method to calculate unsteady airloads on three-dimensional wings. Part 1: Linearized formulation [DLR-FB-89-S8] p 634 N90-24254

A time-marching method for calculating unsteady airloads on three-dimentional wings. Part 2: Full-potential formulation

[DLR-FB-89-59] p 635 N90-24255 Aerodynamic development perspective for traffic aeroplanes p 637 N90-24260

The 30th Airlines International Electronics Meeting
Proceedings
[ETN-90-96973] p 637 N90-24261

[ETN-90-96973] p 637 N90-24261 Transonic wing charge improvements by passive shock boundary layer interference control: Development status and prospects

[ETN-90-96463] p 650 N90-24267 Calculation of the aeroelastic blade stabilization with linearized process

[MITT-87-01] p 666 N90-24272 On simplified analytical flutter clearance procedures for light aircraft

[ĎLR-FB-89-56] p 672 N90-24276 En route noise of turboprop aircraft and their acceptability: Report of tests p 697 N90-24858 En route noise of two turboprop aircraft

[DLR-MITT-89-18] p 697 N90-24859 Noise measurements of turboprop airplanes at different overflight elevations p 697 N90-24860 Additive evaluation criteria for aircraft noise p 698 N90-24867

1

INDIA

Flutter of shaft-supported low aspect-ratio control surfaces p 667 A90-38912

Aeroelastic analysis of a low aspect ratio wing

p 619 A90-38915
Estimation of fatigue crack growth in patched cracked panels p 684 A90-41335

Expert system for pilot assistance - The challenge of an intensive prototyping p 693 A90-38909 Wind shear at Pantelleria airport p 692 A90-39702 Numerical simulation of the behaviour of internal combustion supercharged engines

[AIAA PAPER 90-1873] p 655 A90-40539 Trend analysis and diagnostics codes for training purposes

[AIAA PAPER 90-2394] p 617 A90-42156
Agusta methodology for pitch link loads prediction in preliminary design phase p 646 A90-42465
Use of smart actuators for the tail rotor collective pitch p 688 A90-42483
Direct drive servovalves: Why and how - The Magnaghi Milano answer p 688 A90-42484

Co-development of CT7-6 engines - A continued tradition in technology and reliability p 665 A90-42485 Contribution of engine improvement on next future rotorcraft p 665 A90-42488

EH-101 main rotor hub application of thick carbon fiber unidirectional tension bands p 618 A90-42489 Hydraulic accumulators and high pressure bottles in composite material p 688 A90-42493

A computer code for the prediction of aerodynamic characteristics of lifting airfoils at transonic speed [DLC-EST-TN-030] p 632 N90-23359

Prediction of aerodynamic performance of airfoils in low Reynolds number flows
[DLC-EST-TN-031] p 632 N90-23360
Problems of internal acoustics in two and three

Problems of internal acoustics in two and three dimensional cavities with deformable walls using the MSC/Nastran code

[DLC/STR-INT-TN-004] p 699 N90-24876

J

JAPAN

Simulation of the reduction characteristics of scattering from an aircraft coated with a thin-type absorber by the spatial network method p 638 A90-39855

Calculation of stability derivatives for stender hodies using boundary element method p 620 A90-40181 The cryogenic wind tunnel as a testing tool for n 672 A90-40400 airframe/propulsion systems A numerical investigation of supersonic inlet using implicit TVD scheme [AIAA PAPER 90-2135] p 621 A90-40612 Development of the jet-swirl high loading combustor [AIAA PAPER 90-2451] p 658 A90-40633 Vorticity distribution of vortex street in the wake of a p 623 A90-41751 circular cylinder Critical review of design philosophies for recent transport p 684 A90-41753 of plasma torch WIG effect vehicles Some governing parameters of pt igniter/flameholder in a scramjet combustor [AIAA PAPER 90-2098] p 661 A90-42017 Application of 3-D Navier-Stokes computation to bowed stacking turbine vane design [AIAA PAPER 90-2129] p 625 A90-42035 Aeroelastic response characteristics of a rotor executing arbitrary harmonic blade pitch variations p 646 A90-42464

Analytical study of dynamic response of helicopter in autorotative flight p 670 A90-42469

N

MEXICO

Helicopter control design using feedback linearization techniques p 668 A90-40817

N

**NETHERLANDS** 

Usage monitoring of military helicopters

p 651 A90-39984 Ultrasonic regression rate measurement in solid fuel ramjets

[AlAA PAPER 90-1963] p 656 A90-40573 Experimental and computational flammability limits in a solid fuel ramjet [AlAA PAPER 90-1964] p 676 A90-40574

Computation of viscous aerodynamic characteristics of 2-D airfoils for helicopter applications

p 631 A90-42440

Fractographic observations on fatigue crack growth in 2024-T3 sheet material under flight-simutation loading [LR-592] p 689 N90-23760 Activities report in aerospace and aerodynamics

Activities report in aerospace and aerodynamics
[ETN-90-96774] p 699 N90-24224
NORWAY

An aircraft noise study in Norway p 698 N90-24872

P

POLAND

Discrete Fourier transform with high resolution for low frequencies applied to the modal analysis of aircraft vibration p 679 A90-38975 Design of new Polish primary radars AVIA DM/CM

p 638 A90-41035
A visualization study of the interaction of a free vortex
with the wake behind an airfoil p 623 A90-41119
The influence of control-surface compensation
parameters on the hinge moment characteristics

Application of mathematical modeling to the study of rigid helicopter rotors p 643 A90-41738 Influence of some geometrical and design parameters

Influence of some geometrical and design parameters on the hinge moment characteristics of rudders p 643 A90-41739 Investigations of the influence of slot blowing from the upper wing surface on the flow ground the wing and its

Investigations of the influence of slot blowing from the upper wing surface on the flow around the wing and its aerodynamic characteristics p 623 A90-41740 Digital autopilot for light aircraft p 653 A90-41741 Onboard digital recording system for flight tests

p 653 A90-41742

S

SPAIN

Use of pulse radars for helicopters detection - Design constraints p 683 A90-41073

SWEDEN

Damage tolerance of carbon fibre reinforced plastic sandwich panels p 675 A90-40047
Low speed testing of a laminar flow airfoil in an adaptive wall wind tunnel

[FFA-TN-1989-08] p 632 N90-23363 Euler code predicted separation at the airfoil trailing

[FFA-TN-1989-30] p 632 N90-23364

#### **SWITZERLAND**

Problems related to aircraft noise in Switzerland p 698 N90-24871

#### T

#### TAIWAN

Finite element analysis of composite panel flutter p 681 A90-40032

Measurements of turbulent dual-jet interaction [AIAA PAPER 90-2105] p 624 A90-42019

Numerical simulations of gas turbine combustor flows
[AIAA PAPER 90-2305] p.686 A90-42116
Structure analysis of burning liquid-fueled spray in a
confined combustor

[AIAA PAPER 90-2444] p 677 A90-42174
The influence of swirl on velocity, temperature and species characteristics in a can combustor [AIAA PAPER 90-2454] p 664 A90-42177

#### U.S.S.R.

Numerical solution of the problem of supersonic flow of a viscous gas past a concave conical wing

p 619 A90-39465 Mathematical modeling of plane parallel separated flows

past bodies p 619 A90-39475
Boundary layer stability in the case of transonic external

flow p 619 A90-39514 Perturbations of higher modes in a supersonic jet

P 619 A90-39516 Wave structure of artificial perturbations in a supersonic boundary layer on a plate p 619 A90-39518

The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges

p 620 A90-39519

Vortex theory for the screw propeller with a hub p 620 A90-39538

Relationship between velocity circulation around a wing profile and vorticity dispersion in a boundary layer

p 620 A90-39539

Air traffic control p 638 A90-39581

Differential-geometrical technique of signal transformation and estimation of position, rate and acceleration parameters using supplementary data sources p 33 A90-41004

sources p 638 A90-41004
The development result of SPEKTR automated air traffic
control (ATC) system with extended grade of automation
for terminal and hub areas p 639 A90-41058

Synthesis of optimal multidimensional digital systems for the simulation of the angular motions of a flight vehicle under random loading p 669 A90-41957

The investigation of heat transfer in cooled blades of gas turbines

[AIAA PAPER 90-2144] p 685 A90-42043 Experimental turbofan using liquid hydrogen and liquid natural gas as fuel

[AIAA PAPER 90-2421]

p 663 · A90-42170

## UNITED KINGDOM

Improvement of helicopter handling qualities using H(infinity)-optimisation p 667 A90-38965 Implementation of a transputer-based flight controller

p 667 A90-38966 The EH101 electronic instrument system

Combustion characteristics of a model can-type combustor p 676 A90-40479 Identification of multivariable models of jet engines

[AlAA PAPER 90-1874] p 655 A90-40540
Design of digital self-selecting multivariable controllers for jet engines

[AIAA PAPER 90-1875] p 655 A90-40541 Simulation of inviscid blade-row interaction using a

Simulation of inviscid blade-row interaction using a linearised potential code

[AIAA PAPER 90-1916] p 621 A90-40555 An image analysis method for vehicle stabilization

p 668 A90-40914
Experimental studies of combustor dilution zone aerodynamics. II - Jet development p 659 A90-40947
Experiments on the active control of the transmission

aerodynamics. II - Jet development p 659 A90-40947 Experiments on the active control of the transmission of sound through a clamped rectangular plate p 695 A90-41109

SMAS - An expert system for configuring a research flight simulator p 694 A90-41191
The effects of toughening stresses on liquid impact

induced fracture p 692 A90-41315
The six component magnetic suspension system for wind tunnel testing p 673 A90-41725
Large receiver aircraft - The performance and longitudinal stability and control during air to air refuelling p 669 A90-41767

The performance of a combustor pre-diffuser incorporating compressor outlet guide vanes [AIAA PAPER 90-2165] p 661 A90-42053

[AIAA PAPER 90-2165] p 661 A90-42053 Numerical modeling of an impinging jet in cross-flow [AIAA PAPER 90-2246] p 686 A90-42093 Hypersonic (T-0) pinch and aerospaceplane

propulsion [AIAA PAPER 90-2474] p 675 A90-42189

Active control of helicopter cabin noise

p 645 A90-42434
EH101 development progress p 646 A90-42442
The safety analysis approach for the EH101

p 635 A90-42456
A comprehensive approach to coupled rotor-fuselage dynamics p 646 A90-42460

A technique for the tuning of helicopter flight control systems p 670 A90-42467

The place of knowledge based systems in helicopter dynamic system condition prognosis

p 618 A90-42475
The modular HUM system p 618 A90-42476
New systems for helicopter and aircraft vibration
monitoring 0 653 A90-42477

monitoring p 653 A90-42477
EH101 vibration control p 647 A90-42496
Estimation of rotor blade incidence and blade

Estimation of rotor blade incidence and blade deformation from the measurement of pressures and strains in flight p 647 A90-42497

Flight tests to explore tail rotor limitations in the low speed envelope p 647 A90-42498

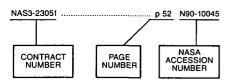
Characterisation of fatigue of aluminium alloys by acoustic emission. Part 2: Discrimination between primary and other emissions

[AERE-R-13303-PT-2] p 678 N90-23523 The computation of turbulent thin shear flows associated with flow around multielement aerofoils

p 633 N90-24240 A study of the technology required for advanced vertical take-off aircraft

[ETN-90-96786] p 650 N90-24268

# Typical Contract Number Index Listing



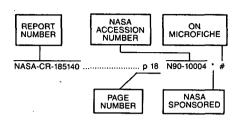
Listings in this index are arranged alphanumerically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under the contract are arranged in ascending order with the AIAA accession numbers appearing first. The accession number denotes the number by which the citation is identified in the abstract section. Preceding the accession number is the page number on which the citation may be found.

AF PROJ. 1926	p 689	N90-23762
	p 637	N90-24258
AF PROJ. 2307	p 689	N90-23687
,	p 634	N90-24250
AF PROJ. 2402	p 654	N90-23398
AF PROJ. 2418	p 678	N90-23538
7.1.1.00.2.1.0	p 689	N90-23752
AF PROJ. 2480	p 678	N90-23571
AF PROJ. 2688	p 692	N90-23832
AF PROJ. 3005	p 631	N90-23349
7.1. 7.7. 2.2. 2.2.2 3	p 634	N90-24249
AF PROJ. 3035	p 671	N90-23409
BMFT-LFF-84318	p 646	A90-42457
DA PROJ. 1L1-62105-AH-84	p 650	N90-24270
DA PROJ. 1L1-62211-A-47-AA	p 633	N90-24239
DA PROJ. 1L1-62211-AH-7-AA	p 632	N90-24237
DAAJ02-87-C-0022	p 637	N90-24259
DAAL03-87-G-0004	p 668	A90-40886
DASG60-85-C-0122	p 624	A90-42018
DE-AC04-76DP-00789	p 622	A90-40681
DE-A004-70D1-00703	p 678	N90-24430
DEN3-335	p 687	A90-42165
DFG-BE-343/17	p 623	A90-40749
DFG-SFB-212	p 645	A90-42278
DI G OI D 212	p 646	A90-42468
DFG-ZI-18-31	p 620	A90-39782
DTFA01-86-C-00023	p 674	N90-24277
DTFA01-87-C-00014	p 635	N90-23368
DTFA01-88-C-00059	p 641	N90-24263
FMV-82260-88-061-73-001	p 632	N90-23364
FY1455-86-N-0657	p 678	N90-23571
F08635-86-C-0309	p 682	A90-40930
F33615-81-C-3403	p 637	N90-24258
F33615-83-C-2339	p 626	A90-42161
	p 626	A90-42162
F33615-84-C-2432	p 661	A90-42051
F33615-84-C-3404	p 689	N90-23762
F33615-85-C-2515	p 686	A90-42068
F33615-85-C-2575	p 683	A90-40943
F33615-86-C-2600	p 671	N90-23409
F33615-86-C-2616	p 661	A90-42050
F33615-86-C-2623	p 684	A90-41997
F33615-86-C-5007	p 689	N90-23752
F33615-87-C-2739	p 656	A90-40554
F33615-87-C-2767	p 655	A90-40530
F33615-87-C-2822	p 655	A90-40530
F33615-87-C-3020	p 634	N90-24249
F33615-87-C-3403	p 684	A90-41334
F33615-88-C-2836	p 685	A90-42040
F33615-88-C-2846	p 685	A90-42041
F33615-88-C-5437	p 678	N90-23538
1 330 13-00-0-3437	P 0/0	1100-2000

F49620-85-C-0027	p 689	N90-23687
	-	
F49620-86-K-0020	р 679	A90-38854
F49620-88-C-0006	р 631	N90-23349
F49620-88-C-0020	p 634	N90-24250
F49620-88-C-0053	p 693	A90-40885
NAGW-965	p 677	A90-42117
NAG1-372	p 667	A90-40689
NAG1-602	p 665	N90-23401
NAG1-716	p 633	N90-24242
NAG1-793	p 622	A90-40682
NAG2-209	p 670	A90-42462
NAG2-477	p 670	A90-42462
NAG3-499	p 623	A90-40937
NAG3-630	p 690	N90-24514
NAG3-998	p 667	A90-40557
NASW-4435	p 649	N90-23394
•	p 649	N90-23395
	p 649	N90-23396
	p 650	N90-23397
NAC4 47704	p 650	N90-24266
NAS1-17794	p 658	A90-40622
NAS1-17919	p 620	A90-39780 A90-42044
NAS1-17970	p 625 p 642	A90-42044 A90-40130
NAS1-18000	p 622	A90-40692
NAS1-18099	p 695	N90-24103
NAS1-18140	p 631	N90-23348
NAS1-18140	p 637	N90-23346
NAS1-19000	p 634	N90-24246
NAS2-12425	p 650	N90-24265
NAS2-12518	p 642	A90-40166
NAS3-23720	p 622	A90-40686
NAS3-24080	p 649	N90-23393
NAS3-24341	p 666	N90-24274
NAS3-24350	p 682	A90-40930
NAS3-25266	p 674	A90-40587
	p 666	N90-23404
NAS3-25446	p 681	A90-40560
NAS3-25460	p 658	A90-40643
NAS9-17900	p 696	N90-24852
NCA2-310	p 647	A90-42473
NCA2-455	p 677	A90-42117
NCC2-357	p 690	N90-24557
NCC2-366	p 670	A90-42463
NCC2-588	р 648	N90-23386
NCC3-120	p 690	N90-23769
NSC-77-0210-D006-16	p 677	A90-42174
NSC-77-0210-D006-20	p 681	A90-40032
NSC-78-0210-D006-01	p 686	A90-42116
NSF CDR-88-03012	p 668	A90-40912
NSF MSM-88-09132	p 688	A90-42491 A90-40938
N00014-85-K-0347 N00014-86-K-0434	p 683 p 623	A90-40936 A90-40926
	p 676	A90-40570
N00014-87-K-0132	p 623	A90-40941
N00014-89-J-1342	p 683	A90-40938
N00140-86-C-9415	p 657	A90-40603
N00140-87-C-9902	p 661	A90-42051
N00140-88-C-RE04	p 685	A90-42041
PROJ. MSG-89A1	p 650	N90-23397
T06-038	p 640	N90-23378
T0604L	p 640	N90-23377
T0707A	p 640	N90-23379
505-61-51-10	p 632	N90-24237
505-61-51		N90-23399
	p 650	N90-24265
505-61-59-76		N90-24239
505-61-71-69		N90-24238
505-61-71		N90-23413
505-61-91-03		N90-24242
505-62-41-03		N90-24853
505-62-71		N90-23404
505 62 01 11	p 666	N90-24273
505-63-01-11		N90-24660 N90-23348
505-63-21-01 505-66-71-02		N90-23348 N90-24103
505-66-71		N90-24103 N90-23768
505-67-21		N90-23766
555 VI-61	p 636	N90-23374
505-67-41-57		N90-24257
510-01-01		N90-23769
533-02-51		N90-23392
535-03-01-02		N90-24246

535-03-01	- 640	NOO 00000
535-03-01	. рочэ	N9U-23393
535-03-22	. p 666	N90-24274
537-01-11	. p 688	N90-23591
537-03-21-03	p 696	N90-24852
582-01-31	p 665	N90-23403

# Typical Report Number Index Listing



Listings in this index are arranged alphanumerically by report number. The page number indicates the page on which the citation is located. The accession number denotes the number by which the citation is identified. An asterisk (\*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

A-90086	p 636	N90-23373 *	#
A-90090		N90-24265 *	#
A-90122	p 636	N90-23374 *	#
A-90139	p 654	N90-23399 *	#
AD-A218378	p 631	N90-23349	#
AD-A218393	p 636	N90-23371	#
AD-A218493	p 671	N90-23409	#
AD-A218544	p 636	N90-23372	#
AD-A218680	p 689	N90-23762	#
AD-A219545	p 648		#
AD-A219584	p 648	N90-23388	#
AD-A219621	p 689	N90-23687	#
AD-A219651	p 678	N90-23571	#
AD-A219747	p 689	N90-23752	#
AD-A219793	p 631	N90-23353	#
AD-A219820	p 666	N90-24271	#
AD-A220003	p 692	N90-23832	#
AD-A220078	p 672	N90-24275	#
AD-A220079	p 679	N90-24451	#
AD-A220106	p 654	N90-23400	#
AD-A220167	p 674	N90-24277	#
AD-A220239	p 678	N90-23538	#
AD-A220312	p 641	N90-24263	#
AD-A220360		N90-24258	#
AD-A220393	p 654	N90-23398	#
AD-A220525	p 688	N90-23609	#
AD-A220527	p 648	N90-23389	#
AD-A220535	p 665	N90-23402	#
AD-A220593	p 671	N90-23412	#
AD-A220933	p 674	N90-24278	#
AD-A221034	p 634	N90-24249	#
AD-A221099	p 641	N90-24264	#
AD-A221121	p 650	N90-24270	#
AD-A221148	p 637	N90-24259	#
AD-A221220	p 634	N90-24250	#
AD-A221326	p 634	N90-24251	#
AERE-R-13303-PT-2	p 678	N90-23523	#
AFIT/GAE/ENY/90M-02	p 648	N90-23389	#
AFIT/GAE/ENY/90M-1		N90-23412	#
	•		
AFIT/GCS/ENG/90M-01	p 688	N90-23609	#
	•		
AFIT/GE/ENG/90M-5	p 654	N90-23400	#
AFOSR-90-0269TR	p 631	N90-23349	#
AFOSR-90-0296TR	p 689	N90-23687	#
AFOSR-90-0404TR	p 634	N90-24250	#
AIAA PAPER 88-4607	p 670	A90-42466	#
AIAA PAPER 90-1440		A90-39725 *	•••
VIVA I VEED 20. 1446	P 000	NJU-35123	77

AIAA PAPER 90-1493 ...... p 619 A90-39049 \* #

			-
AIAA PAPER 90-1835		p 655	A90-40526 #
	•••••	-	
AIAA PAPER 90-1851		p 655	A90-40530 #
AIAA PAPER 90-1860		p 655	A90-40533 #
AIAA PAPER 90-1873		p 655	A90-40539 #
AIAA PAPER 90-1874		p 655	A90-40540 #
AIAA PAPER 90-1875	***************************************	p 655	A90-40541 #
AIAA PAPER 90-1887		p 660	A90-41981 #
AIAA PAPER 90-1905		p 655	A90-40552 #
AIAA PAPER 90-1906		p 660	A90-41982 #
AIAA PAPER 90-1911		p 624	A90-41983 #
AIAA PAPER 90-1912		p 656	A90-40554 #
AIAA PAPER 90-1916		p 621	A90-40555 #
AIAA PAPER 90-1917		p 656	A90-40556 #
AIAA PAPER 90-1918	***************************************	p 667	A90-40557 * #
AIAA PAPER 90-1920		p 656	A90-40558 * #
AIAA PAPER 90-1921		p 656	A90-40559 * #
AIAA PAPER 90-1931		p 681	A90-40560 * #
AIAA PAPER 90-1935		p 656	A90-40562 * #
AIAA PAPER 90-1957		p 676	A90-40570 #
AIAA PAPER 90-1963		p 656	A90-40573 #
AIAA PAPER 90-1964		p 676	A90-40574 #
AIAA PAPER 90-1986	***************************************	p 674	A90-40582 #
AIAA PAPER 90-2000	***************************************	p 674	A90-40587 * #
AIAA PAPER 90-2003		p 681	A90-40590 #
AIAA PAPER 90-2005		p 621	A90-40592 #
AIAA PAPER 90-2014		p 676	A90-40594 #
AIAA PAPER 90-2015		p 673	A90-41986 #
AIAA PAPER 90-2018		p 621	A90-40596 #
AIAA PAPER 90-2021	•••••	p 684	A90-41987 #
AIAA PAPER 90-2023		p 657	A90-40597 #
AIAA PAPER 90-2025		p 624	A90-41988 * #
AIAA PAPER 90-2026		p 624	A90-41989 #
AIAA PAPER 90-2027		p 657	A90-40598 #
AIAA PAPER 90-2028		p 621	A90-40599 #
AIAA PAPER 90-2030	•••••	p 657	A90-40601 #
AIAA PAPER 90-2031	***************************************	p 660	A90-41990 #
AIAA PAPER 90-2032	•••••		A90-40602 #
AIAA PAPER 90-2033	***************************************	p 657	A90-40603 #
AIAA PAPER 90-2035		p 657	A90-40604 #
AIAA PAPER 90-2036		p 657	A90-40605 #
AIAA PAPER 90-2037		p 658	A90-40606 #
AIAA PAPER 90-2038		p 644	A90-41991 #
AIAA PAPER 90-2041 AIAA PAPER 90-2042	•••••	p 661	A90-41992 #
AIAA PAPER 90-2042	***************************************	p 661 p 684	A90-41993 # A90-41997 #
AIAA PAPER 90-2048	***************************************	p 684	A90-41997 # A90-41999 #
AIAA PAPER 90-2098		p 661	A90-41999 # A90-42017. #
AIAA PAPER 90-2099		p 624	A90-42018 #
AIAA PAPER 90-2105		p 624	A90-42019 #
AIAA PAPER 90-2107		p 684	A90-42020 #
AIAA PAPER 90-2125		p 624	A90-42032 #
AIAA PAPER 90-2126		p 625	A90-42033 #
AIAA PAPER 90-2128		p 625	A90-42034 #
AIAA PAPER 90-2129		p 625	A90-42035 #
AIAA PAPER 90-2133	***************************************	p 685	A90-42037 #
AIAA PAPER 90-2135		p 621	A90-40612 #
AIAA PAPER 90-2136		p 661	A90-42038 #
AIAA PAPER 90-2140		p 685	A90-42040 #
AIAA PAPER 90-2142		p 685	A90-42041 #
AIAA PAPER 90-2144		p 685	A90-42043 #
AIAA PAPER 90-2147		p 625	A90-42044 * #
AIAA PAPER 90-2149		p 625	A90-42045 #
AIAA PAPER 90-2150			A90-42046 #
AIAA PAPER 90-2151		p 644	A90-42047 #
AIAA PAPER 90-2152			A90-42048 #
AIAA PAPER 90-2154			A90-40613 #
AIAA PAPER 90-2159			A90-42050 #
AIAA PAPER 90-2161			A90-42051 #
AIAA PAPER 90-2164			A90-42052 #
AIAA PAPER 90-2165	***************************************		A90-42053 #
AIAA PAPER 90-2166			A90-42054 * #
AIAA PAPER 90-2169			A90-42055 #
AIAA PAPER 90-2170	••••••		A90-42056 #
AIAA PAPER 90-2175			A90-42059 #
AIAA PAPER 90-2176			A90-42060 #
AIAA PAPER 90-2177			A90-42061 #
AIAA PAPER 90-2178			A90-42062 #
AIAA PAPER 90-2190 AIAA PAPER 90-2193			A90-42067 #
	••••••		A90-42068 #
AIAA PAPER 90-2246 AIAA PAPER 90-2248	•••••		A90-42093 # A90-42094 #
AIAA PAPER 90-2248 AIAA PAPER 90-2263			
AIAA PAPER 90-2274			A90-42102 # A90-42103 #
	***************	~ ~~~	1130-12 100 IF

AIAA PAPER 90-2276	p 644	A90-42104 #
AIAA PAPER 90-2278	p 644	A90-42105 #
AIAA PAPER 90-2280 AIAA PAPER 90-2291	p 644 p 686	A90-42106 * # A90-42110 #
AIAA PAPER 90-2305	p 686	A90-42116 #
AIAA PAPER 90-2307	p 677	A90-42117 * #
AIAA PAPER 90-2337 AIAA PAPER 90-2342	p 658 p 626	A90-40622 * # A90-42132 * #
AIAA PAPER 90-2342 AIAA PAPER 90-2344	p 686	A90-42133 #
AIAA PAPER 90-2352	p 626	A90-42136 #
AIAA PAPER 90-2355	p 626	A90-42137 #
AIAA PAPER 90-2382 AIAA PAPER 90-2393	p 675 p 662	A90-42147 # A90-42155 #
AIAA PAPER 90-2394	p 617	A90-42156 #
AIAA PAPER 90-2396 AIAA PAPER 90-2397	p 662	A90-42157 #
AIAA PAPER 90-2397 AIAA PAPER 90-2398	p 662 p 663	A90-42158 # A90-42159 #
AIAA PAPER 90-2403	p 663	A90-42160 #
AIAA PAPER 90-2408	p 626	A90-42161 #
AIAA PAPER 90-2409 AIAA PAPER 90-2411	p 626 p 687	A90-42162 # A90-42163 #
AIAA PAPER 90-2412	p 687	A90-42164 #
AIAA PAPER 90-2413	p 687	A90-42165 * #
AIAA PAPER 90-2414 AIAA PAPER 90-2415	p 687 p 663	A90-42166 # A90-42167 #
AIAA PAPER 90-2417	p 663	A90-42168 * #
AIAA PAPER 90-2419	p 663	A90-42169 #
AIAA PAPER 90-2421 AIAA PAPER 90-2444	p 663 p 677	A90-42170 # A90-42174 #
AIAA PAPER 90-2451	p 658	A90-40633 #
AIAA PAPER 90-2453	p 663	A90-42176 #
AIAA PAPER 90-2454 AIAA PAPER 90-2469	p 664 p 673	A90-42177 # A90-42186 #
AIAA PAPER 90-2473	p 664	A90-42188 #
AIAA PAPER 90-2474	p 675	A90-42189 #
AIAA PAPER 90-2486 AIAA PAPER 90-2492	p 658 p 658	A90-40636 # A90-40637 #
AIAA PAPER 90-2501	p 658	A90-40639 #
AIAA PAPER 90-2508	p 682	A90-40641 #
AIAA PAPER 90-2512 AIAA PAPER 90-2522	p 658 p 664	A90-40643 * # A90-42197 #
AIAA PAPER 90-2728	p 664	A90-42217 #
AIAA PAPER 90-2730	p 626	A90-42218 #
AIAA PAPER 90-2739 AIAA PAPER 90-2752	p 664 p 627	A90-42221 # A90-42225 #
AIAA PAPER 90-2753	p.664	A90-42226 #
AIAA PAPER 90-2754	p 617	A90-40648 #
AIAA-90-1899	p 666	N90-23404 * #
AIAA-90-2452	р 688	N90-23591 * #
ARL-SYS-TM-133	p 641	N90-24264 #
AVSCOM-TM-90-B-015	p 632	N90-24237 * #
AVSCOM-TR-90-B-005	p 633	N90-24239 * #
CSG-124	p 665	N90-23401 * #
DE90-010164	р 678 ·	N90-24430 #
DGLR-89-141		N90-24260 #
DLC-EST-TN-030 DLC-EST-TN-031		
DLC/STR-INT-TN-004	p 699	N90-24876 #
DLR-FB-89-56		N90-24276 #
DLR-FB-89-58	p 634	N90-24254 #
DLR-FB-89-59		*
DLR-MITT-89-18 DODA-AR-005-644	-	
DOT-TSC-FA953-LR4	•	N90-24264 #
DOT-TSC-FA953-LR5	p 697	N90-24857 * #
DOT/FAA/AM-89/14		
DOT/FAA/CT-TN89/40	p 640	N90-23377 #

DOT/FAA/CT-TN89/42 ..... p 640 N90-23379

DOT/FAA/CT-TN90/2	. р 640	N90-23378 #	NAS 1.26:182006			US-PATENT-APPL-S
			NAS 1.26:182023			UC DATENT OF ACC
DOT/FAA/CT-89/32	. р 636	N90-23369 #	NAS 1.26:185158			US-PATENT-CLASS
•			NAS 1.26:185189			US-PATENT-CLASS-
DOT/FAA/DS-88/8	. р 635	N90-23368 #	NAS 1.26:186067			US-PATENT-CLASS-
DOT/FAA/DS-89/16	. р 637	N90-24257 * #	NAS 1.26:186118			US-PATENT-CLASS-
			NAS 1.26:186140 NAS 1.26:186660			US-PATENT-CLASS-
DOT/FAA/PM-87/9-VOL-2	. р 674	N90-24277 #				US-PATENT-CLASS-
=		1100 00700 t #	NAS 1.26:186661 NAS 1.26:186663			US-PATENT-CLASS- US-PATENT-CLASS-
E-4920			NAS 1.26:186670			
E-5012			NAS 1.26:186685			US-PATENT-CLASS- US-PATENT-CLASS-
E-5451		N90-23404 * #	NAS 1.26:4277			US-PATENT-CLASS-
E-5499		N90-24273 * #	NAS 1.26:4299			US-PATENT-CLASS-
E-5554	. р овв	N90-23591 * #	NAS 1.26:4305			US-PATENT-CLASS-
EDR-12909	- 666	NIOO 24274 * #	NAS 1.26:4307			OO-1 ATENT-OBAGO
EDH-12909	. р ооо	1150-24214 #	NAS 1.55:3067			US-PATENT-4,886,89
ERP-1031	n 602	N90-23832 #	NAS 1.60:3005			US-PATENT-4,896,53
ERF-1031	. p 092	N90-23032 #	NAS 1.60:3009			US-PATENT-4,917,33
ETN-90-96350	0.600	N90-23760 #		p 000	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	US-PATENT-4,918,65
ETN-90-96463		N90-24267 #	NASA-CASE-ARC-11425-3	p 678	N90-23475 *	
ETN-90-96474		N90-23375 #				USAAEFA-88-03
ETN-90-96475		N90-24272 #	NASA-CASE-LAR-13628-1	p 689	N90-23707 *	
ETN-90-96480			NASA-CASE-LAR-13983-1		N90-23390 *	USAAVACOM-TR-89-
ETN-90-96498			NASA-CASE-LAR-14056-1		N90-23713 *	
ETN-90-96560		N90-23359 #		•		USAAVSCOM-TM-90-
ETN-90-96561			NASA-CP-3067	p 696	N90-24853 * #	
ETN-90-96565					-	USAAVSCOM-TR-89-
ETN-90-96599			NASA-CR-177547	p 650	N90-24265 * #	
ETN-90-96601			NASA-CR-179625		N90-24274 * #	USAFOEHL-90-026E
ETN-90-96774		N90-24224 #	NASA-CR-181335	p 665	N90-23401 * #	
ETN-90-96781		N90-24260 #	NASA-CR-182006	p 695	N90-24103 * #	UVA/528238/CS90/1
ETN-90-96786			NASA-CR-182023	p 631	N90-23348 * #	
ETN-90-96973			NASA-CR-185158		N90-23393 * #	WRDC-TR-89-2026-V
ETN-90-97006			NASA-CR-185189	p 690	N90-23769 * #	WRDC-TR-89-2138 .
ETN-90-97008			NASA-CR-186067	p 690	N90-24557 * #	WRDC-TR-89-3099 .
ETN-90-97009			NASA-CR-186118		N90-23386 * #	WRDC-TR-89-3110 .
	•		NASA-CR-186140	p 690	N90-24514 * #	WRDC-TR-89-3118 .
FAA-APO-90-3	p 641	N90-24263 #	NASA-CR-186660		N90-23397 * #	WRDC-TR-89-4060 .
			NASA-CR-186661		N90-23396 * #	WRDC-TR-90-3007 .
FFA-TN-1989-08			NASA-CR-186663		N90-23395 * #	WRDC-TR-90-4001 .
FFA-TN-1989-30	p 632	N90-23364 #	NASA-CR-186670		N90-23394 * #	
			NASA-CR-186685		N90-24266 * #	
GAO/RCED-88-160	p 635	N90-23367 #	NASA-CR-4277		N90-24852 * #	
C1 TD 00 0400			NASA-CR-4299 NASA-CR-4305		N90-24242 * # N90-24257 * #	
GL-TR-89-0129	p 692	N9U-23832 #	NASA-CR-4307		N90-24246 * #	
H-1582				•		*
H-1625			NASA-TM-101709		N90-23768 * #	-
			NASA-TM-101722		N90-23392 * #	
ILR-MITT-225(1989)	p 618	N90-24225 #	NASA-TM-102250		N90-23413 * #	
	_		NASA-TM-102631		N90-24221 * #	
INT-PATENT-CLASS-B64C-9/02 .			NASA-TM-102679		N90-24660 * #	
INT-PATENT-CLASS-B64C-9/08 .	p 648	N90-23390 °	NASA-TM-102795			
INT DATENT OF AGO COOK SALE	- 0	NOO 00 175 *	NASA-TM-102807 NASA-TM-102814			
INT-PATENT-CLASS-C07S-9/40 .	p 6/8	N9U-234/5 *	NASA-TM-102814 NASA-TM-103123		N90-23399 * # N90-23404 * #	
INT DATENT CLASS COMM COM	n 60c	NOO 22707 *	NASA-TM-103123		N90-23404 # N90-24273 * #	
INT-PATENT-CLASS-G01M-9/00	h oga	1430-23/0/	NASA-TM-103176		N90-24273 # N90-23591 * #	
ISSN-0171-1242	0.624	NG0-24254 #	NASA-TM-4200			
ISSN-0171-1342ISSN-0171-1342			NASA-TM-4200			
ISSN-0171-1342				,	, ,	•
	P 0/2		NASA-TP-3005	p 665	N90-23403 #	
KU-FRL-831-2	D 648	N90-23386 * #	NASA-TP-3009			
	, - 10	"		•		
L-16725	p 632	N90-24237 * #	NRC-31216	p 674	N90-24278 #	•
L-16737						
L-16742	p 632	N90-24238 * #	NSWC/TR-89-180	p 634	N90-24251 #	
L-16763	p 696	N90-24853 * #				
	-		ONERA, TP NO. 1990-16			
LR-592	p 689	N90-23760 #	ONERA, TP NO. 1990-24			
			ONERA, TP NO. 1990-26			
MDC-K4856	p 634	N90-24250 #	ONERA, TP NO. 1990-27			
			ONERA, TP NO. 1990-28			•
MITT-87-01	p 666	N90-24272 #	ONERA, TP NO. 1990-36	b <i>0</i> 28	A90-41212 #	
MTL-TR-90-12	p 650	N90-24270 #	PPG-CDRL-6	р 637	N90-24258 #	
	•	-	•	-		
NAE-AN-62	p 674	N90-24278 #	PW/ED/FR-20820	p 689	N90-23752 #	•
NAS 1.15:101709	p 689	N90-23768 * #	SAND-90-0421	p 678	N90-24430 #	
NAS 1.15:101722		N90-23392 * #			"	
NAS 1.15:102250		N90-23413 * #	SRA-900049F	p 631	N90-23348 * #	
NAS 1.15:102631		N90-24221 * #		*	•	
NAS 1.15:102679		N90-24660 * #	UDR-TR-88-65	p 689	N90-23762 #	
NAS 1.15:102795		N90-23373 * #	UDR-TR-89-114			
NAS 1.15:102807		N90-23374 * #		•		
NAS 1.15:102814		N90-23399 * #	UILU-ENG-90-2216	p 665	N90-23401 * #	
NAS 1.15:103123		N90-23404 * #				
NAS 1.15:103170			US-PATENT-APPL-SN-010949		N90-23713 *	
NAS 1.15:103176		N90-23591 * #	US-PATENT-APPL-SN-054982		N90-23475 *	
NAS 1.15:4200		N90-24238 * #	US-PATENT-APPL-SN-192563		N90-23390 *	
NAS 1.15:4201	p 632		US-PATENT-APPL-SN-251073		N90-23713 *	
NAS 1.26:177547		N90-24265 * #	US-PATENT-APPL-SN-251438		N90-23707 *	
NAS 1.26:179625		N90-24274 * #	US-PATENT-APPL-SN-493864		N90-23475 *	
NAS 1.26:181335	p 665	N90-23401 * #	US-PATENT-APPL-SN-522629	p 678	N90-23475 *	

October 1990

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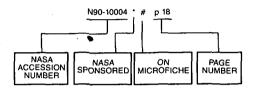
A90-42048

A90-42050

p 685

p 661

#### **Typical Accession Number Index Listing**



Listings in this index are arranged alphanumerically by accession number. The page number listed to the right indicates the page on which the citation is located. An asterisk (\*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

			*** ****	404
A90-38854		p 679	A90-40109	p 681
A90-38888		b 693	A90-40127 *	p 675
A90-38908		p 667	A90-40128	p 642
A90-38909		p 693	A90-40130 * A90-40166 *#	р 642 р 642
A90-38912	#	p 667	A90-40100 # A90-40172 #	p 643
A90-38915	#	p 619	A90-40172 #	p 620
A90-38965	-	p 667	A90-40195	p 652
A90-38966		p 667	A90-40215	p 676
A90-38975	#	p 679	A90-40344	p 643
A90-39002		p 637	A90-40345	p 617
A90-39049	#	p 619	A90-40381	p 652
A90-39180		p 693	A90-40382	p 652
A90-39186		p 679	A90-40392	p 681
A90-39276		p 680	A90-40393	p 681
A90-39286	#	p 641	A90-40394	p 652
A90-39298	#	p 680	A90-40398	p 652
A90-39303	#	p 693	A90-40399	p 652
A90-39403		p 692	A90-40400 #	p 672
A90-39465		p 619	A90-40462	p 652
A90-39475		p 619	A90-40476	p 672
A90-39514		p 619	A90-40479	p 676
A90-39516		p 619	A90-40495 *	p 620
A90-39518		p 619	A90-40501 #	p 621
A90-39519		p 620	A90-40503 #	p 654
A90-39538		p 620	A90-40504 #	p 621
A90-39539		p 620	A90-40512 #	p 654
A90-39581	ш	p 638	A90-40513 #	p 621
A90-39702 A90-39725		p 692	A90-40519 #	p 655
A90-39725 A90-39780		р 680 р 620	A90-40526 #	p 655
A90-39781		p 695	A90-40530 #	p 655
A90-39782	#	p 620	A90-40533 #	p 655
A90-39784		p 680	A90-40539 #	p 655
A90-39786	#	p 680	A90-40540 #	p 655
A90-39801	#	p 620	A90-40541 #	p 655
A90-39814	#	p 620	A90-40552 # A90-40554 #	р 655 р 656
A90-39855	"	p 638	A90-40555 #	ρ 621
A90-39959		p 638	A90-40556 #	p 656
A90-39976		p 641	A90-40557 * #	p 667
A90-39977	#	p 680	A90-40558 * #	p 656
A90-39978	#	p 641	A90-40559 * #	p 656
A90-39979	#	p 680	A90-40560 * #	p 681
A90-39980	#	p 680	A90-40562 * #	p 656
A90-39982	#	p 651	A90-40570 #	p 676
A90-39983	#	p 651	A90-40573 #	p 656
A90-39984	#	p 651	A90-40574 #	p 676
A90-39985	#	p 642	A90-40582 #	p 674
A90-39986	#	p 642	A90-40587 * #	p 674
A90-39987	#	p 681	A90-40590 #	p 681
A90-39988	#	p 642	A90-40592 #	p 621
A90-39989	#	p 642	A90-40594 #	p 676
A90-39991	#	p 675	A90-40594 #	р 621
A90-39992	#	p 642		•
A90-40032		p 681	A90-40597 #	p 657
A90-40047		p 675	A90-40598 #	p 657

p 657

A90-40598

A90-40032 A90-40047

p 675

A90-40599 #	p 621
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A90-42162	#	p 626
A90-42163	#	p 687
A90-42164	#	p 687
A90-42165	•#	p 687
A90-42166	#	p 687
A90-42167	#	p 663
A90-42168	*#	p 663
A90-42169	#	p 663
A90-42170	#	p 663
A90-42174	#	p 677
A90-42176	#	p 663
A90-42177	#	p 664
A90-42186	#	p 673
A90-42188	#	p 664
A90-42189	#	p 675
A90-42197	#	p 664
A90-42217	#	p 664
A90-42218	#	p 626
A90-42221	#	p 664
A90-42225	#	p 627
A90-42226 A90-42278	#	p 664 p 645
A90-42278 A90-42328		p 669
A90-42326 A90-42334		p 687
A90-42341		p 687
A90-42351	#	p 627
A90-42353	#	p 627
A90-42355	#	p 645
A90-42357	#	
A90-42361	#	p 627 p 627
A90-42363	#	p 627
A90-42364	#	p 627
A90-42367	#	p 669
A90-42372	"	p 678
A90-42394	#	p 627
A90-42395	#	p 628
A90-42402	#	p 628
A90-42403	#	p 628
A90-42404	• #	p 628
A90-42405	#	p 628
A90-42406	#	p 628
A90-42407	#	p 645
A90-42412	#	p 629
A90-42413	#	p 629
A90-42415	#	p 629
A90-42416	#	p 629
A90-42417	#	n 645

p 645

A90-42417

N90-25035 \* # N90-25040 \* # N90-25040 \* # N90-25043 \* # N90-25049 \* # N90-25057 \* # N90-25060 \* # N90-25060 \* #

p 635 p 690 p 692 p 651 p 679 p 691 p 691 p 691 p 691

		•	
A90-42418 #	p 629	N90-23395 * #	p 649
A90-42419 #	p 629	N90-23396 * #	p 649
A90-42420 #	p 645	N90-23397 *#	p 650
A90-42422 #	p 629	-	•
A90-42423 #	p 629	N90-23398 #	p 654
A90-42425 * #	p 630	N90-23399 * #	p 654
A90-42431 #	p 630	N90-23400 #	p 654
A90-42432 #	p 673	N90-23401 * #	p 665
A90-42433 * #	p 696	N90-23402 #	p 665
A90-42434 #	p 645	N90-23403 * #	p 665
A90-42435 #	p 630	N90-23404 * #	p 666
		N90-23409 #	p 671
A90-42436 #	p 630	N90-23412 #	p 671
A90-42437 *#	p 630	N90-23413 * #	p 671
A90-42438 #	p 630	N90-23475 *	p 678
A90-42439 #	p 630	N90-23523 #	p 678
A90-42440 #	p 631	N90-23538 #	p 678
A90-42441 #	p 645	N90-23571 #	p 678
A90-42442 #	p 646	N90-23591 *#	p 688
A90-42443 #	p 631	N90-23609 #	p 688
A90-42445 #	p 646	. N90-23687 #	p 689
A90-42447 #	p 653	N90-23707 *	p 689
A90-42448 #	p 653		
A90-42449 #	p 669	N90-23713 *	p 689
A90-42450 #	p 653	N90-23752 #	p 689
A90-42451 #	p 653	N90-23760 #	p 689
A90-42452 #	p 640	N90-23762 #	p 689
A90-42454 #	p 694	N90-23768 * #	p 689
A90-42456 #	p 635	N90-23769 * #	p 690
A90-42457 #	p 646	N90-23832 #	p 692
		N90-23990	p 694
A90-42458 #	p 646	N90-24103 * #	p 695
A90-42460 #	p 646	N90-24221 * #	p 699
A90-42461 #	p 669	N90-24224 # .	p 699
A90-42462 *#	p 670	N90-24225 #	p 618
A90-42463 *#	p 670	N90-24227 #	p 673
A90-42464 #	р 646	N90-24228 #	p 673
A90-42465 #	p 646		p 674
A90-42466 #	p 670		
A90-42467 #	p 670		p 674
A90-42468 #	p 646	N90-24237 * #	p 632
A90-42469 #	p 670	N90-24238 * #	p 632
A90-42470 #	ρ 670	N90-24239 * #	p 633
A90-42471 #	p 670	N90-24240	p 633
A90-42472 #	p 671	N90-24241	p 633
A90-42473 *	p 647	N90-24242 * #	p 633
A90-42474 *#	p 671	N90-24243	p 633
	ρ618	N90-24246 * #	p 634
		N90-24249 #	p 634
	ρ 618	N90-24250 #	p 634
A90-42477 #	p 653	N90-24251 #	p 634
A90-42478 #	p 618	N90-24253 #	p 634
A90-42481 #	p 635	N90-24254 #	p 634
A90-42483 #	p 688	N90-24255 #	p 635
A90-42484 #	p 688	N90-24257 * #	p 637
A90-42485 #	p 665	N90-24258 #	p 637
A90-42486 #	p 665	N90-24259 #	p 637
A90-42487 #	p 665	N90-24260 #	p 637
A90-42488 #	p 665	N90-24261 #	p 637
A90-42489 #	p 618	N90-24261 #	p 641
A90-42490 #	p 688	N90-24263 #	p 641
A90-42491 #	p 688		p 650
A90-42492 #	p 618		
A90-42493 #	p 688	N90-24266 * #	p 650
A90-42494 #	p 647	N90-24267 #	p 650
A90-42495 #	p 647	N90-24268 #	p 650
A90-42496 #	p 647	N90-24270 #	p 650
A90-42497	p 647	N90-24271 #	p 666
A90-42498 #	p 647	N90-24272 #	p 666
A90-42499 #	p 647	N90-24273 * #	p 666
A90-42506	p 631	N90-24274 * #	p 666
	,	N90-24275 #	p 672
N90-23340	p 618	N90-24276 #	p 672
N90-23348 * #	p 631	N90-24277 #	p 674
,,	p 631	N90-24278 #	p 674
N90-23349 #		N90-24430 #	p 678
N90-23353 #	p 631	N90-24451 #	p 679
N90-23359 #	p 632	N90-24514 * #	p 690
N90-23360 #	p 632	NOO 24557 * #	p 690
N90-23363 #	p 632	N90-24660 * #	p 690
N90-23364 #	p 632	N90-24852 * #	p 696
N90-23367 #	p 635	N90-24853 * #	p 696
N90-23368 #	p 635	N90-24854 *#	p 696
N90-23369 #	p 636	N90-24855 *#	p 696
N90-23371 #	p 636	N90-24856 *#	p 696
N90-23372 #	p 636	N90-24857 *#	p 697
N90-23373 * #	p 636	N90-24858 * #	p 697
N90-23374 *#	p 636		
N90-23375 #	p 636	N90-24859 * #	p 697
N90-23377 #	p 640	N90-24860 *#	p 697
N90-23378 #	p 640	N90-24861 * #	p 697
N90-23379 #	p 640	N90-24862 * #	p 697
N90-23386 *#	p 648	N90-24864 * #	p 697
N90-23387 #	p 648	N90-24865 * #	p 698
N90-23388 #	p 648	N90-24867 * #	p 698
N90-23389 #	p 648	N90-24868 * #	p 698
	-	N90-24870 * #	p 698
N90-23390 *	p 648	N90-24871 * #	p 698
N90-23392 *#	p 648	N90-24872 * #	p 698
N90-23393 * #	p 649	N90-24873 * #	p 699
N90-23394 *#	p 649	N90-24876 #	p 699

G-2

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