

# **AERONAUTICAL ENGINEERING**

# A CONTINUING BIBLIOGRAPHY WITH INDEXES





# **AERONAUTICAL ENGINEERING**

### A CONTINUING BIBLIOGRAPHY WITH INDEXES



National Aeronautics and Space Administration Scientific and Technical Information Program Washington, DC 1992

### INTRODUCTION

This issue of Aeronautical Engineering—A Continuing Bibliography (NASA SP-7037) lists 467 reports, journal articles, and other documents originally announced in March 1992 in Scientific and Technical Aerospace Reports (STAR) or in International Aerospace Abstracts (IAA).

Accession numbers cited in this issue are:

 STAR (N-10000 Series)
 N92-13926 — N92-15961

 IAA (A-10000 Series)
 A92-17255 — A92-20826

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 publication 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.

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

A cumulative index for 1992 will be published in early 1993.

Information on availability of documents listed, addresses of organizations, and NTIS price schedules are located at the back of this issue.

iii

11

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# CONTENTS

Category 01	Aeronautics (General)	169
Category 02 Inclu faces	<b>Aerodynamics</b> des aerodynamics of bodies, combinations, wings, rotors, and control sur- s; and internal flow in ducts and turbomachinery.	170
Category 03	<b>Air Transportation and Safety</b> des passenger and cargo air transport operations; and aircraft accidents.	186
Category 04 Inclu (sate	<b>Aircraft Communications and Navigation</b> des digital and voice communication with aircraft; air navigation systems llite and ground based); and air traffic control.	188
Category 05 Inclu	Aircraft Design, Testing and Performance des aircraft simulation technology.	192
Category 06 Inclu	<b>Aircraft Instrumentation</b> des cockpit and cabin display devices; and flight instruments.	197
Category 07 Inclu engin	<b>Aircraft Propulsion and Power</b> des prime propulsion systems and systems components, e.g., gas turbine nes and compressors; and onboard auxiliary power plants for aircraft.	200
Category 08 Inclu	Aircraft Stability and Control des aircraft handling qualities; piloting; flight controls; and autopilots.	203
Category 09 Inclu wind	<b>Research and Support Facilities (Air)</b> des airports, hangars and runways; aircraft repair and overhaul facilities; tunnels; shock tubes; and aircraft engine test stands.	206
Category 10 Inclu facili spac spac spac	<b>Astronautics</b> des astronautics (general); astrodynamics; ground support systems and ies (space); launch vehicles and space vehicles; space transportation; e communications, spacecraft communications, command and tracking; ecraft design, testing and performance; spacecraft instrumentation; and ecraft propulsion and power.	209
Category 11 Inclu phys fuels	<b>Chemistry and Materials</b> des chemistry and materials (general); composite materials; inorganic and cal chemistry; metallic materials; nonmetallic materials; propellants and and materials processing.	212
Category 12 Inclu elect photo and b	<b>Engineering</b> des engineering (general); communications and radar; electronics and rical engineering; fluid mechanics and heat transfer; instrumentation and ography; lasers and masers; mechanical engineering; quality assurance eliability; and structural mechanics.	214

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#### Category 13 Geosciences

Includes geosciences (general); earth resources and remote sensing; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

#### Category 14 Life Sciences

Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and space biology.

#### 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.

#### 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.

#### 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.

#### Category 18 Space Sciences

Includes space sciences (general); astronomy; astrophysics; lunar and planetary exploration; solar physics; and space radiation.

#### Category 19 General

A-1
B-1
C-1
D-1
E-1
F-1
G-1
APP-1

N.A.

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235

238

230

N.A.

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### TYPICAL REPORT CITATION AND ABSTRACT



### **TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT**

	NASA SPONSORED	
ACCESSION NUMBER	→A92-13210* National Aeronautics and Space Administration.	- CORPORATE SOURCE
	Ames Research Center, Moffett Field, CA.	
	- PROBE SHAPES FOR STREAMWISE MOMENTUM AND	
	CROSS-STREAM TURBULENCE INTENSITY	
AUTHOR	→VERNON ROSSOW, J. (NASA, Ames Research Center, Moffett	- AUTHORS' AFFILIATION
	Field, CA) Journal of Aircraft (ISSN 0021-8669), Vol. 28, Nov.	
	1991, p. /41-/49. rets	- JOURNAL TITLE
	Voltan the highly turbulant flowfields at the adapt of inter in	
	when the highly turbulent nownelds at the edges of jets, in	
	augmentors, and in other jet-mixing devices are surveyed with	
	conventional pilot proces, the values indicated by the instruments	
	may contain a significant increment brought about by the dynamics	
	or the edgies. Although the indence of turbulence on the	
	measurements is usually negligible in streams where the turbulence	
	level is 1 percent or less, the ellect of turbulence on static and total	
	pressure measurements can be around 20 percent when the	
	turbulence level exceeds 40 percent. This paper describes a	
	theoretical study that develops probe shapes that directly measure	
	the time-averaged total pressure based on the streamwise component	
	of the velocity vector to obtain a direct measurement of the streamwise	
	momentum. The difference between the time-averaged pressure	
	indicated by such a probe and one that measures the total head	
	based on the entire velocity vector yields the cross-stream turbulence	
	intensity. Author	

# **AERONAUTICAL** ENGINEERING

A Continuing Bibliography (Suppl. 277)

### **APRIL 1992**

#### 01

#### **AERONAUTICS (GENERAL)**

#### A92-17294

#### NATIONAL RESEARCH PROGRAM FOR NONDESTRUCTIVE **INSPECTION OF AGING AIRCRAFT**

CHRIS SEHER (FAA, Technical Center, Atlantic City, NJ) and ALFRED L. BROZ (FAA, Burlington, MA) Materials Evaluation (ISSN 0025-5327), vol. 49, Dec. 1991, p. 1547-1550.

A national research program called National Aging Aircraft Research Program (NAARP) is being developed by the Federal Aviation Administration to ensure that the structural integrity of high-flight-time aircraft is properly maintained. The NAARP consists of six subprograms each of which deals with one of the six factors that affect the aircraft maintenance system: corrosion, fatigue and fracture, maintenance and repair, flight loads, human factors, and nondestructive inspection. The methods used by the program to achieve each of its objectives are discussed. LS.

#### A92-17854#

#### POTENTIAL HYPERSONIC VEHICLES APPLICATIONS

GERARD LARUELLE (Aerospatiale, Les Mureaux, France) and PHILIPPE RAMETTE (Dassault Aviation, Saint-Cloud, France) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 8 p. refs

(AIAA PAPER 91-5086) Copyright

Applications of the vehicles are given including missiles, reconnaissance, commercial transportation, military aircraft, and airbreathing space launchers. The convergence of technological and economic issues is considered along with need in justifying the importance of the aircraft and spacecraft. Key technological issues include propulsion systems, resistant materials, low-mass structures, and guidance equipment for the thermal environment. Hypersonic missiles and reconnaisance vehicles are described and include the Scorpion airbreathing missile, and commercial applications include the Concorde and the Alliance aircrafts. Technological advances are cited for developing space launchers, and design studies are mentioned for advanced SSTO and TSTO launchers such as the Taranis, Oriflamme, and STS 2000.

C.C.S.

### A92-20023

#### AGING AIRCRAFT PROGRAMME ENTAILS MAJOR EFFORT AND EXPENSE

RAY WALDER (International Air Transport Association, Montreal, Canada) ICAO Journal (ISSN 0018-8778), vol. 46, Nov. 1991, p. 6-8

Copyright

The extensive program initiated by the Airworthiness Assurance Task Force formed by ATA to address a number of continuing airworthiness issues related to aircraft aging is presented. Some of the general issues addressed include fatigue testing or teardown of samples of long-service aircraft, establishing a new corrosion prevention and repair program with extensive reporting procedures, and appropriate changes to maintenance programs. The continuing airworthiness of commuter aircraft is also under review, utilizing many of the criteria developed for the larger transport category aircraft. R.E.P.

#### A92-20145

#### A PERSPECTIVE ON AEROSPACE CFD

DEAN R. CHAPMAN (Stanford University, CA) Aerospace America (ISSN 0740-722X), vol. 30, Jan. 1992, p. 16-19, 58. Copyright

An overview is presented of CFD development with emphasis on the computational technology of large eddy simulation (LES) for aerospace research. Though wind tunnel data are still the primary source of flow simulations for fighter aircraft design, LES offers the potential for accurately simulating all of the complex transitional and turbulent flows, although the required computer power is not presently available. The key to LES expectations is experimental data showing the small scales of turbulence to be essentially universal, or at least correlatable, and therefore amenable to reasonably accurate modeling. R.E.P.

#### A92-20146

#### CFD HELPS THE AIR FORCE FLY RIGHT

LARRY P. DAVIS and ALLAN C. SCHELL (USAF, Washington, DC) Aerospace America (ISSN 0740-722X), vol. 30, Jan. 1992, p. 22-26.

Copyright

The USAF overall CFD programs, balanced among basic research, applied research, design applications, and test and evaluation are presented. Consideration is given to the development of EAGLE, a code consisting of surface and volume grid generation codes coupled with an inviscid flow solution code capable of handling complex geometries utilizing a blocked grid structure. Attention is given to the Air Force science and technology program in the area of weather prediction. Other developments include the Socrates Monte Carlo code, which predicts the transport, chemical reactions, and signatures of effluents from spacecraft. REP

N92-13926# Executive Resource Associates, Inc., Arlington, VA.

**GENERAL AVIATION ACTIVITY AND AVIONICS SURVEY, CALENDAR YEAR 1989 Annual Report** 

1989 469 p Prepared in cooperation with Adsystech, Inc., Silver Spring, MD

(PB91-179234; FAA-AMS-420) Avail: NTIS HC/MF A20 CSCL 01B

The results of the Annual General Aviation Activity and Avionics Survey are presented. The survey is conducted by the FAA to obtain information on the activity and avionics of the United States registered general aviation aircraft fleet. Breakdowns of active aircraft, annual flight hours, average flight hours, and other statistics by manufacture/model groups, aircraft type, state, and region of based aircraft and primary use are presented. Also included are fuel consumption, lifetime airframe hours, avionics, engine hours, miles flown estimates, tables for detailed analysis of the avionics capability of the general aviation fleet, estimates of the number of landings, IFR hours flown, and grade of fuel consumed by the general aviation fleet. GRA **N92-13927#** Federal Aviation Administration, Washington, DC. Office of Management Systems.

#### FAA STATISTICAL HANDBOOK OF AVIATION: CALENDAR YEAR 1989

1989 142 p

(PB91-202051; FAA-AMS-420) Avail: NTIS HC/MF A07 CSCL 01B

Statistical information pertaining to the Federal Aviation Administration, the National Airspace System, airports, airport activity, aircraft accidents, aeronautical production and imports/exports, and a glossary of the terms used in the publication are presented. GRA

**N92-13928\*#** Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.

#### THIRD INTERNATIONAL CONFERENCE ON INVERSE DESIGN CONCEPTS AND OPTIMIZATION IN ENGINEERING SCIENCES (ICIDES-3)

GEORGE S. DULIKRAVICH, ed. 1991 608 p Conference held in Washington, DC, 23-25 Oct. 1991 Sponsored in cooperation with NASA, Washington, NSF, and ONR

(NASA-CR-188125; NAS 1.26:188125) Avail: NTIS HC/MF A99 CSCL 01B

Papers from the Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES) are presented. The papers discuss current research in the general field of inverse, semi-inverse, and direct design and optimization in engineering sciences. The rapid growth of this relatively new field is due to the availability of faster and larger computing machines.

**N92-13991#** Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.

INTERNATIONAL AVIATION (SELECTED ARTICLE)

25 Jul. 1991 19 p Transl. into ENGLISH from Guoji Hangkong (China), no. 3, 49-51, 1990 p 42

(AD-A240986; FTD-ID(RS)T-0167-91) Avail: NTIS HC/MF A03 CSCL 01/3

A discussion of China's role in the future of commercial and military aircraft manufacturing is presented. The discussion is given in two parts. The first part describes the relative advantages of delta wing aircraft. The second part gives a description of the state of aircraft manufacturing in the West (United States, United Kingdom, France, and Germany) and then goes on to discuss the need for modernization in China's aircraft industry. GRA

**N92-13992**# Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.

INTERNATIONAL AVIATION (SELECTED ARTICLE)

18 Jul. 1991 22 p Transl. into ENGLISH from Guoji Hangkong (China), no. 10, 49 1989 p 34-36

(AD-A240987; FTD-ID(RS)T-0170-91) Avail: NTIS HC/MF A03 CSCL 21/5

This translation of the Chinese journal, International Aviation, contains two articles. The first article is a discussion of the development of China's first generation augmented turbofan, the WS6. The second article is a description of China's first-generation full-pressure helmet, the TK-4.

**N92-13993**# Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.

#### INTERNATIONAL AVIATION (SELECTED ARTICLES)

11 Sep. 1991 53 p Transl. into ENGLISH from Guoji Hangkong (China), no. 8, 1990 p 8-17

(AD-A241119; FTD-ID(RS)T-0461-91) Avail: NTIS HC/MF A04 CSCL 01/3

The results of ten years of Chinese research on aircraft aeroelastics are presented. The subjects discussed are: the development of the computer study of aerodynamics and wind tunnel testing technology, aerodynamic research by the Beijing Aerodynamic Institute, research on complex flows by the Institute of Fluid Mechanics of the Beijing University of Aeronautics and Astronautics and a type of new model exciter system used in research on aircraft chatter. GRA

N92-14966# David Taylor Research Center, Bethesda, MD. AVIATION DIAGNOSTICS AND MAINTENANCE (ADAM) SYSTEM PRELIMINARY CONCEPT OF OPERATION AND FUNCTIONAL DESCRIPTION Final Report, Oct. 1990 - Sep. 1991

RAYMOND P. LEBEAU, MARK T. KRAMER, JAMES R. CARLBERG, MICHAEL S. DEPRIEST, and HARVEY A. EIKEL Sep. 1991 76 p

(AD-A242598; DTRC-91/017) Avail: NTIS HC/MF A05 CSCL 12/7

The Aviation Diagnostics and Maintenance (ADAM) System is an initiative to acquire, store, distribute, and use technical maintenance information for aircraft in a digitized, integrated, and task-oriented format. The initiative is consistent with DoD Computer-aided Acquisition and Logistics Support (CALS) direction and provides tools for Statistical Process Control (SPC) under Total Quality Management (TQM) concepts. While oriented toward new technology aircraft, segments of the concept have applicability to the existing Naval Aviation inventory. ADAM consists of a maintenance system equipped with state of the art hardware/software through which complete, current and consistent data will be made automatically available in electronic format to all maintenance technicians and production managers, thereby improving maintenance performance and unit readiness with reduced Life Cycle Costs (LCC). The ADAM system incorporates expert system diagnostic techniques, which interface with the aircraft's Built In Test (BIT) data, to generate subsets of optimized maintenance task information for fault isolation and repair processes. This maintenance task information will be available to the technician on both workcenter display devices and on portable display devices which can be used at the work site. GRA

#### 02

#### AERODYNAMICS

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

**A92-17429\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### EIGENVALUE CALCULATION PROCEDURE FOR AN EULER/NAVIER-STOKES SOLVER WITH APPLICATION TO FLOWS OVER AIRFOILS

APARAJIT J. MAHAJAN (NASA, Lewis Research Center, Cleveland; Toledo, University, OH; Duke University, Durham, NC), EARL H. DOWELL, and DONALD B. BLISS (Duke University, Durham, NC) Journal of Computational Physics (ISSN 0021-9991), vol. 97, Dec. 1991, p. 398-413. refs (Contract NAG3-724)

Copyright

A Lanczos procedure is presently applied to a Navier-Stokes (N-S) solver for eigenvalues and eigenvectors associated with the small-perturbation analysis of the N-S equations' finite-difference representation for airfoil flows; the matrix used is very large, sparse, real, and nonsymmetric. The Lanczos procedure is shown to furnish complete spectral information for the eigenvalues, as required for transient-stability analysis of N-S solvers. O.C.

#### A92-17501

#### CFD APPLICATION TO 2D/3D FLOW FIELDS IN SCRAMJET ENGINE

TOSHIRO FUJIMORI, MASAFUMI KAWAI, TAKAKO SUZUKI, YASUNORI ANDO, and YASUNORI OHMORI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 31, July 1991, p. 221-226. In Japanese. refs

CFD plays a major role in the research and development of

hypersonic flight vehicles on the premise that numerical approaches provide simulations of various conditions, including supersonic combustion for which no ground test capability exists. The 2D/3D CFD codes have been developed to simulate the supersonic/hypersonic turbulent reacting flow in supersonic combustion ramjet (Scramjet) engines. The TVD scheme is used to capture shocks, and a finite reaction-rate mode of hydrogen-air combustion is utilized. The current results for the components of Scramjet engines are presented; i.e., inlet, combustor and nozzle by using the CFD codes. Validation of these results are compared with existing experimental and computational results. Author

#### A92-17502

#### SUPERSONIC INLET FLOW COMPUTATION

SHIN-ICHI KURODA Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 31, July 1991, p. 227-229. In Japanese. refs

Supersonic inlet plays the role of partial or whole air-compression process in supersonic/hypersonic air-breathing engines and is a key factor of the engine performance. The ultimate purpose of the present study is to clarify the complex supersonic inlet flow structure by using the computational fluid dynamics (CFD) and thereby contribute to the development of the inlet. In the present paper, a preliminary computation is performed for the flowfield about the experimental inlet model which is designed at Mach number 3.0 and has a bleed chamber. To handle the complex body configuration, a zonal method with slightly overlapped grid is adopted. The Fortified Navier-Stokes approach is used as the interface scheme, which connects each zone with high accuracy and permits the movement of discontinuities across the zonal boundary. Author

#### A92-17817# THREE DIMENSIONAL HYPERSONIC INLETS - LOW SPEED PERFORMANCE

MARK R. ANDERSON and PAUL J. ORTWERTH (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 8 p. refs

#### (AIAA PAPER 91-5021) Copyright

Sidewall compression inlets for hypersonic vehicles offer the potential for high efficiency compression with low distortion. An investigation into three-dimensional inlet performance was conducted to examine lift, drag, spill and starting ability in the low speed range. The Inlet Marching Program (IMP) provided the means by which the analysis was conducted. The inviscid quasi-two-dimensional format of the code provided the accuracy and computational efficiency necessary to make multiple runs needed to determine inlet starting points and design trade studies. Validation of the code by comparison to experimental data and more rigorous CFD solutions are shown. Results of the analysis show strong effects on inlet starting from leading edge sweep and sidewall angle. Author

#### A92-17822# North Carolina State Univ., Raleigh. EFFECT OF NOSE SHAPE ON THREE-DIMENSIONAL STAGNATION REGION STREAMLINES AND HEATING RATES

BASIL HASSAN, FRED R. DEJARNETTE (North Carolina State University, Raleigh), and E. V. ZOBY (NASA, Langley Research Center, Hampton, VA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 16 p. Research supported by USAF and U.S. Navy. refs (Contract NAGW-1072; NCC1-1002)

#### (AIAA PAPER 91-5032) Copyright

A new method for calculating the three-dimensional inviscid surface streamlines and streamline metrics using Cartesian coordinates and time as the independent variable of integration has been developed. The technique calculates the streamline from a specified point on the body to a point near the stagnation point by using a prescribed pressure distribution in the Euler equations. The differential equations, which are singular at the stagnation point, are of the two point boundary value problem type. Laminar heating rates are calculated using the axisymmetric analog concept for three-dimensional boundary layers and approximate solutions to the axisymmetric boundary layer equations. Results for elliptic conic forebody geometries show that location of the point of maximum heating depends on the type of conic in the plane of symmetry and the angle of attack, and that this location is in general different from the stagnation point. The new method was found to give smooth predictions of heat transfer in the nose region where previous methods gave oscillatory results. Author

#### A92-17826#

#### NUMERICAL AND EXPERIMENTAL STUDY OF JET IMPINGEMENT OR INTERACTION EFFECTS AT HYPERSONIC AND SUPERSONIC SPEEDS

C. Y. WANG and Z. H. WANG (Changsha Institute of Technology, People's Republic of China) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs

(AIAA PAPER 91-5038) Copyright The base transverse jet in supersonic crossflow and the jet impingement on obstacle have several applications for aerospace vehicles. Numerical methods and experiment used to analyze above problems are described. Plane two-dimensional and axisymmetrical flowfields have been calculated with MacCormack explicit scheme and implicit vector flux splitting finite volume method. NS and Euler equations are solved. Adopting multiprocessor parallel calculation methods, the computational efficiency is promoted obviously. It is shown that the Mach number of nozzle exit and oncoming flow, the ratio of exit pressure and ambient, the jet mass flow, and the distance between the nozzle exit and the obstacle are the main factors to affect the features of flowfield. The results measured in supersonic wind tunnel for jet impinging solid obstacle are given, in which the Mach number is 2.0 and 3.728. Surface pressure distribution is shown. The hypersonic gun tunnel is introduced briefly. The plan which is going to be performed is presented. Author

#### A92-17841#

#### A LIFTING LINE THEORY FOR SUPERSONIC FLOW APPLICATIONS

I. JADIC (Institute of Applied Mathematics, Bucharest, Romania) and V. N. CONSTANTINESCU (Polytechnical Institute, Bucharest, Romania) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 10 p. refs (AIAA PAPER 91-5058) Copyright

The paper is devoted to the study of a supersonic lifting line theory (SLLT) intended to provide both a means of aerodynamic calculation and a testbench for the validation of the control point position for the related constant pressure panel methods. The model is based on the small perturbations assumption. A constant distribution of bound vortices is assumed along the chord while the spanwise load distribution is calculated by means of trigonometrical series, formally similar to the subsonic methods. The calculated aerodynamic coefficients are in good agreement to the reference data, the precision being compatible with the small perturbations assumption. The control point position obtained is shown to vary as a function of aspect ratio from 100 percent to 88 percent of the local chord. Author

#### A92-17842#

#### ENGINEERING METHOD FOR CALCULATING SURFACE PRESSURES AND HEATING RATES ON VEHICLES WITH EMBEDDED SHOCKS

D. B. LANDRUM, FRED R. DEJARNETTE (North Carolina State University, Raleigh), and BRET L. BOMAN (McDonnell Aircraft Co., Saint Louis, MO) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs (Contract F33615-87-C-3402)

(AIAA PAPER 91-5060) Copyright

An engineering method is described which includes embedded shock waves in three-dimensional surface pressure and heat transfer calculations. Embedded shocks are determined to exist in the flow based on the surface pressure change across discontinuities in the vehicle geometry and obligue shock wave relations. Maslen's approximate technique is used to obtain flowfield

### 02 AERODYNAMICS

properties ahead of the embedded shock. Surface pressures downstream of the shock are calculated by a new Embedded Newtonian pressure method. The importance of accurately modeling the surface geometry including discontinuities is discussed and the ASTUD, QUICK, and spline techniques are compared. Code predictions of pressures and heating rates are compared to experimental data for a generic hypersonic vehicle design. In general the comparison is good, especially considering the complexity of the geometries modeled and the approximate nature of the method. Also, a substantial reduction in solution time and user interaction in comparison to more exact CFD techniques is discussed. These advantages make the approximate method a useful tool in a preliminary design environment.

Author

### A92-17857\*# Air Force Academy, CO. EFFECTS OF UNSTEADY SHOCK IMPINGEMENT ON HIGH-SPEED GASEOUS MIXING

C. W. WOOD (U.S. Air Force Academy, Colorado Springs, CO) and J. A. SCHETZ (Virginia Polytechnic Institute and State AIAA, International Aerospace Planes University, Blacksburg) Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 15 p. Research supported by NASA. refs

(AIAA PAPER 91-5091) Copyright Tests are performed to determine the effects of impinging oscillating shocks of different frequencies on a 15 deg downstream angled, underexpanded, sonic helium jet injected into a supersonic airflow. Information on mixing, penetration, total pressure loss, and turbulence structure from these tests is employed to estimate mixing control achieved by adding an oscillating shock to the helium injection flow field. The principal result of this study is that impingement of an oscillating shock on a high-speed shear layer can be utilized to control the rate of mixing. R.F.P.

#### A92-18352

#### THREE-DIMENSIONAL SOLUTION-ADAPTIVE GRID GENERATION ON COMPOSITE CONFIGURATIONS

YEN TU (USAF, Armament Laboratory, Eglin AFB, FL) and JOE F. THOMPSON (Mississippi State University, Mississippi State) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2025, 2026. Abridged. Previously cited in issue 06, p. 756, Accession no. A90-19799. refs

#### A92-18353

#### COMPLEX VARIABLE BOUNDARY ELEMENT METHOD FOR EXTERNAL POTENTIAL FLOWS

M. MOKRY (National Research Council of Canada, Ottawa) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2027, 2028. Abridged. Previously cited in issue 06, p. 755, Accession no. A90-19694. refs Copyright

#### A92-18358\* Technion - Israel Inst. of Tech., Haifa. NUMERICAL PREDICTION OF SUBSONIC TURBULENT FLOWS OVER SLENDER BODIES AT HIGH INCIDENCE

DAVID DEGANI (Technion - Israel Institute of Technology, Haifa), LEWIS B. SCHIFF, and YUVAL LEVY (NASA, Ames Research AIAA Journal (ISSN 0001-1452), vol. Center, Moffett Field, CA) 29, Dec. 1991, p. 2054-2061. Previously cited in issue 08, p. 1100, Accession no. A90-22163. refs Copyright

#### A92-18361 THREE-DIMENSIONAL LINEAR STABILITY APPROACH TO TRANSITION ON WINGS AND BODIES OF REVOLUTION AT INCIDENCE

TUNCER CEBECI, H. H. CHEN, D. ARNAL, and T. T. HUANG (California State University, Long Beach) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2077-2085. Research supported by U.S. Navy. refs

#### Copyright

The calculation of transition on an infinite swept wing at several angles of incidence for several sweep angles and on a body of revolution at one incidence is investigated with the exp-n method based on the eigenvalue formulation of Cebeci and Stewartson in which the relationship between the two wavenumbers alpha and beta are determined by making use of the saddle-point method. The method, which is based on the solution of the boundary-layer and Orr-Sommerfeld equations by a finite difference procedure, is evaluated in terms of measurements reported for the flow around a swept wing equipped with a cambered leading edge and attached to a half fuselage and for the flow around a prolate spheroid at 10-deg incidence. It is shown to be convenient to use, particularly because the neutral stability curves (zarfs) facilitate the calculation and avoid uncertainties associated with the choice of magnitude and location of the critical frequencies. In general, the calculated values of the onset of transition are in good agreement with measured values. Author

#### A92-18363

#### CONTROL OF HYPERSONIC AERODYNAMIC FORCES WITH SURFACE BLOWING

A. F. MESSITER, T. C. ADAMSON, JR. (Michigan, University, Ann Arbor), and M. D. MATARRESE AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2094-2104. Research supported by U.S. Army. Previously cited in issue 08, p. 1108, Accession no. A90-23710. refs Copyright

#### A92-18365

#### CONFINED NORMAL-SHOCK/TURBULENT-BOUNDARY-LAYER INTERACTION FOLLOWED BY AN ADVERSE PRESSURE GRADIENT

M. SAJBEN, M. J. MORRIS, T. J. BOGAR, and J. C. KROUTIL (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2115-2123. Previously cited in issue 09, p. 1279, Accession no. A89-25299, refs

Copyright

#### A92-18367

#### EXPERIMENTAL INVESTIGATION OF COANNULAR JET FLOW WITH SWIRL ALONG A CENTERBODY

M. O. FREY and F. B. GESSNER (Washington, University, Seattle) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2132-2140. Previously cited in issue 16, p. 2484, Accession no. A90-38751. refs (Contract AF-AFOSR-85-0273)

Copyright

#### A92-18372\* Old Dominion Univ., Norfolk, VA. PREDICTION OF STEADY AND UNSTEADY ASYMMETRIC VORTICAL FLOWS AROUND CIRCULAR CONES

OSAMA A. KANDIL, TIN-CHEE WONG (Old Dominion University, Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, AIAA Journal (ISSN 0001-1452), vol. 29, Dec. Hampton, VA) 1991, p. 2169-2178. Previously cited in issue 06, p. 760, Accession no. A90-19940. refs (Contract NAS1-18584)

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#### A92-18385

#### STRATIFIED FLOW AROUND AN AXISYMMETRIC BODY AT SMALL ANGLE OF ATTACK

H. E. GILREATH (Johns Hopkins University, Laurel, MD) AIAA Journal (ISGN 0001-1452), vol. 29, Dec. 1991, p. 2259-2262. refs

(Contract N00039-89-C-5301)

Copyright

Available analytical methods do not permit the lift coefficient C(L) of an axisymmetric body to be established within a factor of 2.5. Results are presented which indicate that the use of a median C(L) value, in conjunction with a simple horseshoe vortex lift model, yields a workable prediction of the maximum amplitude of

lift-generated internal waves when linear propagation theory is applied. The maximum wake height and extent of collapse are virtually the same for lifting and nonlifting cases. O.C.

#### A92-18387

### SIMILARITY SOLUTIONS FOR SUPERSONIC AXISYMMETRIC FLOWS

HAMDI T. HEMDAN (King Saud University, Riyadh, Saudi Arabia) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2264-2266. refs

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New similarity solutions are presented which are based on the recently developed hypersonic theory of Hemdan (1989). Good results are obtained for pointed-nose slender axisymmetric bodies at zero incidence. The analysis relies on a recent formulation of hypersonic small-disturbance theory; the equations are presently reduced to ordinary differential equations. A smaller number of unknown functions is used, and the equations are easily tractable by further analytical study. O.C.

#### A92-18680

#### NOISE-DRIVEN FLOW

L. HUANG (Cambridge, University, England) Journal of Sound and Vibration (ISSN 0022-460X), vol. 151, Nov. 22, 1991, p. 55-61. Research supported by University of Cambridge.

Copyright

The unsteady field induced in a duct by supersonically travelling waves, when analyzed from a 'wave-fixed' co-ordinate system, becomes the problem of supersonic flow over wavy walls. The mean drag on the confined flow due to the waves and its effect on the flow are of interest. It is shown that for a regularly profiled wavy wall the wave strength remains finite according to linear theory at all axial positions; but for the case of a randomly deformed wall the wave energy increases linearly with downstream distance. One can thus deduce that the mean flow would slow down and give up part of its kinetic energy to waves. Equivalently, it is predicted that random supersonic waves would induce strong acoustic streaming in the direction of wave travel.

#### A92-18769

#### INFLUENCES OF WIND TUNNEL PARAMETERS ON AIRFOIL CHARACTERISTICS AT HIGH SUBSONIC SPEEDS

H. SCHEITLE and S. WAGNER (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Experiments in Fluids (ISSN 0723-4864), vol. 12, Dec. 1991, p. 90-96. refs

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The influences of several wind tunnel parameters on airfoil characteristics are experimentally investigated in a transonic wind tunnel. Quantified as Mach number errors, they show decisive effects and confirm that they have to be taken into consideration in a valuation of test results. Differences in data gained in measurements of several wind tunnels can be partly explained thereby. Author

#### A92-18770

### BASE PRESSURE MEASUREMENTS ON A CONE AT MACH NUMBERS FROM M SUB INFINITY = 5 TO 7

M. TANNER (DLR, Institut fuer Theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) Experiments in Fluids (ISSN 0723-4864), vol. 12, Dec. 1991, p. 113-118. refs Copyright

Results of base pressure measurements performed on a blunt cone in the Ludwieg-Tube facility at the DLR in Goettingen at Mach numbers from M sub infinity = 4.49 to 6.83 are presented. The angle of incidence was varied between 0 and 15 deg. The results show that the base pressure coefficient increases with increasing Mach number, as is also known from other investigations. At these high Mach numbers the base pressure is practically independent of the angle of incidence up to 15 deg. This is in agreement with findings by Pick (1972), which show that the base pressure for M sub infinity is 5.30 and that 6.34 begins to increase with an angle of incidence greater than 20 deg. A comparison with results from earlier free-flight measurements show that the present base pressures agree relatively well with the older ones obtained at very great Reynolds numbers. P.D.

#### A92-18771

## LARGE CHORD TURBINE CASCADE TESTING AT ENGINE MACH AND REYNOLDS NUMBER

D. J. MEE (Oxford, University, England) Experiments in Fluids (ISSN 0723-4864), vol. 12, Dec. 1991, p. 119-124. Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC. refs

Copyright

A technique is presented for producing a flow through a linear cascade of turbine blades of large chord which gives the pressure distribution around a blade the same as that obtained in an infinite cascade for Mach and Reynolds numbers typical of gas turbine operating conditions. Results of experiments with a cascade of three blades of large chord are compared with results from a cascade of nine blades of smaller chord to confirm the validity of the technique. Experiments are performed on the large-chord cascade to examine surface phenomena with high spatial resolution. Boundary layer scales are also increased and profiles on both suction and pressure surfaces of the blade are obtained. Author

#### A92-18900

# ANALYSIS OF SPIRALING VORTICAL FLOWS AROUND SLENDER DELTA WINGS MOVING IN AN INVISCID MEDIUM

A. DAS (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 11, 1991, p. 465-471. refs

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Éuler and Navier-Stokes equations are used to study the physics of vortical flows around delta wings with sharp leading and trailing edges, focusing on the interrelations between the pressure forces and the required radial acceleration for setting in the spiraling flow field. It is concluded that the radial accelerations needed to establish the spiraling flow have to be brought in by the resulting entropy gradients or loss of total pressure. Data obtained for the vortex core reveal the cause of vortex breakdown above the wing, which is mainly initiated by the adverse pressure gradient near the trailing edge, leading to two saddle points. One point causes flow reversal and opposing axisymmetric dipole fields and the other leads to high radial fluxes outwards. O.G.

#### A92-19068

### HYPERSONIC FLOWS OVER SLENDER CIRCULAR CONES AT SMALL ANGLES OF ATTACK

HAMDI T. HEMDAN (King Saud University, Riyadh, Saudi Arabia) Acta Astronautica (ISSN 0094-5765), vol. 25, Dec. 1991, p. 747-756. refs

Copyright

This paper presents a perturbation theory for hypersonic flows past pointed-nose slender bodies of revolution at small angles of attack. The theory presents the counterpart of other theories on two-dimensional flow, axisymmetric flow, and flow past delta wings, in the case of bodies of revolution. Further restricting the analysis to Newtonian flow, a straightforward perturbation in the angle of attack is applied to the equations obtained and the resulting equations are solved only for circular cones. A striking feature of this approach is the absence of a vortical layer and a uniformallly valid solution at body surface and all over the flowfield. In spite of the yaw angle, conical streamlines at cone surface are predicted which bend around toward the leeward plane. Results obtained for the surface pressure and the shock wave of a circular cone compare very well with other approximate calculations and experiment. Author

#### 02 AERODYNAMICS

#### A92-19110

#### THREE-DIMENSIONAL CALCULATION OF LOW-FREQUENCY UNSTEADY TRANSONIC FLOW IN AXIAL TURBINE STAGES [DREIDIMENSIONALE BERECHNUNG DER NIEDERFREQUENT INSTATIONAEREN, TRANSSONISCHEN STROEMUNG IN AXIALTURBINENSTUFEN]

JUERGEN F. MAYER, VEIT SCHABER, and HEINZ STETTER (Stuttgart, Universitaet, Federal Republic of Germany) Forschung im Ingenieurwesen (ISSN 0015-7899), vol. 57, Nov. 1991, p. 165-171. In German, Research supported by Bundesministerium fuer Wirtschaft. refs

Copyright

A finite volume method has been developed for the study of the unsteady processes resulting from the inhomogeneous flow fields in the runners of axial turbine stages. The method permits the three-dimensional frictionless calculation of low-frequency unsteady flows. The varying flow quantities around the perimeter are modeled as corotating rotor blade systems under time-dependent boundary conditions. The resulting cascade pressure distributions are used to determine the cyclic stress amplitudes resulting from the dynamic loads. C.D.

#### A92-19611

#### EFFECT OF SUCTION ON THE STABILITY OF SUPERSONIC BOUNDARY LAYERS. I - SECOND-MODE WAVES. II -FIRST-MODE WAVES

A. A. AL-MAAITAH (Mutah University, Al-Karak, Jordan), A. H. NAYFEH, and J. A. MASAD (Virginia Polytechnic Institute and State University, Blacksburg) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 113, Dec. 1991, p. 591-601. refs (Contract N00014-85-K-0011; NR PROJECT 432-5201)

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The present study investigates the effect of suction on the second (Mach) mode of instability in supersonic and hypersonic 2D boundary layers. The results show that suction has a stabilizing effect on these waves: it reduces the peak amplification and shifts it toward a higher frequency. In the presence of suction, the most amplified Mach mode remains 2D. The effectiveness of suction in stabilizing Mack waves decreases as the Mach number increases. The effect of suction on the first mode of instability of compressible 2D boundary layers is examined. Suction is found to be more effective in stabilizing the viscous instability, and hence it is more effective at low Mach numbers. Suction decreases the amplification rates at all frequencies and narrows down the band of unstable frequencies. For a given frequency, suction decreases the amplification rates at all streamwise locations. Variations of the growth rates of the most amplified first-mode waves with mass flux are found to be almost linear. P.D.

A92-20201\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. STATIC AEROELASTIC ANALYSIS FOR GENERIC

#### **CONFIGURATION WING**

IN LEE (Korea Advanced Institute of Science and Technology, Daejon, Republic of Korea), HIROKAZU MIURA, and MLADEN K. CHARGIN (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 801, 802. Abridged. refs

Copyright

A static aeroelastic analysis capability that calculates flexible air loads for generic configuration wings was developed. It was made possible by integrating a finite element structural analysis code (MSC/NASTRAN) and a panel code of aerodynamic analysis based on linear potential flow theory. The framework already built in MSC/NASTRAN was used, and the aerodynamic influence coefficient matrix was computed externally and inserted in the NASTRAN by means of a DMAP program. It was shown that deformation and flexible air loads of an oblique wing configuration including asymmetric wings can be calculated reliably by this code both in subsonic and supersonic speeds. Author

#### 174

#### A92-20205

#### FLOW SEPARATION PATTERNS OVER AN F-14A AIRCRAFT WING

TSZE C. TAI (U.S. Navy, David W. Taylor Naval Ship Research and Development Center, Bethesda, MD) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 818-827. Research supported by U.S. Navy. Previously cited in issue 07, p. 978, Accession no. A91-22497. refs

#### A92-20211\* High Technology Corp., Hampton, VA NUMERICAL SOLUTION OF THE BOUNDARY-LAYER EQUATIONS FOR A GENERAL AVIATION FUSELAGE

YONG-SUN WIE (High Technology Corp., Hampton, VA) and JULIUS E. HARRIS (NASA, Langley Research Center, Hampton, Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, VA) p. 861-868. Previously cited in issue 06, p. 756, Accession no. A90-19786. refs (Contract NAS1-18240)

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#### A92-20212

#### INVISCID DRAG PREDICTION FOR TRANSONIC TRANSPORT WINGS USING A FULL-POTENTIAL METHOD

J. VAN DER VOOREN and A. J. VAN DER WEES (National Aerospace Laboratory, Amsterdam, Netherlands) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 869-875. Research supported by Netherlands Agency for Aerospace Programs. Previously cited in issue 06, p. 760, Accession no. A90-19926. refs

Copyright

A92-20214

#### **EVALUATION OF EULER SOLVERS FOR TRANSONIC** WING-FUSELAGE GEOMETRIES

SHREEKANT AGRAWAL, SON F. CREASMAN, and ROBERT B. LOWRIE (McDonnell Aircraft Co., Saint Louis, MO) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 885-891. Research supported by McDonnell Douglas Corp. Previously cited in issue 21, p. 3292, Accession no. A90-45935. refs Copyright

#### A92-20218

#### INCOMPRESSIBLE STEADY AERODYNAMICS USING A STANDARD FINITE ELEMENT CODE

S. DE ROSA and G. PEZZULLO (Centro Italiano Ricerche Aerospaziali, Capua, Italy) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 911-913. refs Copyright

Attention is given to a simple solution of the steady incompressible aerodynamic fields around a body, based on an extension of the conventional approach for scalar fields that uses the standard structural FEM code to lifting flowfields. This approach, which enlists standard preprocessing tools developed for structural problems in the solution of aerodynamic problems, is applicable to general 3D bodies and multicomponent airfoils in virtue of its realization of an unstructured mesh. O.C.

#### A92-20304

#### FLAT-ENDED CIRCULAR CYLINDER IN HYPERSONIC **RAREFIED FLOW**

J. K. HARVEY, M. C. CELENLIGIL, R. G. DOMINY, and M. R. GILMORE (Imperial College of Science, Technology, and Medicine, Journal of Thermophysics and Heat Transfer London, England) (ISSN 0887-8722), vol. 6, Jan.-Mar. 1992, p. 35-43. Research supported by Ministry of Defence Procurement Executive. Previously cited in issue 18, p. 2762, Accession no. A89-43225. refs

#### Copyright

A92-20306\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. THREE-DIMENSIONAL THERMAL STRUCTURAL ANALYSIS OF A SWEPT COWL LEADING EDGE SUBJECTED TO SKEWED SHOCK-SHOCK INTERFERENCE HEATING

PRAMOTE SANDRA Р POLESKY, DECHAUMPHAI. CHRISTOPHER E. GLASS (NASA, Langley Research Center, Hampton, VA), and AJAY K. PANDEY (Lockheed Engineering and Journal of Thermophysics and Sciences Co., Hampton, VA) Heat Transfer (ISSN 0887-8722), vol. 6, Jan.-Mar. 1992, p. 48-54. Previously cited in issue 16, p. 2478, Accession no. A90-38412. refs

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National Aeronautics and Space Administration. A92-20378\* Langley Research Center, Hampton, VA.

#### ENGINEERING CALCULATIONS OF THREE-DIMENSIONAL INVISCID HYPERSONIC FLOWFIELDS

CHRISTOPHER J. RILEY (NASA, Langley Research Center, Hampton, VA) and FRED R. DEJARNETTE (North Carolina State Journal of Spacecraft and Rockets (ISSN University, Raleigh) 0022-4650), vol. 28, Nov.-Dec. 1991, p. 628-635. Previously cited in issue 06, p. 801, Accession no. A91-19421. refs Copyright

#### A92-20379

#### WEDGE-INDUCED TURBULENT BOUNDARY-LAYER SEPARATION ON A ROUGHENED SURFACE AT MACH 6.0

P. J. DISIMILE (Cincinnati, University, OH) and N. E. SCAGGS Wright Research Development Center. (USAF, and Wright-Patterson AFB, OH) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 28, Nov.-Dec. 1991, p. 636-645. Research sponsored by USAF. Previously cited in issue 21, p. 3249, Accession no. A89-47630. refs Copyright

#### A92-20488

#### NUMERICAL CALCULATION OF SUBSONIC AND SUPERSONIC AERODYNAMIC LOADS AROUND COMPLEX **CONFIGURATION VEHICLE**

HENGYUAN YAN and QUAN ZHENG (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 9, Dec. 1991, p. 90-96. In Chinese. refs

A unified method for evaluating the forces of subsonic and supersonic steady and unsteady potential flows was developed using the Green function method. The unified method incorporates two special features. First, it makes it possible to avoid singularity of the leading edge by introducing the concept of joint flow field (which is a combination of positive and negative flow fields) is introduced enabling an accurate calculation of the induced drag. Secondly, large quantities of corner point geometric parameters are supplied as computer input. The computer displays based on computer drawings, show the vehicle configuration in different directions and can thus reveal errors hidden in the input of the parameters. Numerical results show that the method can be applied to calculations of aerodynamic loads of a vehicle. 1.5

#### A92-20649

#### MODEL OSCILLATIONS AT HIGH ANGLE OF ATTACK IN A LOW SPEED WIND TUNNEL TEST

TSAIR G. HUANG, JERRY M. CHEN (National Chunghsing University, Taichung, Republic of China), and QUEN Y. SHEEN (Chung-Shan Institute of Science and Technology, Taichung, IAF, International Astronautical Congress, Republic of China) 42nd, Montreal, Canada, Oct. 5-11, 1991. 6 p. refs (IAF PAPER ST-91-001) Copyright

At high angle of attack, asymmetric vortices may occur near the forebody that lead to the generation of significant side forces and moment. As the angle of attack further increases, these asymmetric vortices may become unsteady and induce lateral and longitudinal model oscillations in a widn tunnel test. The model oscillations will cause poor data repeatability. Results of an experiment conducted in a 7 x 10-foot closed circuit, low speed wind tunnel show that oscillatory amplitude increases with increasing angle of attack. It is also found that the maximum oscillatory amplitude occurs in the case of zero sideslip. The model configuration and Mach number may influence the amplitude as well. However, in general, they have little effect on the oscillatory characteristics. Author

A92-20726\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### MEASUREMENTS OF THE FLOW AROUND A

LIFTING-WING/BODY JUNCTION

D. H. WOOD and R. V. WESTPHAL (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 6-12. refs

Copyright

Detailed measurements of all three mean velocity components and five of the six Reynolds stresses have been made around a model of a lifting-wing/body junction. The body was the flat working section floor of a small blower wind tunnel. Measurements of the surface pressure distribution on the NACA 0012 wing showed that the lift coefficient at the body surface was reduced by only 16 percent from the freestream value. It is shown that the near constancy of the bound vorticity requires the formation of aixal vorticity within the body boundary layer. This vorticity was concentrated in the two legs of the necklace vortex formed near the leading edge of the wing. The magnitude of the vorticity was always greater in the leg that developed on the suction surface. By four chord lengths downstream of the trailing edge, the turbulence structure of the suction leg was qualitatively similar to that of a single vortex imbedded in a turbulent boundary layer.

Author

#### A92-20727

#### **EXPLICIT NAVIER-STOKES COMPUTATION OF CASCADE** FLOWS USING THE K-EPSILON TURBULENCE MODEL

ROBERT F. KUNZ (GM Technical Center, Warren, MI) and BUDUGUR LAKSHMINARAYANA (Pennsylvania State University, AIAA Journal (ISSN 0001-1452), vol. 30, Jan. University Park) 1992, p. 13-22. refs

(Contract DAAL03-86-G-0044)

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A fully explicit two-dimensional flow solver, based on a four-stage Runge-Kutta scheme, has been developed and used to predict two-dimensional viscous flow through turbomachinery cascades for which experimental data are available. The formulation is applied to the density-weighted time-averaged Navier-Stokes equations. Several features of the technique improve the ability of the code to predict high Reynolds number flows on highly stretched grids. These include a low Reynolds number compressible form of the k-epsilon turbulence model, anisotropic scaling of artificial dissipation terms, and locally varying timestep evaluation based on hyperbolic and parabolic stability considerations. Comparisons between computation and experiment are presented for both a supersonic and a low-subsonic compressor cascade. These results indicate that the code is capable of predicting steady two-dimensional viscous cascade flows over a wide range of Mach numbers in reasonable computation times. Author

#### A92-20733 GENUINELY UPWIND ALGORITHMS FOR THE MULTIDIMENSIONAL EULER EQUATIONS

C. LACOR and CH. HIRSCH (Brussels, Free University, Belgium) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 56-63. Previously cited in issue 18, p. 2752, Accession no. A89-41842. refs

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A92-20735\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. UPWIND SCHEME FOR SOLVING THE EULER EQUATIONS

**ON UNSTRUCTURED TETRAHEDRAL MESHES** 

NEAL T. FRINK (NASA Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 70-77. refs

Copyright-

An upwind scheme is presented for solving the

three-dimensional Euler equations on unstructured tetrahedral meshes. Spatial discretization is accomplished by a cell-centered finite-volume formulation using flux-difference splitting. Higher-order differences are formed by a multidimensional linear reconstruction process. The solution gradients required for the higher-order differenes are computed by a novel approach that yields highly resolved solutions in regions of smooth flow while avoiding oscillations across shocks without explicitly applying a limiter. Solutions are advanced in time by a three-stage Runge-Kutta time-stepping scheme with convergence accelerated to steady state by local time stepping and implicit residual smoothing. Transonic solutions are presented for two meshes around the ONERA M6 wing and demonstrate substantial accuracy and insensitivity to mesh size. Author

#### A92-20736

#### **NEWTON'S METHOD SOLVER FOR HIGH-SPEED VISCOUS** SEPARATED FLOWFIELDS

PAUL D. ORKWIS and D. S. MCRAE (North Carolina State University, Raleigh) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 78-85. refs

(Contract DAAL03-86-G-0039)

Copyright

A new method for calculating the 2D, laminar Navier-Stokes equations is presented. The method uses Newton's method for nonlinear systems of equations to find steady-state solutions. The Navier-Stokes equations are approximated by finite differences using Roe's flux difference splitting. Second-order accuracy is attained by using Spekreijse's interpolation with Van Albada's limiter. The exact Newton's method Jacobian matrix is inverted by using recent sparse matrix routines. The symbolic manipulation package MACSYMA is used to develop and write the FORTRAN code. Numerical results are presented for flat plate and wedge type attached and separated viscous flow at high supersonic Mach numbers. Author

#### A92-20737

#### NONEQUILIBRIUM HYPERSONIC INVISCID STEADY FLOWS

M. VALORANI, M. ONOFRI, B. FAVINI, and F. SABETTA (Roma I, Universita, Rome, Italy) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 86-93. Previously cited in issue 09, p. 1285, Accession no. A89-25532.

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#### A92-20738\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. INSTABILITIES OF FLOWS OVER BODIES AT LARGE

### INCIDENCE

DAVID DEGANI (NASA, Ames Research Center, Moffett Field, AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. CA) 94-100. Previously cited in issue 06, p. 760, Accession no. A90-19937. refs Copyright

#### A92-20739

SONIC EDDY - A MODEL FOR COMPRESSIBLE TURBULENCE ROBERT E. BREIDENTHAL (Washington, University, Seattle) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 101-104. Previously cited in issue 06, p. 759, Accession no. A90-19876. refs

(Contract AF-AFOSR-87-0366) Copyright

#### A92-20742

ASYMMETRIC SEPARATED FLOWS AT SUPERSONIC SPEEDS M. J. SICLARI (Grumman Corporate Research Center, Bethpage, AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. NY) 124-133. Previously cited in issue 08, p. 1103, Accession no. A90-22233. refs Copyright

A92-20747\* Toledo Univ., OH. TIME DOMAIN FLUTTER ANALYSIS OF CASCADES USING A FULL-POTENTIAL SOLVER

MILIND A. BAKHLE, T. S. R. REDDY, and THEO G. KEITH, JR. (Toledo, University, OH) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 163-170. Previously cited in issue 11, p. 1606, Accession no. A90-29374. refs (Contract NSG-3139)

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#### A92-20760

FORMATION OF SHOCKS WITHIN AXISYMMETRIC NOZZLES E. LOTH, J. BAUM, and R. LOHNER (U.S. Navy, Naval Research Laboratory, Washington, DC) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 268-270. Previously cited in issue 16, p. 2486, Accession no. A90-38782. refs

#### A92-20761

#### **TURBULENT BOUNDARY-LAYER CHARACTERISTICS OVER A** FLAT-PLATE/WEDGE CONFIGURATION AT MACH 6

P. J. DISIMILE (Cincinnati, University, OH) and N. E. SCAGGS (USAF. Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 270-272. Previously cited in issue 21, p. 3286, Accession no. A90-45870. refs

A92-20762\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. SURFACE FLOW PATTERNS ON AN OGIVE-CYLINDER AT INCIDENCE

DAVID DEGANI, MURRAY TOBAK, and G. G. ZILLIAC (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 272-274. refs Copyright

A set of photographs has been obtained which documents the oil-imaged surface flow patterns of an ogive-cylinder at angles-of-attack between 30 and 85 deg, and Reynolds number of 26,000. Attention is given to the possibility that the bistable nature of the flow within the 50-65 deg angle-of-attack range is linked to the coincident appearance of foci in the surface flow patterns, in view of the suggestion that these foci act as the anchor points allowing the forebody vortical structures to roll up and form the forebody's trailing vortex system. O.C.

N92-13951\*# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.). Dept. of Aerodynamics.

#### APPLICATION OF DIRECT INVERSE ANALOGY METHOD (DIVA) AND VISCOUS DESIGN OPTIMIZATION TECHNIQUES

E. GREFF, D. FORBRICH, and H. SCHWARTEN In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 307-324 1991

Avail: NTIS HC/MF A99 CSCL 01A

A direct-inverse approach to the transonic design problem was presented in its initial state at the First International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-1). Further applications of the direct inverse analogy (DIVA) method to the design of airfoils and incremental wing improvements and experimental verification are reported. First results of a new viscous design code also from the residual correction type with semi-inverse boundary layer coupling are compared with DIVA which may enhance the accuracy of trailing edge design for highly loaded airfoils. Finally, the capabilities of an optimization routine coupled with the two viscous full potential solvers are investigated in comparison to the inverse method.

Author

N92-13953\*# Shanghai Inst. of Mechanical Engineering (China). Lab. of Turbomachinery Aerodynamics.

#### VARIATIONAL FORMULATION OF HYBRID PROBLEMS FOR FULLY 3-D TRANSONIC FLOW WITH SHOCKS IN ROTOR

GAO-LIAN LIU In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 337-346 1991 Sponsored in part by the National Natural Science Foundation, Peoples

#### Republic of China

#### Avail: NTIS HC/MF A99 CSCL 01A

Based on previous research, the unified variable domain variational theory of hybrid problems for rotor flow is extended to fully 3-D transonic rotor flow with shocks, unifying and generalizing the direct and inverse problems. Three variational principles (VP) families were established. All unknown boundaries and flow discontinuities (such as shocks, free trailing vortex sheets) are successfully handled via functional variations with variable domain, converting almost all boundary and interface conditions, including the Rankine Hugoniot shock relations, into natural ones. This theory provides a series of novel ways for blade design or modification and a rigorous theoretical basis for finite element applications and also constitutes an important part of the optimal design theory of rotor bladings. Numerical solutions to subsonic flow by finite elements with self-adapting nodes given in Refs., show good agreement with experimental results. Author

N92-13960\*# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.

#### AIRFOIL OPTIMIZATION WITH EFFICIENT GRADIENT CALCULATIONS

THOMAS SORENSEN In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 433-444 Sponsored in part by MIT and NSF 1991

Avail: NTIS HC/MF A99 CSCL 20N

The viscous airfoil design analysis code XFOIL was extended to allow optimization using conformal mapping coefficients as design variables. The optimization technique used was the Steepest Descent method applied to a Penalty Function. The gradients of the aerodynamic variables with respect to the design variables were cheaply calculated as by-products of XFOIL's integral boundary layer Newton solver. The speed of the optimization process further increased by updating the Newton system boundary layer variables after each optimization step using the available gradient information. Two examples are presented. Author

Virginia Polytechnic Inst. and State Univ., N92-13961\*# Blacksburg. Dept. of Aerospace and Ocean Engineering. DESIGN OPTIMIZATION OF TRANSONIC AIRFOILS

C.-Y. JOH, B. GROSSMAN, and R. T. HAFTKA In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 445-456 1991

(Contract NSF DMC-86-15336)

Avail: NTIS HC/MF A99 CSCL 01A

Numerical optimization procedures were considered for the design of airfoils in transonic flow based on the transonic small disturbance (TSD) and Euler equations. A sequential approximation optimization technique was implemented with an accurate approximation of the wave drag based on the Nixon's coordinate straining approach. A modification of the Euler surface boundary conditions was implemented in order to efficiently compute design sensitivities without remeshing the grid. Two effective design procedures producing converged designs in approximately 10 global iterations were developed: interchanging the role of the objective function and constraint and the direct lift maximization with move limits which were fixed absolute values of the design variables Author

#### N92-13969\*# Beijing Univ. (China). Inst. of Fluid Mechanics. AN INVERSE METHOD WITH REGULARITY CONDITION FOR TRANSONIC AIRFOIL DESIGN

ZIQIANG ZHU, ZHIXUN XIA, and LIYI WU In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 541-552 1991

Avail: NTIS HC/MF A99 CSCL 01A

It is known from Lighthill's exact solution of the incompressible inverse problem that in the inverse design problem, the surface pressure distribution and the free stream speed cannot both be prescribed independently. This implies the existence of a constraint on the prescribed pressure distribution. The same constraint exists at compressible speeds. Presented here is an inverse design method for transonic airfoils. In this method, the target pressure distribution contains a free parameter that is adjusted during the computation to satisfy the regularity condition. Some design results are presented in order to demonstrate the capabilities of the method. Author

N92-13970\*# Xian Jiaotong Univ. (China).

#### STUDY OF A NEW AIRFOIL USED IN REVERSIBLE AXIAL FANS

CHAOJUN LI, BAOSUO WEI, and CHUANGANG GU In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 553-562 1991

Avail: NTIS HC/MF A99 CSCL 01A

The characteristics of the reverse ventilation of axial flow are analyzed. An s shaped airfoil with a double circular arc was tested in a wind tunnel. The experimental results showed that the characteristics of this new airfoil in reverse ventilation are the same as those in normal ventilation, and that this airfoil is better than the existing airfoils used on reversible axial fans. Author

### N92-13974\*# Tsinghua Univ., Bejing (China). THE RESEARCH PROGRESS ON HODOGRAPH METHOD OF **AERODYNAMIC DESIGN AT TSINGHUA UNIVERSITY**

ZUOYI CHEN and JINGRONG GUO In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 599-606 1991

Avail: NTIS HC/MF A99 CSCL 01A

Progress in the use of the Hodograph method of aerodynamic design is discussed. It was found that there are some restricted conditions in the application of Hodograph design to transonic turbine and compressor cascades. The Hodograph method is suitable not only to the transonic turbine cascade but also to the transonic compressor cascade. The three dimensional Hodograph method will be developed after obtaining the basic equation for the three dimensional Hodograph method. As an example of the Hodograph method, the use of the method to design a transonic turbine and compressor cascade is discussed. Author

N92-13979# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

#### COMPUTATIONAL FLUID DYNAMICS

D. W. ZINGG, J. J. GOTTLIEB, G. W. JOHNSTON, P. A. SULLIVAN, D. BERGERON, C. P. T. GROTH, D. F. HAWKEN, H. MURTY, T. NELSON, C. WALSH et al. In its Activities of the University of Toronto Institute for Aerospace Studies p 68-70 1989 Avail: NTIS HC/MF A06

A review is presented of University of Toronto Institute of Aerospace Studies theoretical research on computational techniques for the analysis of fluid dynamics problems. In a study of the limits of applicability of boundary-layer equations for transonic airfoil computations, a generalized form of these equations is solved on a fine grid near the airfoil. The solution is embedded into a coarse-grid Navier-Stokes solution, resulting in a very efficient computational method. A new procedure which avoids the need for iteration has been developed for interpolation on a structured, curvilinear, 2-dimensional grid. Euler computations of airfoil flows using the ARC2D code have been compared with analytical solutions. A technique has been developed using Richardson extrapolation which improves the accuracy of numerical solutions to the Euler equations. A new exact Riemann solver has been invented for use in the random-choice method (RCM) for solving hyperbolic conservation laws in 1 space dimension. Studies are also being conducted on the actual convergence rate of the RCM. Two adaptive numerical methods of solving partial differential equations have been studied in depth. An axisymmetric model of tube collapse has been developed, coupled to a 1-dimensional fluid flow model, and applied to the study of tracheal collapse.

CISTI

#### N92-13994 Duke Univ., Durham, NC. ANALYTICAL/NUMERICAL MATCHING AND PERIODIC INVERSION: TWO ADVANCES IN FREE WAKE ANALYSIS Ph.D. Thesis

WAYNE OWEN MILLER 1990 211 p Avail: Univ. Microfilms Order No. DA9122430

Free wake methods are used for the analysis of potential fluid dynamics with embedded vorticity. The vorticity convects with the fluid and induces a velocity field defined by the Biot-Savart law. Free wake methods define vortex dynamics and the induced velocity field by discretizing the vorticity into elements and following their convection. The application of interest to this research was rotorcraft wakes. The scope of the research was wakes that can be modeled by vortex filaments with finite cores, which are used alone to model vortex tubes, or in groups to model vortex sheets. Vortex filaments are discretized into elements which are simple curves that are fit to the filament. This research used the vortex particle, which is the lowest order and most efficient element, but it is only accurate at a distance from the filament. The accuracies of higher order elements were also compared. Analytical/Numerical Matching is a free wake method which improves computational efficiency without compromising accuracy. A wake of N vortex elements requires O (N exp 2) element evaluations, but only O (N) elements are in the near field of a filament. The ANM method uses vortex particles to efficiently generate a solution which is accurate in the far field. The near field is resolved by superimposing an analytical correction. The method is four times faster than previous methods, and an order of magnitude gain is possible. The method was linearized to improve efficiency and open new analysis options. Periodic Inversion is a solution method for rotor wakes in steady flight which enforces their ideal periodic behavior. Periodic Inversion is not a time marching method, and therefore avoids poor convergence behavior at low advance ratios. A unique set of periodic variables was developed for the method, and the resulting problem is in the form of a linear system which is iteratively solved for corrections to a full period of wake. The method was used to study wakes in hover and at low speeds, where free wake solutions have not previously been obtained. The method should allow coupling with panel methods and blade dynamics, and allow for stability analysis of the wake. Dissert, Abstr.

N92-13995\*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

#### DEFINITION OF THE UNSTEADY VORTEX FLOW OVER A WING/BODY CONFIGURATION Final Technical Report, 21 May - 20 Nov. 1991

S. G. LIOU, B. DEBRY, J. LENAKOS, J. CAPLIN, and N. M. KOMERATH 20 Nov. 1991 131 p

(Contract NAG1-1278)

(NASA-CR-180083; NAS 1.26:180083; GITAER-91-6) Avail:

NTIS HC/MF A07 CSCL 01/1

A problem of current interest in computational aerodynamics is the prediction of unsteady vortex flows over aircraft at high angles of attack. A six-month experimental effort was conducted at the John H. Harper Wind Tunnel to acquire qualitative and guantitative information on the unsteady vortex flow over a generic wing-body configuration at high angles of attack. A double-delta flat-plate wing with beveled edges was combined with a slender sharp-nosed body-of-revolution fuselage to form the generic configuration. This configuration produces a strong attached leading edge vortex on the wing, as well as sharply-peaked flow velocity spectra above the wing. While it thus produces flows with several well-defined features of current interest, the model was designed for efficiency of representation in computational codes. A moderate number of surface pressure ports and two unsteady pressure sensors were used to study the pressure distribution over the wing and body surface at high angles of attack; the unsteady pressure sensing did not succeed because of inadequate signal-to-noise ratio. A pulsed copper vapor laser sheet was used to visualize the vortex flow over the model, and vortex trajectories, burst locations, mutual induction of vortex systems from the forebody, strake, and wing, were quantified. Laser Doppler velocimetry was used to quantify all 3 components of the

N92-13996\*# West Virginia Univ., Morgantown. Dept. of

Mechanical and Aerospace Engineering. THE EFFECTS OF WINGLETS ON LOW ASPECT RATIO WINGS AT SUPERSONIC MACH NUMBERS M.S. Thesis Report Feb. 1989 - Apr. 1991

JAMES A. KEENAN and JOHN M. KUHLMAN Washington NASA. Langley Research Center Nov. 1991 347 p (Contract NAG1-951)

(NASA-CR-4407; NAS 1.26:4407) Avail: NTIS HC/MF A15 **CSCL 01/1** 

A computational study was conducted on two wings, of aspect ratios 1.244 and 1.865, each having 65 degree leading edge sweep angles, to determine the effects of nonplanar winglets at supersonic Mach numbers. A Mach number of 1.62 was selected as the design value. The winglets studied were parametrically varied in alignment, length, sweep, camber, thickness, and dihedral angle to determine which geometry had the best predicted performance. For the computational analysis, an available Euler marching technique was used. The results indicated that the possibility existed for wing-winglet geometries to equal the performance of wing-alone bodies in supersonic flows with both bodies having the same semispan. The first wing with winglet used NACA 1402 airfoils for the base wing and was shown to have lift-to-pressure drag ratios within 0.136 percent to 0.360 percent of the NACA 1402 wing-alone. The other base wing was a natural flow wing which was previously designed specifically for a Mach number of 1.62. The results obtained showed that the natural wing-alone had a slightly higher lift-to-pressure drag than the natural wing with winglets. Author

N92-13997\*# Titan Systems, Inc., Princeton, NJ. A.R.A.P. Group.

#### A UNIFIED VISCOUS THEORY OF LIFT AND DRAG OF 2-D THIN AIRFOILS AND 3-D THIN WINGS

JOHN E. YATES Washington NASA. Langley Dec. 1991 96 D

(Contract NASA ORDER L-74809-C)

(NASA-CR-4414; NAS 1.26:4414) Avail: NTIS HC/MF A05 CSCL 01/1

A unified viscous theory of 2-D thin airfoils and 3-D thin wings is developed with numerical examples. The viscous theory of the load distribution is unique and tends to the classical inviscid result with Kutta condition in the high Reynolds number limit. A new theory of 2-D section induced drag is introduced with specific applications to three cases of interest: (1) constant angle of attack; (2) parabolic camber; and (3) a flapped airfoil. The first case is also extended to a profiled leading edge foil. The well-known drag due to absence of leading edge suction is derived from the viscous theory. It is independent of Reynolds number for zero thickness and varies inversely with the square root of the Reynolds number based on the leading edge radius for profiled sections. The role of turbulence in the section induced drag problem is discussed. A theory of minimum section induced drag is derived and applied. For low Reynolds number the minimum drag load tends to the constant angle of attack solution and for high Reynolds number to an approximation of the parabolic camber solution. The parabolic camber section induced drag is about 4 percent greater than the ideal minimum at high Reynolds number. Two new concepts, the viscous induced drag angle and the viscous induced separation potential are introduced. The separation potential is calculated for three 2-D cases and for a 3-D rectangular wing. The potential is calculated with input from a standard doublet lattice wing code without recourse to any boundary layer calculations. Separation is

indicated in regions where it is observed experimentally. The classical induced drag is recovered in the 3-D high Reynolds number limit with an additional contribution that is Reynold number dependent. The 3-D viscous theory of minimum induced drag vields an equation for the optimal spanwise and chordwise load distribution. The design of optimal wing tip planforms and camber distributions is possible with the viscous 3-D wing theory. Author

N92-13998\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A STUDY ON VORTEX FLOW CONTROL ON INLET DISTORTION IN THE RE-ENGINED 727-100 CENTER INLET

DUCT USING COMPUTATIONAL FLUID DYNAMICS

BERNHARD H. ANDERSON, PAO S. HUANG, WILLIAM A. PASCHAL, and ENRICO CAVATORTA (Dee-Howard Co., San Antonio, TX.) 1992 13 p Presented at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA

(NASA-TM-105321; E-6679; NAS 1.15:105321; AIAA-92-0152) Avail: NTIS HC/MF A03 CSCL 01/1

Computational fluid dynamics was used to investigate the management of inlet distortion by the introduction of discrete vorticity sources at selected locations in the inlet for the purpose of controlling secondary flow. These sources of vorticity were introduced by means of vortex generators. A series of design observations were made concerning the importance of various vortex generator design parameters in minimizing engine face circumferential distortion. The study showed that vortex strength, generator scale, and secondary flow field structure have a complicated and interrelated influence on the engine face distortion. over and above the initial geometry and arrangement of the generators. The installed vortex generator performance was found to be a function of three categories of variables: the inflow conditions, the aerodynamic characteristics associated with the inlet duct, and the design parameters related to the geometry, arrangement, and placement of the vortex generators within the outlet duct itself. Author

N92-13999\*# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.

ANALYSIS AND DESIGN OF PLANAR AND NON-PLANAR WINGS FOR INDUCED DRAG MINIMIZATION Annual Progress Report

K. MORTARA, DENNIS M. STRAUSSFOGEL, and MARK D. MAUGHMER Dec. 1991 56 p

(Contract NAG1-1198)

(NASA-CR-189509; NAS 1.26:189509) Avail: NTIS HC/MF A04 **ČSCL 01/1** 

The goal of the work was to develop and validate computational tools to be used for the design of planar and non-planar wing geometries for minimum induced drag. Because of the iterative nature of the design problem, it is important that, in addition to being sufficiently accurate for the problem at hand, they are reasonably fast and computationally efficient. Toward this end, a method of predicting induced drag in the presence of a non-rigid wake is coupled with a panel method. The induced drag prediction technique is based on the Kutta-Joukowski law applied at the trailing edge. Until recently, the use of this method has not been fully explored and pressure integration and Trefftz-plane calculations favored. As is shown in this report, however, the Kutta-Joukowski method is able to give better results for a given amount of effort than the more common techniques, particularly when relaxed wakes and non-planar wing geometries are considered. Using these tools, a workable design method is in place which takes into account relaxed wakes and non-planar wing geometries. It is recommended that this method be used to design a wind-tunnel experiment to verify the predicted aerodynamic benefits of non-planar wing geometries. Author

N92-14001\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

LEWICE/E: AN EULER BASED ICE ACCRETION CODE

MARK G. POTAPCZUK 1992 25 p Presented at the 30th

Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA

(NASA-TM-105389; E-6778; NAS 1.15:105389; AIAA-92-0037) Avail: NTIS HC/MF A03 CSCL 01/1

A new version of the LEWICE ice accretion computer code was developed which calculates the ice growth on two dimensional surfaces, incorporating the effects of compressibility through the solution of the Euler equations. The code is modular and contains separate stand-alone program elements that create a grid, calculate the flow field parameters, calculate the droplet trajectory paths, determine the amount of ice growth, and plot results. This code increases the applicability of ice accretion predictions by allowing calculations at higher Mach numbers. The new elements of the code are described. Calculated results are compared to experiment for several cases, including a LEWICE example case and a thin airfoil section at a Mach number of 0.58. Author

N92-14002\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### ANALYSIS OF AN ADVANCED DUCTED PROPELLER SUBSONIC INLET

CHANTHY IEK, DONALD R. BOLDMAN, and MOUNIR IBRAHIM (Cleveland State Univ., OH.) 1992 18 p Proposed for presentation at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA

(NASA-TM-105393; E-6784; NAS 1.15:105393; AIAA-92-0274)

Avail: NTIS HC/MF A03 CSCL 01/1

A time marching Navier-Stokes code called PARC (PARC2D for 2-D/axisymmetric and PARC3D for 3-D flow simulations) was validated for an advanced ducted propeller (ADP) subsonic infet. The code validation for an advanced ducted propeller (ADP) subsonic inlet. The code validation was implemented for a non-separated flow condition associated with the inlet operating at angles-of-attack of 0 and 25 degrees. The inlet test data were obtained in the 9 x 15 ft Low Speed Wind Tunnel at NASA Lewis Research Center as part of a cooperative study with Pratt and Whitney. The experimental study focused on the ADP inlet performance for take-off and approach conditions. The inlet was tested at a free stream Mach number of 0.2, at angles-of-attack between O and 35 degrees, and at a maximum propeller speed of 12,000 RPM which induced a corrected air flow rate of about 46 lb/sec based on standard day conditions. The computational grid and flow boundary conditions (BC) were based on the actual inlet geometry and the funnel flow conditions. At the propeller face, two types of BC's were applied: a mass flow BC and a fixed flow properties BC. The fixed flow properties BC was based on a combination of data obtained from the experiment and calculations using a potential flow code. Comparison of the computational results with the test data indicates that the PARC code with the propeller face fixed flow properties BC provided a better prediction of the inlet surface static pressures than the predictions when the mass flow BC was used. For an angle-of-attack of 0 degrees, the PARC2D code with the propeller face mass flow BC provided a good prediction of inlet static pressures except in the region of high pressure gradient. With the propeller face fixed flow properties BC, the PARC2D code provided good prediction of the inlet static pressures. For an а angle-of-attack of 25 degrees with the mass flow BC, the PARC3D code predicted statis pressures which deviated significantly from the test data; however, with the fixed flow properties BC, a good comparison with the test data was obtained. Author

N92-14968\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

WIND TUNNEL INVESTIGATION OF VORTEX FLOWS ON F/A-18 CONFIGURATION AT SUBSONIC THROUGH TRANSONIC SPEED

GARY E. ERICKSON Washington Dec. 1991 166 p (NASA-TP-3111; L-16799; NAS 1.60:3111) Avail: NTIS HC/MF A08 CSCL 01/1

A wind tunnel experiment was conducted in the David Taylor Research Center 7- by 10-Foot Transonic Tunnel of the wing leading-edge extension (LEX) and forebody vortex flows at subsonic

and transonic speeds about a 0.06-scale model of the F/A-18. The primary goal was to improve the understanding and control of the vortical flows, including the phenomena of vortex breakdown and vortex interactions with the vertical tails. Laser vapor screen flow visualizations, LEX, and forebody surface static pressures, and six-component forces and moments were obtained at angles of attack of 10 to 50 degrees, free-stream Mach numbers of 0.20 to 0.90, and Reynolds numbers based on the wing mean aerodynamic chord of 0.96 x 10(exp 6) to 1.75 x 10(exp 6). The wind tunnel results were correlated with in-flight flow visualizations and handling qualities trends obtained by NASA using an F-18 High-Alpha Research Vehicle (HARV) and by the Navy and McDonnell Douglas on F-18 aircraft with LEX fences added to improve the vertical tail buffet environment. Key issues that were addressed include the sensitivity of the vortical flows to the Reynolds number and Mach number; the reduced vertical tail excitation, and the corresponding flow mechanism, in the presence of the LEX fence; the repeatability of data obtained during high angle-of-attack wind tunnel testing of F-18 models; the effects of particle seeding for flow visualization on the quantitative model measurements; and the interpretation of off-body flow visualizations obtained using different illumination and particle seeding techniques. Author

**N92-14969\***# Arizona State Univ., Tempe. Dept. of Mechanical and Aerospace Engineering.

#### NUMERICAL SIMULATION OF SWEPT-WING FLOWS Progress Report

HELEN L. REED Dec. 1991 55 p

(Contract NAG1-1158)

(NASA-CR-189457; NAS 1.26:189457) Avail: NTIS HC/MF A04 CSCL 01/1

Efforts of the last six months to computationally model the transition process characteristics of flow over swept wings are described. Specifically, the crossflow instability and crossflow/Tollmien-Schlichting wave interactions are analyzed through the numerical solution of the full 3D Navier-Stokes equations including unsteadiness, curvature, and sweep. This approach is chosen because of the complexity of the problem and because it appears that linear stability theory is insufficient to explain the discrepancies between different experiments and between theory and experiment. The leading edge region of a swept wing is considered in a 3D spatial simulation with random disturbances as the initial conditions.

N92-14972# Ballistic Research Labs., Aberdeen Proving Ground, MD.

#### TRANSONIC NAVIER-STOKES COMPUTATIONS FOR A SPINNING BODY OF REVOLUTION Final Report, Jul. 1989 -Jul. 1991

JUBARAJ SAHU Sep. 1991 43 p

(Contract DA PROJ. 1L1-61102-AH-43)

(AD-A241015; BRL-TR-3265) Avail: NTIS HC/MF A03 CSCL 20/9

A zonal, implicit, time-marching Navier-Stokes computational technique has been used to compute three dimensional transonic flow fields over a projectile. Flow field computations have been performed at M = 0.94 for spin rates of 0 and 4900 rpm and at angles of attack, alpha = 0,4, and 10 degrees. All the computations have been performed on the Cray-2 supercomputer. Details of the flow field such as Mach number contours and surface pressure distributions are presented. Computer surface pressures are compared with available experimental data for the same conditions and the same configuration. Computer results show the large circumferential pressure distribution over the boattail region as well as the nonlinear effect of the angle of attack. Aerodynamic force and moment coefficients (normal force, pitching moment, Magnus force, and Magnus moment) have been obtained from the computed pressures and are compared with the data. The computed results are generally in good agreement with the data at a low angle of attack for both nonspinning and spinning conditions. At a high angle of attack, the agreement is good for

the nonspinning case and is less satisfactory for the spinning case. GRA

**N92-14973#** European Space Agency, Paris (France). **AEROTHERMODYNAMICS FOR SPACE VEHICLES** 

B. BATTRICK, ed. Jul. 1991 570 p In ENGLISH and FRENCH The 1st European Symposium was held in Noordwijk, Netherlands, 28-30 May 1991; sponsored by ESTEC, AAAF/CNES and DGLR/DARA/DLR

(ESA-SP-318; ISBN-92-9092-114-5; ETN-92-90680) Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Papers concerning the development of aerothermodynamics for space vehicles, covering problems of high speed flight for advanced launchers, reentry vehicles and planetary landers are presented. The focus of the symposium was the new technology of 'aerothermodynamics', which includes classical aerodynamics, thermodynamics, and thermochemistry. The applications presented and discussed covered external flow over vehicles and internal flow through vehicle propulsion systems, at speeds ranging from the low subsonic, through transonic, to supersonic and hypersonic. The flight trajectories addressed included ascent to space from planetary surfaces, descent from space to planetary surfaces, flight through low density atmospheres, and aerobraking by atmospheric entry.

ESA

N92-14974# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Propulsion and Aerothermodynamics Div. AEROTHERMODYNAMIC CHALLENGES FOR ESA PROGRAMMES

W. BERRY In its Aerothermodynamics for Space Vehicles p 3-10 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

A history of aerothermodynamic activities in the European Resrach Organization/European Space Space Agency (ENRO/ESA) is given. Between 1964 and 1988 these were devoted to satellite aerodynamics for low Earth orbit missions and rocket engine exhaust plume dynamics. The creation of an aerodynamic capability at the European Space Research and Technology Center (ESTEC) is mentioned, and the programs involving substantial aerothermodynamics are listed. The aerothermodynamic challenges for future ESA mission in its science. Earth observation, and space transportation programs, are addressed, and design solutions offerred. Within the science programs the Cassini/Huygens, Rosetta, and Mars missions are considered. Within the Earth observation programs the Aristoteles mission is considered. Within the space transportation programs, Ariane-5, Hermes, and reusable winged launchers are considered. Design tools and engineering facilities needed for modern aerothermodyanmics are discussed; ESA's research and development activities in aerothermodynamics are addressed. One of these activities is to prepare and implement a Technology Research Program (TRP) designed to prepare the technology needed for Europe's space program. Activities in progress or planned within the TRP are addressed. They include development of Navier-Stokes algorithms, work in aerothermochemistry effects in hypersonic flows, work on parallel processing for aerothermodynamics, transition criteria in hypersonic flows, and work on measurement techniques in hypersonic flows. ESA

#### N92-14981# Aeronautical Research Inst. of Sweden, Bromma. HYPERSONIC FLOW PAST DELTA WING FLOW SIMULATED BY NAVIER-STOKES SOLUTIONS

S. SRINIVASAN, P. ELIASSON, and A. RIZZI *In* ESA, Aerothermodyanmics for Space Vehicles p 73-78 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Numerical simulations for the laminar hypersonic flow past a blunt edged delta wing were performed by solving the Navier-Stokes equations. These simulations were performed for four different angles of attack: 0, 15, 25, and 30 degrees. The Navier-Stokes equations were solved using the explicit finite volume-four stage Runge-Kutta scheme. The intent is to reach a reasonable understanding of the computed flow fields, including flow separation, shear layers, vortices, shock waves, and entropy losses, and also to study the effect of the angle of attack on the flow features. It was observed that in the case of blunt edged delta wings at high angles of attack, the hypersonic flow is dominated by a shear layer that separates just past the blunt leading edge forming a more distributed vortical region over the wing, rather than a concentrated vortex structure as observed at lower speeds. The solutions are analyzed and compared with available experimental data. The computed results agree qualitatively with the experimental data but not quantitatively. ESA

N92-14985# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.

#### SIMULATION REQUIREMENTS FOR RCS PLUME: FLOWFIELD INTERACTION MODELLING ON A WINGED REENTRY VEHICLE

T. POERTNER *In* ESA, Aerothermodynamics for Space Vehicles p 101-106 Jul. 1991 Sponsored by CNES

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During the initial phase of reentry, the control over a winged vehicle is to be achieved by the Reaction Control System (RCS). For reasons of safety and performance, the reliable prediction of the actual efficiency of a planned RCS configuration is necessary. For the realistic configuration, the interference flowfield is so complex that extrapolations from either existing realistic or too greatly simplified configurations will not yield reliable quantitative prediction of RCS efficiency. As the problem is not accessible to theoretical analysis, efforts should be focused on experimental investigations using realistic models of the intended configurations. For this purpose, simulation requirements are derived based on Shuttle related NASA experience.

#### **N92-14986#** Ecole Polytechnique Federale de Lausanne (Switzerland). Inst. of Hydraulic Machines and Fluid Mechanics. **A MULTIBLOCK FLOW SOLVER FOR INVISCID HYPERSONIC FLOWS**

JAN B. VOS and C. M. BERGMAN (Royal Inst. of Tech., Stockholm, Sweden) *In* ESA, Aerothermodynamics for Space Vehicles p 109-114 Jul. 1991 Sponsored in part by Commission Suisse d'Encouragement des Recherches Scientifiques

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The development of multiblock flow solvers on structured grids is considered. The present version of the solver solves the three dimensional Euler equations for transonic, supersonic, and hypersonic flows. The Euler equations are solved by the finite volume method using a space centered, explicit time marching scheme augmented by artificial dissipation terms. Equilibrium and nonequilibrium air chemistry were implemented. The multiblock solver is written on top of the MEL-COM data base system, and uses a dynamic memory manager to allocate the storage for the variables in each block. Results of multiblock calculations for the flow over a wedge and of single block calculations for the flow around the Hermes Manned Spaceplane at 76 km altitude are presented. ESA

**N92-14987#** Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. for Design Aerodynamics.

#### STEPS TOWARDS AN EFFICIENT AND ACCURATE METHOD SOLVING THE EULER EQUATIONS AROUND A RE-ENTRY CONFIGURATION AT SUPER- AND HYPERSONIC SPEED

J. SCHOENE, T. STREIT, and N. KROLL In ESA, Aerothermodynamics for Space Vehicles p 115-120 Jul. 1991 Sponsored in part by CNES

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Modifications and extensions of a Euler code which enable efficient computations of accurate solutions for supersonic and moderate hypersonic flows are described. These modifications involve a more robust central spatial discretization as well as the implementation of an upwind biased discretization operator. In order to increase the efficiency of the code, a space marching technique is incorporated within regions with supersonic flow only. The resolution of the flow field in the domain of interest is enhanced through the adaptation of the far field to the bow shock. Numerical results of a Hermes type configuration at supersonic and moderate hypersonic speeds are presented. The accurate prediction of discontinuities using the upwind formulation is demonstrated. The advanatge of far field adaptation and space marching technique is verified. Comparisons with experimental data show that methods based on the equations of inviscid flow can predict flight mechanical derivatives with high accuracy. **FSA** 

N92-14990# International Centre for Numerical Methods in Engineering, Barcelona (Spain).

#### FLOW AND TEMPERATURE COMPUTATIONS FOR SPACE VEHICLES USING ADAPTIVE FINITE ELEMENT TECHNIQUES

F. QUINTANA, E. ONATE, and J. MIQUEL CANET *In* ESA, Aerothermodynamics for Space Vehicles p 135-140 Jul. 1991 Sponsored in part by Instituto de Cooperacion Iberoamericana Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Computations of the laminar Navier-Stokes equations in hypersonic cases are studied using an explicit finite element method with adaptive non-structured mesh techniques to capture, accurately, the strong variations of the boundary layer and shocks. A pressure switched artificial dissipation is added to prevent oscillations in the vicinity of discontinuities. Some of the problems solved are discussed.

**N92-14992#** Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.

#### BASE PRESSURE MEASUREMENTS ON A CONE AT HYPERSONIC MACH NUMBERS: A CONTRIBUTION TO AEROTHERMODYNAMICS FOR SPACE VEHICLES

M. TANNER In ESA, Aerothermodynamics for Space Vehicles p 149-153 Jul. 1991

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Base pressure measurements performed in a 6.8 degrees cone at Mach number from M infinity = 4.99 to 6.83 at angles of incidence from alpha = 0 to 15 degrees in turbulent flow are described. The results show that the base pressure is for these Mach numbers practically independent of the angle of incidence alpha for these relatively small alpha values. The results are approximately in agreement with those achieved during free flight measurements at full scale Reynolds numbers indicating that in turbulent flow the base pressure does not depend on the Reynolds number. In a discussion concerning some theoretical methods for the prediction of base pressure it is shown that the author's theory gives results, which are in very good agreement with experiments. ESA

**N92-14993**# Cranfield Inst. of Tech., Bedford (England). College of Aeronautics.

#### FLOW OVER A DELTA WING AT HYPERSONIC SPEEDS

H. BABINSKY and J. L. STOLLERY *In* ESA, Aerothermodynamics for Space Vehicles p 155-158 Jul. 1991

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The flow over the lower surface of a simple hypersonic vehicle fitted with trailing edge flaps was studied by taking pressure measurements in a hypersonic gun tunnel at M = 8.2 and Re = 6,300,000/m. Flow visualization was carried out with Schlieren photographs and liquid crystals. All experiments indicated a large separated area due to the pressure rise on the flap. The large heating near the reattachment line was indicated by the liquid crystal experiments. The shape of the separated region proved to

be strongly influenced by the local state of the boundary layer. The presence of the forebody and the interaction of the bow shock with the boundary layer on the wing caused large changes in the local separation position. FSA

N92-14994# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Wind Tunnel Div.

#### EXPERIMENTAL STUDY OF HYPERSONIC SHOCK WAVE BOUNDARY LAYER INTERACTIONS BY MEANS OF **INFRARED TECHNIQUE**

A. HENCKELS, P. HERZOG, and F. MAURER In ESA, Aerothermodynamics for Space Vehicles p 159-164 Jul. 1991 Sponsored by DFG

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Convective surface heating due to shock wave boundary layer interaction phenomena is a critical problem for the design of thermal protection systems of future hypersonic vehicles. Tunnel experiments are presented which demonstrate how interaction phenomena can be visualized by infrared thermovision; the infrared image indicates the position of flow separation and reattachement by the temperature pattern. The capability of the used measurement technique is demonstrated and thereby the nature of shock wave boundary layer interaction is studied. The three dimensional ramp flow field, an impinging shock wave boundary of a flat plate, and an axial corner configuration under 20 degrees angle of attack were investigated. All test runs were performed in a hypersonic blow down facility at Mach numbers 6.0 and 8.7 for laminar flow condition. One interesting result achieved is the evidence that Goertler vortices are generated on a flat plate due to shock wave boundary layer interaction. ESA

N92-14995# Societe d'Etudes et de Services pour Souffleries et Installations Aerothermodynamiques, Paris (France). Lab. d'Aerothermique.

#### **EXPERIMENTAL INVESTIGATION OF TRANSVERSE JET** EFFECTS RELATED TO HYPERSONIC SPACE VEHICLES

J. ALLEGRE, M. RAFFIN, and J. P. CARESSA (Centre National de la Recherche Scientifique, Meudon-Bellevue, France ) ESA, Aerothermodynamics for Space Vehicles p 165-170 In Jul. 1991

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Some indication on the flow interaction process which is associated with jet controls is given. A few examples of flight results on reaction control jets were presented for the Space Shuttle Orbiter. Some comparisons, with preflight predictions extrapolated from wind tunnel data obtained at lower Mach numbers and at a higher density, show some discrepancies mainly for the early stage of reentry. Experiments were carried out under rarefied hypersonic flow conditions on delta wings with trailing edge jet spoilers. Quantitative data show the jet effects in the measured aerodynamic coefficients. For the strong interaction flow regime and at various wing angles of attack, experimental results demonstrate the jet spoiler efficiency as compared with a solid spoiler efficiency. At a Mach number of 20 and under rarefied flow conditions, some preliminary experimental investigations were initiated on the Hermes model equipped with pitch reaction jet controls. It was found that at high altitudes, the flow rarefaction leads to very low efficiencies of control surfaces. For orbital flight conditions, jet control systems are than necessary to provide the required space vehicle maneuvering. Also, during the early phase of reentry, jets are used, sometimes in concert with control surfaces, to provide the vehicle aerodynamic control. **FSA** 

N92-14996# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.

#### INTERFERENCE HEATING NEAR FIN/BODY JUNCTIONS ON HYPERSONIC VEHICLES

Z. U. HAQ, G. T. ROBERTS, and R. A. EAST In ESA, Aerothermodynamics for Space Vehicles p 171-176 Jul. 1991 Sponsored by RAE

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Surface heat transfer and pressure data are presented for flat plate/fin configurations tested in an intermittent hypersonic wind tunnel at Mach 6.85. The heat transfer data were deduced from color images which show the response of thermochromic liquid crystals to the transient heating of the model of the flow. In particular, localized areas of high heat flux were apparent in the interference zones adjacent to the fin/body junction. The pressure data obtained for two fin configurations showed similar features, indicating some relationship between surface heat transfer and pressure. The influence of fin bluntness and sweep on the interference heating are described. ESA

N92-14998# Institut National de Recherche d'Informatique et d'Automatique, Valbonne (France).

#### NUMERICAL SIMULATIONS AROUND MODELS IN HYPERSONIC WIND TUNNELS

R. ABGRALL and A. MERLO In ESA, Aerothermodynamics for Space Vehicles p 189-195 Jul. 1991 Prepared in cooperation with Centre National de la Recherche Scientifique, Marseilles, France

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Some very preliminary results about the problem of extrapolating the results obtained in wind tunnel to real flight conditions are related. Two experiments are proposed (the geometry is axisymmetric in both cases). The first one is the simulation of the complete nozzle with a model inside. The conditions at infinity for the models are nonuniform, in chemical and vibrational nonequilibrium. In the second experiment, the same model with an appropriate scaling parameter is considered where the conditions at infinity are obtained with the same Mach number, velocity and binary scaling parameter but with a uniform flow at chemical and vibrational equilibrium. Since this is only a preliminary study, the flows are assumed to be inviscid. The physical and chemical model used is detailed. The numerical scheme is described and the two numerical experiments performed are discussed. ESA

N92-15000# Centro Italiano Ricerche Aerospaziali, Naples. HIGH ENTHALPY NOZZLE FLOWS

G. RUSSO, SALVATORE BORRELLI, G. LEONE, and ANTONIO SCHETTINO In ESA, Aerothermodynamics for Space Vehicles p Jul. 1991 Sponsored in part by Italian Space Agency 209-220 and CNES

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High enthalpy nozzle flows such as those that will be generated in the Hermes related Scirocco plasma wind tunnel are dealt with. The analysis of physical phenomenologies is made by means of a calculation procedure. The chemical and vibrational nonequilibrim effects are evidentiated with respect to the specific nozzles performance and an attempt to generalize the results in terms of parametric dependencies is made. **FSA** 

N92-15005# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.

#### VERIFICATION AND APPLICATION OF THE NSFLEX METHOD FOR HYPERSONIC FLOW CONDITIONS

K. M. WANIE and M. A. SCHMATZ In ESA, Aerothermodynamics for Space Vehicles p 249-257 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk,

Netherlands, HC 90 Dutch guilders

The need of hypersonic reentry and cruise vehicle design to calculate viscous flow past entire configurations with wings, fins, flaps and propulsion system represents one of the major challenges for computational fluid dynamics. There is, however, still a considerable lack of experience for hypersonic flow calculations and therefore an extensive testing and verification of the numerical methods and physical modeling is essential. The verification of the multiblock Navier-Stokes code NSFLEX and its application to hypersonic flow problems is thus focused upon. The governing

equations and the solution method are reviewed. The fundamental details of the multiblock incorporation, like indirect addressing and use of boundary indicators, are described. The verification is done by geometrically simple test cases. The capabilities of the method are demonstrated for realistic hypersonic configurations. ESA

#### N92-15006# Fluid Gravity Engineering Ltd., Witley (England). HYPERSONIC AEROTHERMODYNAMIC COMPUTATIONS USING A POINT-IMPLICIT TVD METHOD

M. P. NETTERFIELD *In* ESA, Aerothermodynamics for Space Vehicles p 259-266 Jul. 1991

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Validation cases which are typical of hypersonic reentry problems are presented for a three dimensional Navier-Stokes code with fully coupled nonequilibrium thermochemistry. The code uses a Total Variation Diminishing (TVD) formulation for the inviscid fluxes, a point implicit relaxation method of time marching, and a 2 temperature thermodynamic model, with source terms also treated in a point implicit manner. The validation cases presented include the hypersonic laminar flow over a compression corner, and high enthalpy chemically reacting flow over a circular cylinder.

N92-15008# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.

VISCOUS SHOCK-LAYER EQUATIONS FOR THE

CALCULATION OF REENTRY AEROTHERMODYNAMICS

ROLAND K. HOELD In ESA, Aerothermodynamics for Space Vehicles p 273-280 Jul. 1991

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Three dimensional Viscous Shock Layer (VSL) equations, which are derived from the Navier-Stokes equations by an order of magnitude analysis, are presented. They hold for the windward flow field of reentry vehicles at hypersonic flow conditions. Rarefaction effects are modeled at the body surface and at the bow shock by slip boundary conditions. Results of the VSL code 'VISSLA' for equilibrium real gas calculations are discussed. The influence of the slip boundary conditions, coming along with growing Knudsen numbers of the higher altitudes of reentry trajectories, is demonstrated. Comparisons with other computationa fluid dynamic codes like 'NSFLEX' (Navier-Stokes calculation) show the accuracy of the VSL equations and verify the code. ESA

N92-15014# Centre National de la Recherche Scientifique, Chatenay-Malabry (France).

## HYPERSONIC VISCOUS SHOCK LAYER IN THERMOCHEMICAL NONEQUILIBRIUM

F. THIVET, S. CANDEL, and M. Y. PERRIN *In* ESA, Aerothermodynamics for Space Vehicles p 325-333 Jul. 1991 Sponsored by Avions Marcel Dassault; Direction des Recherches, Etudes et Techniques; and CNRS

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The basic features of a hypersonic flow are reviewed and some models for equilibrium thermodynamic properties, chemical kinetics, and transport properties of air at high temperatures are presented. To precisely describe the stagnation regions of a typical reentry vehicle, the aerodynamics of the flow is reduced to the viscous shock layer approximation. An original and fast method is presented to solve the resulting free boundary parabolic system of equations based on Newton iterations on a fixed boundary domain. A vibrational nonequilibrium model is introduced in order to determine the sensitivity of the flow to this phenomenon. The relaxation equations resulting from the kinetic theory are presented. The relaxation times involved are calculated using an extension of the SSH theory and on some experimental data. The full coupling between vibrational and chemical nonequilibrium is taken into account. The influence of these phenomenon is made evident in results obtained for different geometries. FSA

N92-15016# Rome Univ. (Italy). Dipartimento di Meccanica e Aeronautica.

### INFLUENCE OF CHEMICAL MODELING ON THE SOLUTION OF HYPERSONIC SHOCK LAYERS

F. SABETTA, B. FAVINI, and M. ONOFRI In ESA, Aerothermodynamics for Space Vehicles p 343-347 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Hypersonic flows about ellipses at high angle of attack are analyzed by means of nonequilibrium, equilibrium, and inert gas with gamma = 1.2 models. It is shown that the proposed technique of chemical rate equation integration marching along streamlines allows the nonequilibrium model to accurately compute the stagnation point conditions where equilibrium must be attained. The comparison between the three model results indicates that the equilibrium model can not be considered an acceptable approximation in computing hypersonic flow fields, since it underpredicts the blowshock stand off distance and overpredicts the call temperature. The inert gas model with gamma = 1.2 can only be used as a crude approximation for evaluating the wall pressure.

#### N92-15017# OHB-System G.m.b.H., Bremen (Germany, F.R.). FALKE AND COBRA TECHNOLOGY DEVELOPMENT IN AERODYNAMICS AND AEROTHERMODYNAMICS

B. STECKEMETZ, J. EWALD, W. WIENSS, A. TEGTMFIER C FRIEBEL, and GEORG KOPPENWALLNER (Hyperschall-Technologie-Goettingen, Germany, F.R.) *In* ESA, Aerothermodynamics for Space. Vehicles p351-358 Jul. 1991 Previously announced in IAA as A91-13281 Copyright Avail: NTIS HC/MF A24, ESA, EPD, ESTEC, Nourowijk, Netherlands, HC 90 Dutch guilders

Wind tunnel measurements and numerical methods are well established tools to simulate the actual flow around aerodynamically supported vehicles in atmospheric flight. There are, however, limitations e.g., in the transonic and hypersonic flight regime caused by noncompliance with similarity laws, viscosity and heat conductance effects, chemical kinetics, etc. which strongly influence the accuracy of measurements and numerical calculations. Major results of two projects are reported. Both projects aim at supporting wind tunnel measurements and numeric simulations by test flights under free flight conditions. The FALKE project mainly covers the transonic and lower supersonic flight conditions, whereas COBRA is intended to cover the hypersonic speed regime.

**N92-15020\*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### AERODYNAMIC HEATING ON AFE DUE TO NONEQUILIBRIUM FLOW WITH VARIABLE ENTROPY AT BOUNDARY LAYER EDGE

P. C. TING, W. C. ROCHELLE, S. A. BOUSLOG, L. T. TAM (Lockheed Engineering and Sciences Co., Houston, TX.), C. D. SCOTT, and D. M. CURRY *In* ESA, Aerothermodynamics for Space Vehicles p 371-376 Jul. 1991

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A method of predicting the aerobrake aerothermodynamic environment on the NASA Aeroassist Flight Experiment (AFE) vehicle is described. Results of a three dimensional inviscid nonequilibrium solution are used as input to an axisymmetric nonequilibrium boundary layer program to predict AFE convective heating rates. Inviscid flow field properties are obtained from the Euler option of the Viscous Reacting Flow (VRFLO) code at the boundary layer edge. Heating rates on the AFE surface are generated with the Boundary Layer Integral Matrix Procedure (BLIMP) code for a partially catalytic surface composed of Reusable Surface Insulation (RSI) times. The 1864 kg AFE will fly an aerobraking trajectory, simulating return from geosynchronous Earth orbit, with a 75 km perigee and a 10 km/sec entry velocity. Results of this analysis will provide principal investigators and thermal analysts with aeroheating environments to perform experiment and thermal protection system design. ESA

**N92-15025#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Div. de Thermophysique.

HYPERSONIC INVISCID FLOW FIELD SIMULATIONS AROUND REENTRY VEHICLES WITH FLAP DEFLECTION

J. L. DACOSTA In ESA, Aerothermodynamics for Space Vehicles p 407-412 Jul. 1991

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The study of the reentry phase of spacecrafts like the European Hermes Spaceplane needs the determination of complex three dimensional flows. In order to simulate such hypersonic flows, a multidomain Euler code, named FLU3M, was developed. This code is based upon an explicit/implicit finite volume method of MUSCL type using structured grids. Calculations can be performed either by a time dependent method for subsonic region of the flow, or by space marching procedure for supersonic regions. The hypersonic flowfield around Hermes configurations is investigated. Computations are performed at a freestream Mach number of 10 and 25, for 30 degrees angle of attack and without any sideslip. The simulation is realized under perfect gas or equilibrium air assumption. The aims of the paper are mainly to show the feasibility of three dimensional computations around complex geometries including flap deflection and real ras effects, and to evaluate accurately the flap efficiency. ESA

**N92-15031#** Hyperschall-Technologie-Goettingen (Germany, F.R.).

BEHAVIOUR AND MODELLING OF THE

AEROTHERMODYNAMICS OF BALLISTIC ENTRY VEHICLES IN THE HIGH ALTITUDE FLOW REGIMES

GEORG KOPPENWALLNER and DIETER JOHANNSMEIER *In* ESA, Aerothermodynamics for Space Vehicles p 461-467 Jul. 1991

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Special aerodynamic methods, which allow fast aerodynamic performance prediction, are needed for initial design and trajectory calculations. During reentry the flow behavior changes from free molecular through the rarefied regimes to continuum hypersonic. In addition the Mach number decreases from 25 down to low hypersonic. A semiempirical method was adopted to develop formulae for the aerodynamic data prediction. The approach applies the axisymmetric bodies and allows the prediction of lift and drag during the hypersonic entry phase. The bridging between free molecular and continuum flow is based on experiments and on Newtonian and free molecular theory. ESA

N92-15032# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.

#### APPLICABILITY OF BRIDGING METHODS TO HYPERSONIC

**RAREFIED FLOW AERODYNAMICS OF REENTRY VEHICLES** ROLF-D. BOETTCHER *In* ESA, Aerothermodynamics for Space Vehicles p 469-476 Jul. 1991

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Local bridging methods for transition flow aerodynamics are applied to several shapes including Hermes. Results are compared to wind tunnel data and analyzed with respect to method applicability limits. The conclusion drawn states the necessity of tailoring the methods to the specific configuration under investigation, in close cooperation with wind tunnel experiments.

ESA

**N92-15035#** Aerospatiale, Les Mureaux (France). Theoretical Aerodynamic Branch.

#### TRANSITIONAL FLOWS AROUND RE-ENTRY BODIES

JEAN-FRANCOIS PALLEGOIX *In* ESA, Aerothermodynamics for Space Vehicles p 491-496 Jul. 1991 Sponsored by Avions Marcel Dassault

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Flow calculations as solutions of the Boltzmann equation, using

the Direct Simulation Monte Carlo (DSMC) method, are presented. The code used was developed in order to calculate flows around complex three dimensional bodies like Hermes. The algorithms for moving molecules and searching for their impact on the wall are based on simple criteria, furthermore the code is fully vectorized. Four calculations on Hermes shape and two other calculations are presented and compared with wind tunnel data, in terms of aerodynamic coefficients or heat transfer. For each calculation, the number of cells and molecules is given, together with storage and Central Processing Unit (CPU) requirements. The discrepancies between calculations and measurements are checked with a simulation of the nonuniformity in the wind tunnel flow. ESA

**N92-15039\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### AEROTHERMODYNAMICS FOR UNITED STATES ADVANCED PROGRAMS

WILLIAM M. PILAND In ESA, Aerothermodynamics for Space Vehicles p 515-533 Jul. 1991

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A series of graphics relating to aerothermodynamics is presented. They following topics are shown: space transportation architecture options and systems, vehicle shapes and design goals, aerothermodynamics (including hypersonic entry), computational fluid dynamics, ground based testing, aeroassist environment, and airbreathing propulsion. ESA

**N92-15040#** Aerospatiale, Les Mureaux (France). Theoretical Aerodynamic Branch.

### COMPUTATION OF AERODYNAMIC COEFFICIENTS ON HERMES-ARIANES CONFIGURATION

CHRISTOPHE GRASSIN *In* ESA, Aerothermodynamics for Space Vehicles p 537-542 Jul. 1991 Sponsored by CNES Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk,

Netherlands, HC 90 Dutch guilders

A numerical prediction of aerothermodynamic coefficients, for the Hermes-Ariane configuration, based on structured-nonstructured Euler solvers is presented. The application is performed for Mach number 1.47 and an angle of attack of 3 degrees. Results are found to compare well with experimental data. ESA

**N92-15041#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### GRID IMPACT ON 3D HYPERSONIC FLOWS

J. HAEUSER, H. WONG, J. GRAWE, and W. BERRY *In its* Aerothermodynamics for Space Vehicles p 543-548 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Four, three dimensional (3D), Euler solutions for the Hermes configuration are presented and the impact of the distance of the first layer of points, from the surface, on the pitching moments and lift coefficients is investigated. Results are given. It was shown that for Euler solutions of three dimensional vehicles the computational grid has a strong impact on some of the aerodynamic parameters, which by far exceed the design margins. Therefore, three dimensional solutions have to be checked for grid dependence. This situation is aggravated when a Navier-Stokes solver is used to interactively convert an Euler grid into a Navier-Stokes grid by removing or adding grid lines using a specified distribution to capture the boundary layer. A set of 100,000 points can be deleted/added in a few minutes.

N92-15042# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).

#### AEROTHERMODYNAMIC CHALLENGES OF THE SAENGER SPACE-TRANSPORTATION SYSTEM

E. H. HIRSCHEL In ESA, Aerothermodynamics for Space Vehicles

#### p 549-558 Jul. 1991

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The two stage to orbit Saenger space transportation system is considered. The technology development concentrates first on the needs of the lower stage. Its requirements for aerothermodynamics and propulsion integration are sketched. The aerothermodynamic design challenge is discussed. The design tools and the design methodology are reviewed. The validation of both the computational and the experimental methods, as well as the test of vehicle components, like the inlet and control surfaces, make the experimental vehicle Hytex mandatory. Contents and workplan of the technology program 'Aerothermodynamics and propulsion integration' are laid out. Selected results from the current work are presented. ESA

#### N92-15045# Naval Postgraduate School, Monterey, CA. PRELIMINARY INVESTIGATION OF THE SHOCK-BOUNDARY LAYER INTERACTION IN A SIMULATED FAN PASSAGE M.S. Thesis

CHRISTOPHER C. COLLINS Mar. 1991 129 p (AD-A242656) Avail: NTIS HC/MF A07 CSCL 20/4

A two dimensional, two passage simulation of the relative flow through a transonic fan at M = 1.4 was designed with a view to providing an apparatus in which to assess the effectiveness of passive vortex generator techniques in alleviating shock-boundary layer interaction effects. The design of the model and the results of six test runs in the transonic cascade blowdown wind tunnel are described. Schlieren photographs of the shock structure were obtained at back pressures lower than the design value. The back-pressure control valve was identified as being critical to completing the experimental simulation. The flow through the cascade geometry was computed at design pressure ratio using an Euler code. Modifications to the grid are recommended before thin-layer Navier-Stokes calculations are performed. GRA

N92-15047\*# Institute for Computer Applications in Science and Engineering, Hampton, VA. PROGRESS WITH MULTIGRID SCHEMES FOR HYPERSONIC

### FLOW PROBLEMS Final Report

R. RADESPIEL (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R. ) and R. C. SWANSON Dec. 1991 43 p Submitted for publication

(Contract NAS1-18605)

(NASA-CR-189579; ICASE-91-89; NAS 1.26:189579) Avail: NTIS HC/MF A03 CSCL 01/1

Several multigrid schemes are considered for the numerical computation of viscous hypersonic flows. For each scheme, the basic solution algorithm uses upwind spatial discretization with explicit multistage time stepping. Two level versions of the various multigrid algorithms are applied to the two dimensional advection equation, and Fourier analysis is used to determine their damping properties. The capabilities of the multigrid methods are assessed by solving three different hypersonic flow problems. Some new multigrid schemes based on semicoarsening strategies are shown to be quite effective in relieving the stiffness caused by the high aspect ratio cells required to resolve high Reynolds number flows. These schemes exhibit good convergence rates for Reynolds numbers up to 200 x 10(exp 6) and Mach numbers up to 25.

Author

#### N92-15048\*# Eloret Corp., Sunnyvale, CA. EXPERIMENTAL RESEARCH OF THE AERODYNAMICS OF NOZZLES AND PLUMES AT HYPERSONIC SPEEDS Final Technical Report, 1 Aug. 1988 - 31 Dec. 1991 EARL R. KEENER 7 Jan. 1992 42 p

(Contract NCC2-553)

(NASA-CR-187316; NAS 1.26:187316) Avail: NTIS HC/MF A03 CSCL 01/1

The purpose was to experimentally characterize the flow field created by the interaction of a single expansion ramp nozzle (SERN) flow with a hypersonic external stream. Data were obtained from a generic nozzle/afterbody model in the 3.5 Foot Hypersonic

Wind Tunnel of the NASA Ames Research Center. The model design and test planning were performed in close cooperation with members of the National Aero-Space Plane (NASP) computational fluid dynamics (SFD) team, so that the measurements could be used in CFD code validation studies. Presented here is a description of the experiment, the extent of the measurements obtained, and the experimental results.

Author

N92-15049\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### THE BENCHMARK AEROELASTIC MODELS PROGRAM: DESCRIPTION AND HIGHLIGHTS OF INITIAL RESULTS

ROBERT M. BENNETT, CLINTON V. ECKSTROM, JOSE A. RIVERA, JR., BRYAN E. DANSBERRY, MOSES G. FARMER, and MICHAEL H. DURHAM Dec. 1991 13 p Presented at the AGARD Structures and Materials Panel Specialists' Meeting on Transonic Unsteady Aerodynamics and Aeroelasticity, San Diego, CA, 9-11 Oct. 1991

(NASA-TM-104180; NAS 1.15:104180; AGARD-PAPER-25) Avail: NTIS HC/MF A03 CSCL 01/1

An experimental effort was implemented in aeroelasticity called the Benchmark Models Program. The primary purpose of this program is to provide the necessary data to evaluate computational fluid dynamic codes for aeroelastic analysis. It also focuses on increasing the understanding of the physics of unsteady flows and providing data for empirical design. An overview is given of this program and some results obtained in the initial tests are highlighted. The tests that were completed include measurement of unsteady pressures during flutter of rigid wing with a NACA 0012 airfoil section and dynamic response measurements of a flexible rectangular wing with a thick circular arc airfoil undergoing shock boundary layer oscillations. Author

N92-15050\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### A FAST IMPLICIT UPWIND SOLUTION ALGORITHM FOR THREE-DIMENSIONAL UNSTRUCTURED DYNAMIC MESHES

JOHN T. BATINA Dec. 1991 8 p Presented at the AIAA 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992

(NASA-TM-104186; NAS 1.15:104186) Avail: NTIS HC/MF A02 CSCL 01/1

A fast implicit upwind algorithm for the solution of the time-dependent Euler equations is presented for aerodynamic analysis involving unstructured dynamic meshes. The spatial discretization of the scheme is based on the upwind approach of Roe, referred to as flux-difference splitting (FDS). The FDS approach is naturally dissipative and captures shock waves and contact discontinuities sharply. The temporal discretization of the scheme involves an implicit time-integration using a two-sweep procedure Gauss-Seidel relaxation procedure. The is computationally efficient for either steady or unsteady flow problems. A detailed description is given of the implicit upwind solution algorithm along with results which assess the capability. The results are presented for the NACA 0012 airfoil and for the Boeing 747 aircraft. The 747 geometry includes the fuselage, wing, horizontal and vertical tails, under-wing pylons, and flow-through engine nacelles. Euler solutions for the 747 aircraft on an unstructured tetrahedral mesh containing approximately 100,000 cells were obtained to engineering accuracy in less than one hour CPU time on a Cray-2 computer. Author

N92-15051\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH,

#### RESULTS OF AN ICING TEST ON A NACA 0012 AIRFOIL IN THE NASA LEWIS ICING RESEARCH TUNNEL

JAIWON SHIN and THOMAS H. BOND 1992 21 p Presented at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA

(NASA-TM-105374; E-6761; NAS 1.15:105374; AIAA-92-0647) Avail: NTIS HC/MF A03 CSCL 01/1

Tests were conducted in the Icing Research Tunnel (IRT) at

#### 02 AERODYNAMICS

the NASA Lewis Research Center to document the current capability of the IRT, focused mainly on the repeatability of the ice shape over a range of icing conditions. Measurements of drag increase due to the ice accretion were also made to document the repeatability of drag. Surface temperatures of the model were obtained to show the effects of latent-heat release by the freezing droplets and heat transfer through the ice layer. The repeatability of the ice shape was very good at low temperatures, but only fair at near freezing temperatures. In general, drag data shows good repeatability. Author

**N92-15052\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### A TURBULENCE MODEL FOR ICED AIRFOILS AND ITS VALIDATION

JAIWON SHIN, HSUN H. CHEN, and TUNCER CEBECI (California State Univ., Long Beach.) 1992 17 p Presented at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA

(NASA-TM-105373; E-6760; NAS 1.15:105373; AIAA-92-0417) Avail: NTIS HC/MF A03 CSCL 01/1

A turbulence model based on the extension of the algebraic eddy viscosity formulation of Cebeci and Smith developed for two dimensional flows over smooth and rough surfaces is described for iced airfoils and validated for computed ice shapes obtained for a range of total temperatures varying from 28 to -15 F. The validation is made with an interactive boundary layer method which uses a panel method to compute the inviscid flow and an inverse finite difference boundary layer method to compute the viscous flow. The interaction between inviscid and viscous flows is established by the use of the Hilbert integral. The calculated drag coefficients compare well with recent experimental data taken at the NASA-Lewis Icing Research Tunnel (IRT) and show that, in general, the drag increase due to ice accretion can be predicted well and efficiently.

#### 03

#### AIR TRANSPORTATION AND SAFETY

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

#### A92-20024 F27 AGING AIRCRAFT PROGRAMME EMPHASIZES CORROSION PREVENTION

WOLF W. BRINGS ICAO Journal (ISSN 0018-8778), vol. 46, Nov. 1991, p. 9-14.

Copyright

An F27 aging aircraft working group (AAWG) was formed in 1990 to ensure the continued integrity of the F27 aircraft throughout its presently approved life of 90,000 flights. Basic issues addressed by the AAWG include the review of service actions dependent on special repetitive inspection, the review and recommendations for improvement to the corrosion prevention programs, and the review of supplemental inspection documents for effectiveness. Attention is given to a review of the structural integrity program, multiple repair areas, corrosion inspections, and the corrosion control program. R.E.P.

#### A92-20126

### ANALYSIS TECHNIQUE FOR LIGHTNING ATTACHMENT ZONING OF AIRCRAFT

C. H. KING and T. P. OGDEN (Boeing Co., Seattle, WA) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 5 p. refs

The design of aircraft lightning-protection systems is often based on aircraft zoning considerations which identify the most likely points of lightning attachment. Attention is presently given to a computer analysis technique which determines the probability of

186

initial lightning attachment to aircraft surfaces on the basis of the 'rolling sphere' method. The method proceeds by envisioning a 25-m radius sphere which represents the severe case step-leader for lightning attachment as it rolls over the surface of the aircraft. The probability of attachment for each point is determined from geometrical considerations. O.C.

#### A92-20127

### ON THE ACCURACY OF AN AIRCRAFT-BORNE AMBIENT ELECTRIC-FIELD MEASURING SYSTEM

K. L. HEWITT, J. KOSITSKY, R. A. MAFFIONE, and J. S. THAYER (SRI International, Menlo Park, CA) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 9 p. refs

An investigation is conducted of the problems posed by the airborne measurement of electric fields, with emphasis on measurement-system accuracy. Airframe enhancement factors can be ascertained by placing a scale model of the aircraft in a uniform electrostatic field; these scale-model experiment results, which were verified on the basis of shapes with known solutions, can be used to estimate the scale-model enhancement factor errors. Attention is given to the enhancement factors of a NASA F-106B research aircraft, which were used in Monte Carlo simulations of error propagation. These simulations show that errors in the computed ambient field can rise exponentially when enhancement-factor errors exceed some threshold which is a function of the matrix equation and type of field computed. O.C.

#### A92-20129

### ANALYSIS AND MODELING OF LIGHTNING STRIKES TO THE F106B, CVF580, AND C160 AIRCRAFT

TERENCE RUDOLPH, RODNEY A. PERALA, and RICHARD S. COLLIER (Electro Magnetic Applications, Inc., Lakewood, CO) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 12 p. refs (Contract DAAH01-85-DA-015)

Three-dimensional time domain finite difference models of the NASA F106B, FAA CV580, and French Transall C160 aircraft have been used to investigate in-flight transient lightning data. These models are linear and use transfer function techniques to determine lightning currents given a measured response at one point on the aircraft and attachment and detachment locations. Comparisons of measured and calculated waveforms are made for all three aircraft. Author

#### A92-20651

### FAIR WEATHER CONVECTION AND LIGHT AIRCRAFT ACCIDENTS

LAI-CHEN CHIEN (National Central University, Chungli, Republic of China), W. C. LIANN, and T. K. YEH IAF, International Astronautical Congress, 42nd, Montreal, Canada, Oct. 5-11, 1991. 11 p. refs

(IAF PAPER ST-91-004) Copyright

The possible role of fair weather convection in initiating accidents of the light aircrafts is investigated. The role of dry convective gust is incorporated by modeling downdrafts and horizontal and vertical wind speed variance using statistical relationships for the atmosphere boundary layer. It is shown that light aircraft experience the variation in lift during flight in fair weather conditions. Author

#### A92-20720

#### FATAL OCCUPATIONAL INJURY RELATED TO HELICOPTERS IN THE UNITED STATES 1980-1985

CAROL CONROY, JULIE C. RUSSELL, WILLIAM E. CROUSE, THOMAS R. BENDER, and JUDITH A. HOLL (PHS, National Institute for Occupational Safety and Health, Morgantown, WV) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 63, Jan. 1992, p. 67-71. refs

Copyright

The characteristics of occupational traumatic fatalities caused by helicopters are examined with attention given to pilot experience, environmental circumstances, and demographic data. About 59

#### A92-20722

#### ANALYSIS OF CHANGES IN THE PILOT POPULATION AND **GENERAL AVIATION ACCIDENTS**

JAMES E. BRUCKART (U.S. Army, Aeromedical Research Laboratory, Fort Rucker, AL) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 63, Jan. 1992, p. 75-79. refs Copyright

The decreasing number of accidents and the evolving pilot population are investigated in terms of cross-correlation including such parameters as age distribution, certification, and flying habits. FAA surveys and accident data are employed to study trends in pilot-age distribution, certification, aircraft use, flight planning, and weather conditions relevant to general aviation accidents. The mean pilot age increased from 35 to 40 in the span of time studied (1968-1987), and the numbers of pilots with certifications increased for both Air Transport Pilot and instrumentation. The accident experience expected for the period studied based on the 1968-1973 data predicts 40 percent more accidents than actually occurred, and adjusted accident rates show significant reductions in accidents in all age groups as compared to actual accident experience over the last 20 years. The results are positive confirmation of actual aviation-safety advances related to improved CCS pilot performance.

N92-14006# National Transportation Safety Board, Washington, DC

AIRCRAFT ACCIDENT REPORT: NORTHWEST AIRLINES, INC., FLIGHTS 1482 AND 299. RUNWAY INCURSION AND COLLISION, DETROIT METROPOLITAN/WAYNE COUNTY AIRPORT, ROMULUS, MICHIGAN, DECEMBER 3, 1990 25 Jun. 1991 178 p (PB91-910405; NTSB/AAR-91/05; REPT-5416-B) Avail: NTIS

HC/MF A09 CSCL 01/3

The runway collision of two Northwest Airlines aircraft is examined on a runway at the Detroit Metropolitan/Wayne County Airport, Romulus, MI, on 3 Dec. 1990. The safety issues discussed are airport marking and lighting, cockpit resource management, air traffic control procedures in low visibility conditions, flight attendant procedures during evacuation; and design of the DC-9 tailcone emergency release system. Safety recommendations concerning these issues were made to the FAA, the Detroit Metropolitan/Wayne County Airport, and Northwest Airlines, Inc. Author

Royal Aerospace Establishment, Farnborough N92-14007# (England). Aerospace Div.

#### LIGHTNING PROTECTION REQUIREMENTS FOR AIRCRAFT: A PROPOSED SPECIFICATION

G. A. M. ODAM, A. W. HANSON, and R. H. EVANS 16 May 1991 50 p Revised

(RAE-TM-FS(F)-632-REV-ISSUE-1; BR303122; ETN-92-90319) Copyright Avail: NTIS HC/MF A03

The RAE/FS8 recommendation for a specification to define United Kingdom Ministry of Defence requirements for the lightning protection of aircraft is presented. The following are covered: background and advisory material, certification, design and testing requirements. **FSA** 

N92-15053# Dayton Univ. Research Inst., OH. Structural Integrity Div.

#### STUDY OF THE ENGINE BIRD INGESTION EXPERIENCE OF THE BOEING 737 AIRCRAFT Final Report, Oct. 1986 - Sep. 1989

PETER W. HOVEY, DONALD A. SKINN, and JOSEPH J. WILSON Oct. 1991 196 p (Contract DTFA03-88-C-00024)

(DOT/FAA/CT-89/16; DOT/FAA/CT-89/29; DOT/FAA/CT-90/28; UDR-TR-90-108) Avail: NTIS HC/MF A09

The objective of this report is to determine the relationship of bird weight, number of birds ingested, geographic location, season, time of day, phase of flight, and engine type to the frequency of bird ingestion events and the extent of engine damage, if any, resulting from the ingested birds. The statistical analysis of reported bird ingestions experienced by commercial B737 airplanes worldwide over a 3-year reporting period is used to summarize the service threat and level of engine damage experienced by these airplanes. The findings of the analysis will be helpful in defining minimum engine design requirements for resistance to damage as a result of bird ingestions. Moreover, this study will provide a comparison between the experience of a contemporary high bypass ratio turbofan engine (CFM56) and an older low bypass ratio turbofan engine with a smaller inlet (JT8D) exposed to similar aircraft-bird ingestion environments. Author

N92-15054# Cranfield Inst. of Tech., Bedford (England). Applied Psychology Unit.

#### PASSENGER KNOWLEDGE OF AIRLINE SAFETY INFORMATION

P. J. FENNELL, J. R. HARRIS, and H. C. MUIR Nov. 1988 32 p

(CRANFIELD-AERO-9111; ISBN-1-871564-31-X; ETN-92-90704)

Avail: NTIS HC/MF A03; Coll. of Aeronautics, Cranfield Inst. of Technology, Cranfield, Bedford MK43 0AL, England, HC 8 sterling pounds

Five hundred passengers participated in an investigation into their knowledge of the preflight briefing and the safety card information. A tendency was observed for passengers to overestimate their ability to recall some aspects of the preflight briefing and safety card. Males had a higher score on questions regarding safety information than females, although this difference may be due to the fact that the majority of business passengers are male. Some aspects of the preflight briefing and the safety card information were identified as requiring clarification in order to ensure that all passengers are to utilize the information correctly in an emergency. 79.9 percent of passengers pay attention to the briefing on most flights, and 59.7 percent read the card on most flights. It is suggested that these percentages are likely to overestimate the actual percentage of passengers who pay attention. Frequent passengers reported paying the least attention to briefings and safety cards, though they also had more knowledge of safety information than less frequent passengers. To ensure the safety of all passengers, it is important that both frequent and infrequent passengers are motivated to pay more attention to safety information and to increase their knowledge. Suggestions made by passengers regarding methods which they believe could increase attention are included. ESA

N92-15055# National Transportation Safety Board, Washington, DC

AIRCRAFT ACCIDENT/INCIDENT SUMMARY REPORT: MIDAIR COLLISION INVOLVING LYCOMING AIR SERVICES PIPER AEROSTAR PA-60 AND SUN COMPANY AVIATION DEPARTMENT BELL 412, MERION, PENNSYLVANIA, APRIL 4, 1991

17 Sep. 1991 29 p

(PB91-910407; NTSB/AAR-91/01/SUM) Avail: NTIS HC/MF A03 CSCL 01/3

An explanation is presented for the midair collision involving a Lycoming Air Services Piper Aerostar PA-60 and a Sun Company Aviation Dept. Bell 412. The safety issues discussed include pilot judgement, the training and checking of flight crews, the adequacy of the PA-60 flight manual, and FAA surveillance of the carrier.

Author

#### AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

#### A92-17422

#### NEW SITING TECHNIQUES FOR THE ILS GLIDE SLOPE

R. H. MCFARLAND (Ohio University, Athens) Navigation (ISSN 0028-1522), vol. 38, Fall 1991, p. 235-246. refs Copyright

The most recent innovations relating to the contemporary Instrument Landing System glide slope are discussed in the context of need, and consequently goals, for providing greater capability, availability, and quality. Capability refers to obtaining acceptable performance at sites that have previously been judged terribly difficult or impossible. Availability is crucial because history shows that the most negative impact on flight safety comes from the absence of a glide slope, not the existence of a malfunctioning one or one that is operating poorly. Higher-quality beam structures are desired because of more automatic flight operations using the glide slope. Author

#### A92-18172

#### USE OF DISTANCE-MEASURING EQUIPMENT (DME) FOR CORRECTING ERRORS IN POSITION, VELOCITY, AND WIND MEASUREMENTS FROM AIRCRAFT INERTIAL NAVIGATION SYSTEMS

ALFRED R. RODI (Wyoming, University, Laramie), JAMES C. FANKHAUSER, and ROBIN L. VAUGHAN (NCAR, Boulder, CO) Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572), vol. 8, Dec. 1991, p. 827-834. refs

(Contract NSF ATM-82-05776; NSF ATM-85-02517; NSF ATM-89-12555; NSF ATM-87-02993)

### Copyright

Aircraft distance-measuring-equipment (DME) data are used to update position, velocity, and wind measurements from inertial navigation systems (INS) measurements. Data from conventional single-channel DME sets, suitably calibrated, are shown to be adequate to resolve the Schuler oscillation and correct INS positions to better than 1-km accuracy. The satellite-based Navstar global position system (GPS) is rapidly superseding other systems for external position reference. However, DME is reliable and very accurate and has been recorded on many research datasets. The principal limitation of the DME is that it is restricted to land-based navigation. The regression technique used does not necessitate multiple DME receivers or station switching and involves few restrictions on the collection of the data. However, the results improve when more that one station is used. Comparisons with other navigation systems (interferometer and loran) demonstrate the method's skill in resolving INS errors. Intercomparisons among several research aircraft flying in close formation support the method's usefulness in correcting biases in INS data. Author

#### A92-18482\* California State Univ., Fullerton.

**Z-BASIC ALGORITHM FOR COLLISION AVOIDANCE SYSTEM** ROGER G. DEAR (California State University, Fullerton) and YOSEF S. SHERIF (JPL, Pasadena, CA) IEEE Transactions on Systems, Man, and Cybernetics (ISSN 0018-9472), vol. 21, July-Aug. 1991, p. 915-921. refs

#### Copyright

A Ž-Basic prediction algorithm for an aircraft ground-based collision avoidance system is presented. This system searches for mutually overlapping prediction intervals that are influenced by the aircrafts' maneuver capabilities and surveillance accuracy. Z-Basic provides a powerful, fast, interactive, simple to use, and inexpensive Basic compiler. The algorithm is applied to a typical terminal airspace situation. The computer program was executed on Macintosh+, and the execution was less than one minute. The program is easy to understand and implement.

A92-18505

#### NAVSAT - A CIVIL COMPLEMENT TO GPS AND GLONASS

M. HAUNSCHILD, N. NIKLASCH (MAN Technologie AG, Munich, Federal Republic of Germany), B. EISSFELLER (Kayser-Threde GmbH, Munich, Federal Republic of Germany), J. MERKEL, W. SCHAEFER (Stuttgart, Universitaet, Federal Republic of Germany), and S. LESCHIUTTA (Torino, Politecnico, Turin, Italy) IAF, International Astronautical Congress, 42nd, Montreal, Canada, Oct. 5-11, 1991. 16 p. refs

(IAF PAPER 91-490) Copyright

A satellite-navigation system is described in terms of its primary civil application, system design and structure, and predicted levels of user-equivalent range error. Navsat is designed to support small repeater-transponder navigation payloads on host satellites such as the Inmarsat. With signals that are compatible with GPS and Glonass, the Navsat can provide navigation-signal uplinks, satellite-position determination, communication, and time transfer in the case of intrasystem synchronization. The potential services to be provided by the Navsat system are similar to those of existing Inmarsat stations. Present developments include dynamic modeling with a Kalman filter, satellite-health monitoring, and transponder design. Navsat is intended to supplement existing navigation satellites and thereby solve the corresponding integrity problem for civil aviation requirements. C.C.S.

#### A92-19211

#### MIL-STD-1553 DATA BUS/PCM MULTIPLEXER SYSTEM

ERLE W. MALONE (Boeing Aerospace and Electronics, Seattle, WA) and PHILLIP BREEDLOVE (Loral Conic, San Diego, CA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 125-133.

Copyright

A telemetry system which integrates MIL-STD-1553 bus data, dual-simplex bus data, vehicle performance data, and environmental sensor data multiplexing involves many interfacing constraints. The engineering design considerations and hardware constraints required to implement this system are presented in this paper. Author

#### A92-19214

#### COMPRESSION TECHNIQUES FOR VIDEO TELEMETRY

ALAN DEUTERMANN and RICHARD SCHAPHORST (Delta Information Systems, Inc., Horsham, PA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 165-172. Copyright

The basic differential PCM and variable length coding technique is compared with alternative coding techniques. Alternative compression techniques that are reviewed include transform coding, bit plane coding, and vector quantization. All candidate techniques are viewed as containing four elements: signal processing, signal conditioning, quantization, and variable length coding. The four techniques are evaluated and compared from the standpoint of picture quality and compression ratio. R.E.P.

#### A92-19216

# TELEMETRY ANTENNA PATTERNS FOR SINGLE AND MULTI-ELEMENT ARRAYS

JAMES L. RIEGER (U.S. Navy, Naval Weapons Center, China Lake, CA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 183-192. refs

Copyright

The use of multiple antennas (or multiport) antennas for vehicular telemetry causes patterns to result which are unknown and not well understood by the telemetry designer. When the antenna ports are separated by distances of more than a half wavelength, the resulting patterns are rarely what was intended. The antenna plotting program, an extension of an earlier University of Utah antenna plotting routine, allows rapid creation of patterns for up to 30 (or more) antennas of like polarization displaced from each other in all three axes. Single-port antennas are modeled as compound antennas to produce the observed pattern, and combinations of these single-port antennas are then plotted. Case studies are shown for an aircraft and a missile body. Author

#### A92-19278

### DESIGN AND IMPLEMENTATION OF A TOTAL FLIGHT TEST SYSTEM

KENNETH G. COONCE and GARY A. SCHUMACHER (Loral Data Systems, Sarasota, FL) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 833-842.

Copyright

This paper describes the overall system design and performance characteristics of a complete telemetry system for a new flight test center which Loral Data Systems is currently under contract to provide to a European government. The system encompasses subsystems for airborne data acquisition and flight line check-out, a mobile ground telemetry system, and a fixed facility. The fixed facility includes a ground telemetry system for real-time data processing and test control, and a data processing system for post-flight analysis. The system represents a fully integrated approach to flight test systems which addresses the end-to-end requirements from airborne data acquisition and real-time flight monitoring through aircraft performance and stability/control analysis. The architecture of the ground systems illustrates how preprocessing can be utilized to create powerful real-time telemetry systems even with modest general-purpose computer capability.

Author

#### A92-19279 HIGH RATE PCM DATA RECEIVING, RECORDING AND RELYING

WILLIAM A. RICE and WILLIAM G. MONTANO (U.S. Army, Data Collection Div., White Sands Missile Range, NM) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 843-849. Copyright

The paper examines specific applications at White Sands Missle Range (WSMR) concerning the certification of airborne telemetry packages to receive, relay, and record Pulse Code Modulations telemetry data. Two new methods are currently used at the Missile Range to relay high rate telemetry data: the lightwave fiber system, which has been employed in four telemetry links; and the digital microwave links from a transportable telemetry acquisition and relay system (TTARS) to Jig-67 and from Jig-67 to Jig-56.

A.S.B.

N92-14009 Communications Gillies, Inc., Sainte Lambert (Québec).

#### **ELECTRONIC SYSTEMS IN TRANSPORTATION**

MICHA AVNI, ed. (Transport Canada Aviation, Ottawa, Ontario) Montreal, Quebec Transport Canada Sep. 1989 133 p Canadian Conference on Electrical and Computer Engineering held in Montreal, Ontario, 17-20 Sep. 1989

(Contract CNT PROJ. 6902)

(TP-9983; CTN-91-60231) Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601,

Montreal, PQ H2Z 1X4 Canada

Papers relating to electronic systems are given. Major topics include descriptions of work carried out under the auspices of Transport Canada's Transport Development Center, research into microwave landing systems, the use of electronic distance measuring equipment in automated aircraft control and landing, automated airport runway management, the use of electronic systems in search and rescue missions, airspace management systems, baggage inspection systems, and information systems development for marine, road, and rail transport.

N92-14012# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). IMAGE-SUPPORTED NAVIGATION FOR TESTING

#### INSTRUMENT LANDING SYSTEMS

U. BROKOF and F. KNABE *In* Communications Gillies, Inc., Electronic Systems in Transportation p 10-13 Sep. 1989 Avail: Transportation Development Centre, 200 Rene Levesque

Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada The testing of instrument landing systems (ILS) at airports is constrained by requirements of the International Civil Aviation Organization (ICAO) as well as safety and economic considerations. A new test system developed by the Cooperative Flight Measurement Systems Group of the German Aerospace Research Establishment is described. Basic navigation is done by an inertial navigation system. Multiple distance measuring equipment is incorporated to improve en route navigation. A video system connected to an image processor uses runway threshold markings to update position information to a high degree of accuracy during the approach. The system works without ground staff or special installations. Computation of calibration data is accomplished in flight following the approach. Simulations and flight tests indicate that the required accuracy for ICAO category III flights can be achieved with two video measurements at both ends of the runway. Three dimensional position data are computed continuously allowing approaches at different angles and curved approaches. The system is ready for test with microwave landing systems.

CISTI

#### N92-14015# Allied-Signal Aerospace Co., Baltimore, MD. MLS SYSTEM ERROR MODEL IDENTIFICATION AND SYNTHESIS

R. J. KELLY *In* Communications Gillies, Inc., Electronic Systems in Transportation p 22-28 Sep. 1989

Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada

A technique is described which can in principle identify the error sources in navigation systems and can also perform the inverse operation of synthesizing an error generator whose output is statistically equivalent to the original error data. A methodology is described for identifying the microwave landing system (MLS) error components (both deterministic and random) from flight error records. After the model has been identified, the error components are synthesized to form an MLS error generator. The difficult step in the model development is identifying the random error components. A general technique is presented for developing a statistically equivalent MLS error generator using only a fraction of the data storage required to store the actual flight test data (400:1 data compression). This is an important consideration because the error generator must have in storage a library representative of MLS signals worldwide. The random error model is synthesized using the latest computer algorithms in system identification theory to develop autoregressive moving average (ARMA) models. It is also determined whether the random error model of flight data measured at a given runway is statistically equivalent to the signals generated at other airports. In other words, is there some invariant signal structure in the random error components which can be generalized to simplify the aircraft flight control system (AFCS) engineer's design task. Precision distance measuring equipment (DME/P) flight test data recently collected by the Federal Aviation Administration (FAA) is analyzed to demonstrate the System Identification methodology. The technique applies to all navigation systems. CISTI

N92-14018# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).

DME GROWTH ELEMENTS AND THEIR USE WITH MLS

A. BECKER (Transport Canada Aviation, Ottawa, Ontario ) In Communications Gillies, Inc., Electronic Systems in Transportation p 36-39 Sep. 1989

(Contract CNT PROJ. 6902)

Avail: Transportation Development Centre, 200 Rene Levesque

Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada The TIME Reference Scanning Beam System, selected by

#### 04 AIRCRAFT COMMUNICATIONS AND NAVIGATION

the International Civil Aviation Organization (ICAO) as the standard microwave landing system (MLS), provides vertical and horizontal guidance in an approach sector of plus or minus 60 deg. Development of a 360 deg azimuth element to be integrated with the MLS was recommended. This paper describes a distance measuring equipment (DME) based concept for this application. The system utilizes the unused pulse space in the conventional DME systems to provide a 360 deg guidance subsystem. The system provides aircraft with a 360 deg azimuth element to be integrated with the microwave landing system (MLS). When hardware components of precision DME (DME/P) technology are used, the azimuth 2 sigma error can be kept below 0.2 deg. This accuracy is quite satisfying for the envisaged application. After the aircraft has landed, the complete position of the aircraft can be detected with high accuracy. By using the full data link capability, the information needed for a roll guidance and airport surveillance system can be made available on the ground as well as in the CISTI air.

N92-14025# Aviation Planning Services Ltd., Montreal (Quebec).

À STRATEGY FOR EXPLOITING THE FULL POTENTIAL OF MLS BASED TERMINAL PROCEDURES IN CANADA

K. ROMI SINGH *In* Communications Gillies, Inc., Electronic Systems in Transportation p 63-68 Sep. 1989

Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada

This paper describes the regulatory research conducted in Canada in order to define the airspace requirements for microwave landing system (MLS) based terminal procedures. In particular, the extent of research and the time frame required for the translation of research findings into regulatory standards is addressed. It briefly explores some of the incremental compatibilities that research should bring to the operation of commercial air carriers such as the capacity to facilitate more through-put in the air traffic control system. Constraints which have prevented full exploitation of MLS by commercial air carriers are discussed. A discussion of concerns voiced by the user community. especially pilots, on the proposed replacement of instrument landing systems by MLS is provided. A review of industry concerns. Canada-specific applications and issues, and a proposal for a research strategy for Canada is also included. Projects on curved path and/or segmented path approaches, advanced procedures at multi-airport metropolitan areas, general aviation and/or computer capacity enhancement, and assessment of reduced landing minima are of particular interest to Canada from an operational point of view. CISTI

N92-14028# Mitre Corp., McLean, VA.

### AUTOMATED PROBLEM RESOLUTION PROTOTYPE IN AUTOMATED EN ROUTE AIR TRAFFIC CONTROL

C. VANESSA FONG *In* Communications Gillies, Inc., Electronic Systems in Transportation p 99-102 Sep. 1989

Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada

Automated En Route Air Traffic Control (AERA) is part of the advanced automation system software currently being developed by the Federal Aviation Administration (FAA) to modernize the air traffic control system. Implementation of AERA involves three packages: AERA 1, AERA 2, and AERA 3. Automated problem resolution (APR) is a function within AERA 2 that generates resolution to conflicts detected by the automated problem detection function, and AERA 1 capability. In order to prepare APR algorithmic specifications for the advanced automation system, an APR prototype was developed in the FAA MITRE AERA 2 laboratory at the MITRE Corp. This prototype is a tool designed for evaluating rules and algorithms for resolving aircraft-aircraft and aircraft-space conflicts in both radar and nonradar environments. The evaluation is performed with FAA field evaluation personnel. The APR prototype is implemented in a Symbolics Lisp machine using the Knowledge Engineering Environment (KEE) expert systems shell. It has three major functions: conflict and resolution information display, problem detection, and resolution generation. This paper discusses the overall characteristics of the APR prototype and, specifically, the conflict and resolution information display, and the resolution generation capabilities of the prototype. CISTI

#### N92-14029# CompEngServ Ltd., Ottawa (Ontario). A UNIQUE APPROACH TO AIRCRAFT CONFLICT RESOLUTION USING ARTIFICIAL INTELLIGENCE TECHNIQUES

I. G. SMITH, C. A. CRABB, G. R. RAM, and M. R. ATTISHA *In* Communications Gillies, Inc., Electronic Systems in Transportation p 103-106 Sep. 1989

Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada

CompEngServ Ltd. has recently completed a project to develop and test a proof of concept, aircraft conflict resolution advisory system for non-radar airspace. This system, known as CORES (conflict resolution system), predicts losses of separation and presents ranked resolution alternatives. CORES deals with the difficult problem of convergence and has been successfully tested using a wide range of scenarios. The algorithm consists of three stages: (1) The initial resolution stage classifies the conflict as one of six different basic types and selects strategies to test accordingly. Strategies which induce no conflicts are selected. (2) The relax constraints stage, in which cases not resolved in stage one are subject to more extreme strategies in an attempt to discover a conflict free resolution. (3) If this fails the convergence stage is invoked. This stage examines all strategies which have previously failed because they induced one or more further conflicts. The goal of this stage is to suggest partial solutions which result in better overall airspace in terms of criticality and difficulty of induced conflicts. The system was successfully tested with a set of scenarios designed to exercise all stages of the algorithm.

CISTI

N92-14033# Syms (Raymond A.) and Associates, Bridge Water, NJ.

### OPERATIONAL SURVEY: VFR HELIPORT APPROACHES AND DEPARTURES Final Report

RAYMOND A. SYMS and RANDAL A. WIEDEMANN Aug. 1991 66 p Prepared for Systems Control Technology, Inc., Arlington, VA

(Contract DTFA01-87-C-00014)

(SCT-91RR-26; DOT/FAA/RD-90/5) Avail: NTIS HC/MF A04

A field survey about helicopter performance and operational considerations pertaining to heliport design issues is documented. Helicopter operators, manufacturers' flight instructors, and FAA Technical Center pilots were surveyed in an attempt to relate their actual visual flight rule (VFR) helicopter operating techniques to heliport airspace requirements. The opinions and information obtained from the 88 pilots surveyed from around the country represent 17 types of helicopter models operating at a broad spectrum of density altitudes. The specific data has been summarized and characterized so as to be representative of the civil helicopter industry. Results show a wide variation in opinion, even among pilots flying the same aircraft models, about what constitutes safe straight approach and departure distances, adequate acceleration distances, and realistic climb angles. Pilots opinions indicate that they can climb at higher angles than are indicated by the profiles presented in Helicopter Physical and Performance Data, DOT/FAA/RD-90-3, in order to clear close-in obstacles. However, in flying these higher angles, pilots are flying through portions of the height/velocity envelope that the FAA and the manufacturers recommend be avoided. During the formal review process a number of FAA officials concluded that in many instances the pilots perceived performance capabilities that exceeded the aircrafts' performance capabilities. Also, of concern were instances when the aircraft could perform the maneuver, but the steep climb/descent angles needed would substantially increase the risk of an accident. Author

N92-14034# Computer Technology Associates, Inc., McKee City, NJ.

#### EVALUATION OF TRIPLE SIMULTANEOUS PARALLEL ILS APPROACHES SPACED 4300 FEET APART, PHASE 4A Final Report, Apr. 1990 - Oct. 1991

LLOYD HITCHCOCK, TERENCE FISCHER, L. W. BENSEL, GLORIA YASTROP, RICKIE JONES, RENEE LUONGO, KIMBERLY REARDON, and BARBARA STARZEL-DEHEL Sep. 1991 139 p

(Contract DTFA03-89-C-00023)

(ACD-340; DOT/FAA/CT-91/6) Avail: NTIS HC/MF A07

This study was part of an ongoing effort to evaluate plans for increasing air traffic capacity and to evaluate the feasibility of using multiple simultaneous parallel Instrument Landing System (ILS) approaches. The objective was to evaluate the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC). The proposed configuration consisted of triple parallel runways 10,000 ft long, spaced 4300 ft apart with even thresholds. The controllers were able to satisfactorily resolve more than 90 percent of the blunders in this simulation. Of the 244 blunders simulated, only 23 blunders resulted in aircraft violating the criterion miss distance of 500 ft. The controllers stated that they were able to maintain the 500-ft miss distance with the exception of a few 30 degree blunders (appendix A). The controllers indicated that a departure monitor position would be unnecessary because all of the functions of the departure monitor controller could be provided by local and departure control positions. Finally, the controllers reported that higher update rate radar sensors and improved displays would enhance their performance. The Multiple Parallel Technical Work Group (TWG). based on their observations during the simulations and their understanding of the contingencies that must be accounted for in such an operation, determined that triple simultaneous parallel approach operations spaced at 4300 ft would not be acceptable if controllers were required to use ASR-9 Radar and the Automated Radar Terminal System (ARTS) 3A displays. Author

N92-14036\*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering. IMAGE-BASED RANGING AND GUIDANCE FOR

ROTORCRAFT Final Report P. K. A. MENON Dec. 1991 79 p

(Contract NCC2-575)

(NASA-CR-184829; NAS 1.26:184829) Avail: NTIS HC/MF A05 CSCL 17/7

Primary emphasis was on the development of vision-based navigation methods for rotorcraft nap-of-the-earth flight regime. A family of field-based ranging algorithms were developed. These ranging schemes are capable of handling both stereo and motion image sequences, and permits both translational and rotational camera motion. The algorithms require minimal computational effort and appear to be implementable in real time. A series of papers were presented on these ranging schemes, some of which are included in this report. A small part of the research effort was expanded on synthesizing a rotorcraft guidance law that directly uses the vision-based ranging data; this work is discussed.

Author

N92-15058# Mitre Corp., Bedford, MA. THE PROBLEM OF MULTIPLE SOLUTIONS IN AREA NAVIGATION AND COMPUTED CENTERLINE OPERATIONS WITH THE MICROWAVE LANDING SYSTEM Final Report FREDERICK D. POWELL Aug. 1991 77 p (Contract F19628-89-C-0001)

(AD-A242757; MTR-11023; ÉSD-TR-91-213) Avail: NTIS HC/MF A05 CSCL 17/7

In normal geometries of siting of the ground units, the Microwave Landing System (MLS) observations in the avionics of azimuth and elevation angles plus slant range from a Distance Measuring Equipment (DME) transponder yield a unique solution for the aircraft location. However, for some unconventional geometries of the ground units in a very few, preexisting installations, these observations can be consistent with two solutions for aircraft location within the MLS coverage volume. It appears that the basic MLS concept has not dealt with this multiple solutions situation, which is possible within the present international agreements. This report shows that the MLS avionics position reconstruction algorithms, which determine the aircraft location in Cartesian coordinates and are essential in area navigation, computed centerline approach, and ground operations, such as deceleration and turnoff, cannot tell which of the two solutions is true and which is false from internal data. The problem can be avoided by new constraints on the permitted sites for the MLS ground units, by restrictions on the aircraft flight paths, or by Kalman filters or equivalents in the avionics. These constraints, restrictions, and filters are defined.

#### N92-15060\*# Douglas Aircraft Co., Inc., Long Beach, CA. MICROWAVE LANDING SYSTEM AUTOLAND SYSTEM ANALYSIS Final Report

J. B. FEATHER and B. K. CRAVEN Dec. 1991 62 p (Contract NAS1-18028)

(NASA-CR-189551; NAS 1.26:189551; C1-1X2-TN-393) Avail: NTIS HC/MF A04 CSCL 17/7

The objective was to investigate the ability of present day aircraft equipped with automatic flight control systems to fly advanced Microwave Landing Systems (MLS) approaches. The tactical approach used to achieve this objective included reviewing the design and autoland operation of the MD-80 aircraft, simulating the MLS approaches using a batch computer program, and assessing the performance of the autoland system from computer generated data. The results showed changes were required to present Instrument Landing System (ILS) procedures to accommodate the new MLS curved paths. It was also shown that in some cases, changes to the digital flight guidance systems would be required so that an autoland could be performed.

Author

N92-15061# Systems Control Technology, Inc., Arlington, VA. ROTORCRAFT LOW ALTITUDE IFR BENEFIT/COST ANALYSIS: OPERATIONS ANALYSIS Interim Report No. 2

ROBERT K. ANOLL, LEN D. DZAMBA, LINDA J. LABELLE, RANDAHL N. LINDGREN, ROBERT B. NEWMAN, and DEBORAH J. PEISEN Dec. 1991 192 p (Contract DTFA01-87-C-00014)

(SCT-90RR-44; DOT/FAA/DS-89/10) Avail: NTIS HC/MF A09 The Rotorcraft Master Plan advocates the establishment of additional communications, navigation, and surveillance (CNS) facilities, as well as the analysis and development of systems to satisfy the increasing demand for widespread instrument flight rules (IFR) rotorcraft operations within the National Airspace System (NAS). The objective of this study is to determine if there is an economic basis for improvement of these low altitude IFR services within the NAS in order to better support rotorcraft IFR operations. The findings of this study will aid FAA decisionmaking in that regard. In view of prior implementation decisions on Loran-C, the emphasis in this effort is on communications, surveillance, procedural changes, and avionics. This report is one of a series of three reports that address rotorcraft low altitude IFR benefit/cost analysis. This second interim report defines operational requirements and constraints for selected rotorcraft missions. A candidate list of 50 sites around the country, selected for their potential to benefit from increased low altitude IFR services, is presented. Radar and communications coverages in those areas are then identified. CNS improvements to be provided by implementation of the NAS plan, relevant FAA policies, air traffic control (ATC) procedures, and avionics improvements are analyzed for their potential to benefit low altitude rotorcraft IFR operations. A benefit/cost methodology to determine where the most benefits would accrue from improvements in rotorcraft low altitude IFR services or changes in ATC procedures is presented. Author

#### 05

#### **AIRCRAFT DESIGN, TESTING AND** PERFORMANCE

Includes aircraft simulation technology.

#### A92-17876 CABIN STRUCTURAL VIBRATION AND NOISE FOR TRANSPORT AIRCRAFT

GENKICHI FUJIWARA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 39, no. 453, 1991, p. 497-503. In Japanese. refs

In this analysis of cabin structural vibration and noise of transport aircraft, evaluations of sound pressure level are addressed. Noise features such as engine vibration, multiple pure tone, and blade passing frequency are examined, and the vibration tolerance of human body is discussed. Y.P.Q.

#### A92-19606

#### NONLINEAR LANDING GEAR BEHAVIOR AT TOUCHDOWN

D. YADAV and R. P. RAMAMOORTHY (Indian Institute of Technology, Kanpur, India) ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control (ISSN 0022-0434), vol. 113, Dec. 1991, p. 677-683. refs

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Landing gear dynamics for an aircraft is analyzed with a heave-pitch model having telescopic main gear and articulated nose gear using an oleopneumatic shock absorber. System equations are presented incorporating the effects of linkage dynamics, frictional forces, and nonlinearities in the tire, air spring, and damping forces. Sensitivity of the system response to variations in some shock strut parameters is investigated for the landing touchdown impact phase to bring about improvement in the performance. Author

#### A92-19819

#### DAMAGE TOLERANCE OF THE FIGHTER AIRCRAFT 37 VIGGEN. I - ANALYTICAL ASSESSMENT. II - EXPERIMENTAL VERIFICATION

BJORN PALMBERG, PER-OLOF BOMAN, MATS-OLOF OLSSON, and ANDERS F. BLOM (Aeronautical Research Institute of Sweden, IN: Fatigue 90; Proceedings of the 4th International Bromma) Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2227-2238. Research supported by Defence Material Administration of Sweden. refs

Copyright

The damage tolerance of the 37 Viggen fighter aircraft is analyzed. Load spectra are presented along with the results stress analysis, fracture mechanics, and fatigue crack propagation. The results of analysis are successfully verified by a comparison with experimental results from damage-tolerance tests on the wing attachment frame of 37 Viggen and on the fin of a newer version of this aircraft, the JA 37 Viggen. It was found that the tested components were damage tolerant during the original fail safe design lives. LS.

#### A92-19924

#### **DORNIER 328 FIRST FLIGHT**

MICHAEL MECHAM Aviation Week and Space Technology (ISSN 0005-2175), vol. 136, Jan. 6, 1992, p. 30-33.

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A review is presented of the design, development, and results of the initial test flights of the Do. 328 regional transport. The overhead wing design includes triangular tip planforms that reduce drag without reliance on winglets and approximates an ideal elliptical lift distribution along its span. By utilizing a combination of aerodynamics, propeller design, dampening, and a tuned fuselage, it is expected that 75 percent of the passengers will be

#### A92-19925

#### **EVALUATIONS OF X-29 HIGH-AOA REGIME SHOW PROMISE** FOR FUTURE FIGHTERS

WILLIAM B. SCOTT and MICHAEL MECHAM Aviation Week and Space Technology (ISSN 0005-2175), vol. 136, Jan. 6, 1992, p. 50, 51.

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Recent flight tests prompted by the X-29's demonstrating that a forward-swept wing, integrated aerodynamics and a stabilizing digital flight control system could give fighters distinct maneuvering advantages at high angles of attack (AOA) are evaluated. Pilots were able to stabilize at angles of attack over 50 deg in an aircraft modified to incorporate a flow visualization and pressure measurement system to investigate high-AOA forebody flow characteristics. RFP

#### A92-20000#

TECHNOLOGY IN THE LIVES OF AN AIRCRAFT DESIGNER

I. T. WAALAND (Northrop Advanced Technology and Design Center, Pico Rivera, CA) AIAA, Aircraft Design and Operations Meeting, Baltimore, MD, Sept. 23, 1991. 17 p. (AIAA PAPER 91-3069) Copyright

An autobiographical account is given of the configurational design development history of U.S. tactical and strategic aircraft from the mid-1950s to the present. The configurational aerodynamics efforts detailed encompass the E-2 AEW carrier-based aircraft, the F-111B, the F-14A, the Space Shuttle, the F/A-18, and the B-2 stealth bomber. The increasing complexity of both aircraft and the design process is held to have significantly increased the isolation of engineering disciplines, precluding the most natural pathways to 'concurrent engineering'. O.C.

#### A92-20134

#### WHOLE AIRCRAFT LIGHTNING INDIRECT EFFECTS EVALUATION USING LOW LEVEL INJECTION TECHNIQUES

S. J. HOLDEN (Aeroplane and Armament Experimental Establishment, Salisbury, England), D. T. JORDAN (Royal Aerospace Establishment, Farnborough, England), and E. G. STEVENS (ERA Technology, Ltd., Leatherhead, England) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 9 p. refs Copyright

The responses of an aircraft and its cable bundles to free-field illumination from a transient EM field can be ascertained by means of a technique which uses the data acquired from low-level, swept-frequency carrier wave (LLSFCW) EM field-coupling measurements. An investigation has accordingly been conducted into techniques for injecting LLSFCW and transient currents into an aircraft that is enclosed in an external coaxial return conductor system, in order to evaluate return-conductor systems and compare the results of low level CW injection with high and low level pulse injection. Attention is given to the extrapolation of the low-level injection techniques for the clearance of aircraft for indirect lightning-strike effects. 0.0

#### A92-20136

#### THE USE OF FINITE DIFFERENCE ELECTROMAGNETIC ANALYSIS IN THE DESIGN AND VERIFICATION OF MODERN AIRCRAFT

B. I. WAHLGREN, M. G. BACKSTROM (Saab-Scania, AB, Linkoping, Sweden), R. A. PERALA, and P. M. MCKENNA (Electro Magnetic Applications, Inc., Lakewood, CO) International Conference on Lightning and Static Electricity, University of Bath. England, Sept. 26-28, 1989. 9 p. refs

The numerical EM modeling of aircraft and such interior elements as equipment bays and cabling has in the last decade reached a high stage of sophistication as a design and verification tool, in conjunction with high-speed large-memory computation

resources. Attention is presently given to illustrations of the usefulness and accuracy of such modeling in the case of lightning strikes, which are EM phenomena too complex to simulate through ground testing. The effects of lightning on 3D surfaces and carbon fiber-reinforced polymer composite structures of the JAS39 fighter are noted. O.C.

### A92-20202\* Texas A&M Univ., College Station. DIRECT-INVERSE TRANSONIC WING-DESIGN METHOD IN CURVILINEAR COORDINATES INCLUDING VISCOUS INTERACTION

ROBERT R. RATCLIFF and LELAND A. CARLSON (Texas A & M University, College Station) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 803, 804. Abridged. Previously cited in issue 21, p. 3263, Accession no. A89-47663. refs (Contract NAG1-619)

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#### A92-20203

#### FOUR DECADES OF TRANSONIC FIGHTER DESIGN

RAY WHITFORD (Cranfield Institute of Technology, Shrivenham, Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. England) 1991, p. 805-811. Previously cited in issue 22, p. 3649, Accession no. A88-51960. refs Copyright

#### A92-20208

#### FLIGHT TEST OF A HALF-SCALE UNMANNED AIR VEHICLE

R. M. HOWARD (U.S. Naval Postgraduate School, Monterey, CA), Journal of Aircraft (ISSN J. C. TANNER, and D. F. LYONS 0021-8669), vol. 28, Dec. 1991, p. 843-848. Previously cited in issue 14, p. 2130, Accession no. A90-33890. refs

#### A92-20209

#### AIRCRAFT LANDING-INDUCED TIRE SPINUP

JOE PADOVAN (Akron, University, OH), AMIR KAZEMPOUR (Goodyear Tire and Rubber Co., Akron, OH), and YONG H. KIM (SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 1-4, 1990, SAE Paper 901910) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 849-854. Previously cited in issue 21, p. 3590, Accession no. A91-48594. refs Copyright

N92-13929\*# National Aerospace Lab., Amsterdam (Netherlands).

**REVIEW OF AERODYNAMIC DESIGN IN THE NETHERLANDS** TH. E. LABRUJERE In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 1-30 1991 Avail: NTIS HC/MF A99 CSCL 01C

Aerodynamic design activities in the Netherlands, which take place mainly at Fokker, the National Aerospace Laboratory (NLR), and Delft University of Technology (TUD), are discussed. The survey concentrates on the development of the Fokker 100 wing, glider design at TUD, and research at NLR in the field of aerodynamic design. Results are shown to illustrate these activities. Author

N92-13930\*# Tokyo Univ., Sagamihara (Japan). Inst. of Space and Astronautical Science.

#### **AERODYNAMIC AIRCRAFT DESIGN METHODS AND THEIR** NOTABLE APPLICATIONS: SURVEY OF THE ACTIVITY IN JAPAN

KOZO FUJII and SUSUMU TAKANASHI (National Aerospace Lab., Tokyo, Japan ) In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 31-44 Avail: NTIS HC/MF A99 CSCL 01C 1991

An overview of aerodynamic aircraft design methods and their recent applications in Japan is presented. A design code which was developed at the National Aerospace Laboratory (NAL) and is in use now is discussed, hence, most of the examples are the result of the collaborative work between heavy industry and the National Aerospace Laboratory. A wide variety of applications in transonic to supersonic flow regimes are presented. Although design of aircraft elements for external flows are the main focus, some of the internal flow applications are also presented. Recent applications of the design code, using the Navier Stokes and Euler equations in the analysis mode, include the design of HOPE (a space vehicle) and Upper Surface Blowing (USB) aircraft configurations. Author

#### N92-13931\*# Aviation Inst., Bucharest (Romania). ON A GLOBAL AERODYNAMIC OPTIMIZATION OF A CIVIL TRANSPORT AIRCRAFT

G. SAVU and O. TRIFU In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 45-54 1991 Avail: NTIS HC/MF A99 CSCL 01C

An aerodynamic optimization procedure developed to minimize the drag to lift ratio of an aircraft configuration: wing - body - tail, in accordance with engineering restrictions, is described. An algorithm developed to search a hypersurface with 18 dimensions. which define an aircraft configuration, is discussed. The results, when considered from the aerodynamic point of view, indicate the optimal configuration is one that combines a lifting fuselage with a canard. Author

N92-13932\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### INVERSE AIRFOIL DESIGN PROCEDURE USING A **MULTIGRID NAVIER-STOKES METHOD**

J. B. MALONE and R. C. SWANSON In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 55-66 1991

Avail: NTIS HC/MF A99 CSCL 01C

The Modified Garabedian McFadden (MGM) design procedure was incorporated into an existing 2-D multigrid Navier-Stokes airfoil analysis method. The resulting design method is an iterative procedure based on a residual correction algorithm and permits the automated design of airfoil sections with prescribed surface pressure distributions. The new design method, Multigrid Modified Garabedian McFadden (MG-MGM), is demonstrated for several different transonic pressure distributions obtained from both symmetric and cambered airfoil shapes. The airfoil profiles generated with the MG-MGM code are compared to the original configurations to assess the capabilities of the inverse design method. Author

#### N92-13933\*# Boeing Computer Services Co., Seattle, WA. A COMPARISON OF TWO CLOSELY-RELATED APPROACHES TO AERODYNAMIC DESIGN OPTIMIZATION

G. R. SHUBIN and P. D. FRANK In Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 67-78 1991 Avail: NTIS HC/MF A99 CSCL 01C

Two related methods for aerodynamic design optimization are compared. The methods, called the implicit gradient approach and the variational (or optimal control) approach, both attempt to obtain gradients necessary for numerical optimization at a cost significantly less than that of the usual black-box approach that employs finite difference gradients. While the two methods are seemingly quite different, they are shown to differ (essentially) in that the order of discretizing the continuous problem, and of applying calculus, is interchanged. Under certain circumstances, the two methods turn out to be identical. We explore the relationship between these methods by applying them to a model problem for duct flow that has many features in common with transonic flow over an airfoil. We find that the gradients computed by the variational method can sometimes be sufficiently inaccurate to cause the optimization to fail. Author **N92-13948\*#** Warsaw Technical Univ. (Poland). Inst. of Applied Mechanics and Aviation Technology.

#### DESIGN OF 3-DIMENSIONAL COMPLEX AIRPLANE CONFIGURATIONS WITH SPECIFIED PRESSURE DISTRIBUTION VIA OPTIMIZATION

KRZYSZTOF KUBRYNSKI *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 263-280 1991

#### Avail: NTIS HC/MF A99 CSCL 01C

A subcritical panel method applied to flow analysis and aerodynamic design of complex aircraft configurations is presented. The analysis method is based on linearized, compressible, subsonic flow equations and indirect Dirichlet boundary conditions. Quadratic dipol and linear source distribution on flat panels are applied. In the case of aerodynamic design, the geometry which minimizes differences between design and actual pressure distribution is found iteratively, using numerical optimization technique. Geometry modifications are modeled by surface transpiration concept. Constraints in respect to resulting geometry can be specified. A number of complex 3-dimensional design examples are presented. The software is adopted to personal computers, and as result an unexpected low cost of computations is obtained.

**N92-13949\***# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Theoretical Fluid Mechanics.

### EXTENDED MAPPING AND CHARACTERISTICS TECHNIQUES FOR INVERSE AERODYNAMIC DESIGN

H. SOBIECZKY and Y. J. QIAN *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 281-292 1991

Avail: NTIS HC/MF A99 CSCL 01C

Some ideas for using hodograph theory, mapping techniques and methods of characteristics to formulate typical aerodynamic design boundary value problems are developed. The inverse method of characteristics is shown to be a fast tool for design of transonic flow elements as well as supersonic flows with given shock waves. Author

### **N92-13954\*#** Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.

#### AERODYNAMIC SHAPE OPTIMIZATION OF ARBITRARY HYPERSONIC VEHICLES

GEORGE S. DULIKRAVICH and SCOTT G. SHEFFER *In its* Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 347-358 1991 Sponsored in part by Pennsylvania State Univ., University Park

#### Avail: NTIS HC/MF A99 CSCL 01C

A new method was developed to optimize, in terms of aerodynamic wave drag minimization, arbitrary (nonaxisymmetric) hypersonic vehicles in modified Newtonian flow, while maintaining the initial volume and length of the vehicle. This new method uses either a surface fitted Fourier series to represent the vehicle's geometry or an independent point motion algorithm. In either case, the coefficients of the Fourier series or the spatial locations of the points defining each cross section were varied and a numerical optimization algorithm based on a quasi-Newton gradient search concept was used to determine the new optimal configuration. Results indicate a significant decrease in aerodynamic wave drag for simple and complex geometries at relatively low CPU costs. In the case of a cone, the results agreed well with known analytical optimum ogive shapes. The procedure is capable of accepting more complex flow field analysis codes. Author

N92-13955\*# Windsor Univ. (Ontario). Dept. of Mathematics and Statistics.

### ANALYSIS AND DESIGN OF TRANSONIC AIRFOILS USING STREAMWISE COORDINATES

R. M. BARRON and C.-F. AN *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and

Optimization in Engineering Sciences (ICIDES-3) p 359-370 1991

Avail: NTIS HC/MF A99 CSCL 01C

A new approach is developed for analysis and design of transonic airfoils. A set of full potential equivalent equations in von Mises coordinates is formulated from the Euler equations under the irrotationality and isentropic assumptions. This set is composed of a main equation for the main variable, y, and a secondary equations for the secondary variable, R. The main equation is solved by type dependent differencing combined with a shock point operator. The secondary equation is solved by marching from a non-characteristic boundary. Sample computations on NACA 0012 and biconvex airfoils show that, for the analysis problem, the present approach achieves good agreement with experimental C sub p distributions. For the design problem, the approach leads to a simple numerical algorithm in which the airfoil contour is calculated as part of the flow field solution.

N92-13958\*# General Electric Co., Cincinnati, OH. Aircraft Engines.

#### AN INVERSE METHOD FOR THE AERODYNAMIC DESIGN OF THREE-DIMENSIONAL AIRCRAFT ENGINE NACELLES

R. A. BELL and R. D. CEDAR *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 405-417 1991

Avail: NTIS HC/MF A99 CSCL 01C

A fast, efficient and user friendly inverse design system for 3-D nacelles was developed. The system is a product of a 2-D inverse design method originally developed at NASA-Langley and the CFL3D analysis code which was also developed at NASA-Langley and modified for nacelle analysis. The design system uses a predictor/corrector design approach in which an analysis code is used to calculate the flow field for an initial geometry, the geometry is then modified based on the difference between the calculated and target pressures. A detailed discussion of the design method, the process of linking it to the modified CFL3D solver and its extension to 3-D is presented. This is followed by a number of examples of the use of the design system for the design of both axisymmetric and 3-D nacelles.

**N92-13959\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### VORTEX GENERATOR DESIGN FOR AIRCRAFT INLET DISTORTION AS A NUMERICAL OPTIMIZATION PROBLEM

BERNHARD H. ANDERSON and RALPH LEVY (Scientific Research Associates, Inc., Glastonbury, CT.) /n Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 419-431 1991

Avail: NTIS HC/MF A99 CSCL 01C

Aerodynamic compatibility of aircraft/inlet/engine systems is a difficult design problem for aircraft that must operate in many different flight regimes. Takeoff, subsonic cruise, supersonic cruise, transonic maneuvering, and high altitude loiter each place different constraints on inlet design. Vortex generators, small wing like sections mounted on the inside surfaces of the inlet duct, are used to control flow separation and engine face distortion. The design of vortex generator installations in an inlet is defined as a problem addressable by numerical optimization techniques. A performance parameter is suggested to account for both inlet distortion and total pressure loss at a series of design flight conditions. The resulting optimization problem is difficult since some of the design parameters take on integer values. If numerical procedures could be used to reduce multimillion dollar development test programs to a small set of verification tests, numerical optimization could have a significant impact on both cost and elapsed time to design new aircraft. Author

N92-13981# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

#### FLIGHT RESEARCH J. H. DELEEUW and TAI QUACH et al. In its Activities of the

University of Toronto Institute for Aerospace Studies p 76-77 1989

Avail: NTIS HC/MF A06

A brief review of flight research carried out at the University of Toronto Institute for Aerospace Studies (UTIAS) is provided. Work has continued on helicopter parameter estimation in collaboration with the Flight Research Laboratory or the National Aeronautical Establishment. Under the auspices of the Advisory Group for Aeronautical Research Development (AGARD) Working Group 18, this project is to analyze with UTIAS algorithms the flight test data for three helicopters: the BO-105, the Puma, and the Apache. Recent work has concentrated on parameter estimation in the context of 6 degrees of freedom, linear models, using the time domain methods of step-wise regression, and maximum likelihood estimation. Attention was also given to the determination of the subset of all parameters in the model that are significant in describing the helicopter response for the particular maneuvres of the flight tests. This was done by a series of verification analyses, where model parameters obtained from one experiment were used for predicting the response for an independent experiment. A study of the criteria for helicopter model selection was carried out, which examined whether the flight dynamics of conventional maneuvers can be successfully modelled by a 6 degree of freedom model without determining the complete set of stability and control derivatives. CISTI

N92-14037\*# United Technologies Research Center, East Hartford, CT.

#### HIGH TEMPERATURE STATIC STRAIN GAGE DEVELOPMENT Final Report, Jun. 1983 - Oct. 1990

C. O. HULSE, R. S. BAILEY, H. P. GRANT, W. L. ANDERSON, and J. S. PRZYBYSZEWSKI Aug. 1991 130 p

(Contract NAS3-23722)

(NASA-CR-189044; NÁS 1.26:189044; R90-916528-80) Avail: NTIS HC/MF A07 CSCL 01/3

Final results are presented from a program to develop a thin film static strain gage for use on the blades and vanes of running, test stand gas turbine engines with goals of an 3 x 3 mm gage area and total errors of less than 10 pct. of + or - 2,000 microstrain after 50 hrs at 1250 K. Pd containing 13 Wt. pct. Cr was previously identified as a new strain sensor alloy that appeared to be potentially usable to 1250 K. Subsequently, it was discovered, in contrast with its behavior in bulk, that Pd-13Cr suffered from oxidation attack when prepared as a 4.5 micron thick thin film. Continuing problems with electrical leakage to the substrate and the inability of sputtered alumina overcoats to prevent oxidation led to the discovery that sputtered alumina contains appreciable amounts of entrapped argon. After the argon has been exsolved by heating to elevated temperatures, the alumina films undergo a linear shrinkage of about 2 pct. resulting in formation of cracks. These problems can be largely overcome by sputtering the alumina with the substrate heated to 870 K. With 2 micron thick hot sputtered alumina insulation and overcoat films, total 50 hr, drifts of about 100 microstrain (2 tests) and about 500 microstrain (1 test) were observed at 1000 and 1100 K, respectively. Results of tests on complete strain gage systems on constant moment bend bars with Pd temperature compensation grids revealed that oxidation of the Pd grid was a major problem even when the grid was overcoated with a hot or cold sputtered alumina overcoat.

Author

N92-14038\*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering

INTEGRATION OF DYNAMIC, AERODYNAMIC, AND STRUCTURAL OPTIMIZATION OF HELICOPTER ROTOR BLADES Final Report, 15 Oct. 1986 - 30 Nov. 1991 DAVID A. PETERS 30 Nov. 1991 22 p (Contract NAG1-710)

(NASA-CR-189018; NAS 1.26:189018) Avail: NTIS HC/MF A03 **ČSCL 01/3** 

Summarized here is the first six years of research into the integration of structural, dynamic, and aerodynamic considerations in the design-optimization process for rotor blades. Specifically discussed here is the application of design optimization techniques for helicopter rotor blades. The reduction of vibratory shears and moments at the blade root, aeroelastic stability of the rotor, optimum airframe design, and an efficient procedure for calculating system sensitivities with respect to the design variables used are discussed. Author

#### N92-14039\*# Textron Bell Helicopter, Fort Worth, TX. **TECHNOLOGY NEEDS FOR HIGH SPEED ROTORCRAFT (3) Final Report**

JACK DETORE and SCOTT CONWAY Oct. 1991 110 p (Contract NAS2-13072) (NASA-CR-177592; A-92013; NAS 1.26:177592) Avail: NTIS

HC/MF A06 CSCL 01/3 The spectrum of vertical takeoff and landing (VTOL) type aircraft is examined to determine which aircraft are most likely to

achieve high subsonic cruise speeds and have hover qualities similar to a helicopter. Two civil mission profiles are considered: a 600-n.mi. mission for a 15- and a 30-passenger payload. Applying current technology, only the 15- and 30-passenger tiltfold aircraft are capable of attaining the 450-knot design goal. The two tiltfold aircraft at 450 knots and a 30-passenger tiltrotor at 375 knots were further developed for the Task II technology analysis. A program called High-Speed Total Envelope Proprotor (HI-STEP) is recommended to meet several of these issues based on the tiltrotor concept. A program called Tiltfold System (TFS) is recommended based on the tiltrotor concept. A task is identified to resolve the best design speed from productivity and demand considerations based on the technology that emerges from the recommended programs. HI-STEP's goals are to investigate propulsive efficiency, maneuver loads, and aeroelastic stability. Programs currently in progress that may meet the other technology needs include the Integrated High Performance Turbine Engine Technology (IHPTET) (NASA Lewis) and the Advanced Structural Concepts Program funded through NASA Langley. Author

N92-14042# Centre d'Essais Aeronautique Toulouse (France). Lab. des Materiaux Metalliques.

**MECHANICAL QUALIFICATION TESTS FOR MATERIALS USED IN THE FABRICATION OF AIRCRAFT PARTS [ESSAIS** MECANIQUES ENTRANT DANS LE CADRE DE LA **QUALIFICATION DE MATERIAUX POUR LA REALISATION DE** PIECES (AVION). PROCES-VERBAL DE L'ESSAI M5-5443/01] J. C. FAURE 12 Jun. 1991 64 p In FRENCH

(CEAT-M5-5443/01; ETN-92-99978) Avail: NTIS HC/MF A04 The mechanical tests performed to qualify several materials applied in aircraft components are described. The aim of the study is to define the rules concerning the principles of the tests and how to structure the results to be presented. The preparation of the sample, the test parameters and the analysis of the results are also defined. The tests were performed on light alloys, steels, titanium alloys and refractory alloys. The mechanical properties of the materials were evaluated by tests involving: resilience, strain, toughness, crack propagation and fatigue. The results of the mechanical tests are not included. ESA

N92-14043# Centre d'Essais Aeronautique Toulouse (France). Lab. des Essais Statiques.

**OPTIMIZATION OF THE CALCULATION MARGINS OF** LANDING GEARS UNDER EXTREME LOADS. RUPTURE STATIC TESTS. PART 1: PROGRAM AND TEST IMPLANTATION [OPTIMISATION DES MARGES DE CALCUL A CHARGE EXTREME POUR ATTERRISSEURS. ESSAIS STATIQUES A RUPTURE D'EPROUVETTES D'ETUDE. PROGRAMME ET INSTALLATION D'ESSAI. PROCES-VERBAL DE L'ESSAI S 8 6551 PARTIEL 1]

M. LAVIRON 5 Jul. 1991 30 p In FRENCH

(CEAT-S8-6551-PARTIEL-1-PT-1; ETN-92-99979) Avail: NTIS HC/MF A03

The aim of the study is to evaluate the failure resistance of sample landing gear of different dimensions and of different materials. Simple or combined load tests are used. The purpose of the evaluation is to improve the laws and criteria in determining

the most accurate failure parameters. Machined samples of steel and aluminum alloys are described. The samples were submitted to tensile, bending, and shear tests, which could be applied alone or combined. The cross sections of the samples were either tube, I, or H shaped. For each test performed, the extensometric equipment, the displacement sensors, and the measurement curves are given. ESA

N92-14044# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.

#### THE TWO-BAY CRACK PROBLEM IN FUSELAGES BUILT IN GLARE AND ARALL

K. J. J. M. ZAAL May 1991 17 p

(LR-653; ETN-92-90418) Avail: NTIS HC/MF A03

The two bay crack problem as a possibly important subject for certification of pressurized fuselages is addressed. For fuselages with a GLARE or ARALL skin, the residual strength and remaining fatigue life after a large scale accidental damage seem to be realistic certification subjects. The evaluation of the two bay crack problem in a fuselage built in GLARE or Aramid Reinforced Aluminum Laminate (ARALL) introduces some new problems, compared to fuselages built in aluminum. The description of the anisotropy, the fast fracture behavior in GLARE and ARALL, require an extension of the design tools presently being used to evaluate the two bay crack problem in fuselages with aluminum skin. To model the residual strength of GLARE and ARALL, both the application of the K(sub I,C) factor and the R curve are being studied. Both methods can be used in design tools such as finite element methods and the displacement compatibility method. To study the remaining fatigue life of a fuselage with a damaged GLARE or ARALL skin, Marissen's fatigue crack growth model may be used. Slight simplifications, which are thought to lead to conservative results, may be required in Marissen's model for an efficient application in design tools intended to evaluate the two bay crack problem. ESA

N92-14045# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.

#### BULGING OF FATIGUE CRACKS IN A PRESSURIZED AIRCRAFT FUSELAGE

D. CHEN and J. SCHIJVE May 1991 41 p Presented at the 16th ICAF Symposium, Tokyo, Japan, 22-24 May 1991

(LR-655; ETN-92-90420) Avail: NTIS HC/MF A03

Fatigue crack growth and residual strength must be considered as part of the damage problem of a pressurized aircraft fuselage. Longitudinal cracks offer problems because they occur in a curved thin sheet structure under biaxial loading conditions and internal pressure. The fatigue crack edges bulge outwards (out of plane deformation) which considerably complicates the fracture mechanics analysis. The problem is analyzed empirically and theoretically. Three test set ups were developed respectively for sheet specimens with a large radius of curvature loaded by internal air pressure and hoop stress. Fatigue crack growth and residual strength tests were carried out on aluminum alloy sheet specimens and some panels of new metal sheet/fiber laminates (Aramid Reinforced Aluminum Laminate (ARALL) and GLARE). Analytical relations were developed to obtain K values, which account for the nonlinear behavior associated with sheet curvature and bulging out of the crack edges. The predictions agree with the present test results, and with results from the literature obtained by finite element method calculations for fuselages and in full scale fatigue **FSA** tests.

N92-15065# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.

MONITORING LOAD EXPERIENCE OF INDIVIDUAL AIRCRAFT J. B. DEJONGE 3 Sep. 1990 12 p Presented at 17th ICAS Congress, Stockholm, Sweden, Sep. 1990

(NLR-TP-90084-U; ETN-92-90432) Avail: NTIS HC/MF A03

The actual service load experience of aircraft may differ appreciably from design assumptions. The necessity to monitor service loads is generally recognized now for military aircraft. A general review of the overall life management procedure commonly

used today is given. Specific elements in this procedure are discussed in some detail. Specific attention is paid to the amount of scatter in severity between different flights and the required sample sizes of flight load measurements for obtaining reliable average load spectrum data. Possible causes for variation in load experience between different aircraft flying the same duty are analyzed. It is concluded that Individual Aircraft Tracking (IAT), if necessary at all, can usually be adequately accomplished by administrative means, indicated as Usage Monitoring. ESA

N92-15066# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).

DEVELOPMENT AND EVALUATION OF A FINITE ELEMENT MODEL FOR A FIBER COMPOSITE HELICOPTER FUSELAGE ENTWICKLUNG UND AUSWERTUNG EINES FINITE-ELEMENTE-MODELLS EINER HUBSCHRAUBERZELLE IN FASERVERBUNDBAUWEISE]

HANS BARNERSSOI 10 Oct. 1990 In GERMAN: 11 p Presented at the I-DEAS/CAEDS User's ENGLISH summary Conference, Schluchsee, Fed. Republic of Germany, 10-12 Oct. 1990

(MBB-UD-0584-90-PUB; ETN-92-90612) Avail: NTIS HC/MF A03

Taking the German-French helicopter TIGER as an example, the use of the laminate module at pre- and post-processing is emphasized. The advantages of such modules are shown. The three dimensional surface program CARTA is described. The model is composed of points, splines, and curves. The process of laminate construction is explained. The computational process is described. It is shown that in the present version, girder elements in fiber composites cannot be idealized. A criterion of failure is introduced for fiber plates and girder elements and for local instability of sandwich elements. **ESA** 

#### N92-15067# Naval Postgraduate School, Monterey, CA. FLIGHT OPERATIONS FOR HIGHER HARMONIC CONTROL **RESEARCH M.S. Thesis**

JAMES J. MCGOVERN Mar. 1991 63 p (AD-A242478) Avail: NTIS HC/MF A04 CSCL 20/11

The Department of Aeronautics and Astronautics at the Naval Postgraduate School (NPS) is interested in extending the useful life of Naval helicopters. Recognizing the need to reduce vibrations caused by aerodynamic loads on the rotor system, a Higher Harmonic Control (HHC) research effort has begun. The test vehicle of the HHC system is a Remotely Piloted Helicopter (RPH). This thesis contains an overview of the NPS HHC research effort including basic helicopter dynamics, HHC theory, and establishes research milestones. An RPH flight operations program was developed that included the first flights of two out of three RPH's being used in the research effort, identification of data and data acquisition requirements, and initial hover vibration tests. The vibration tests produced data of limited value. The two bladed RPH tested appears to produce peak accelerations at roughly twice the main rotor speed. This indicates that like a full scale helicopter, the largest vibrations do enter the airframe through the rotor system and are not a result of engine vibrations. Hence, RPH's are suitable for HHC research. This effort completed one portion of the long term HHC research and can lead to the practical and safe testing of a fully functioning HHC system. GRA

#### N92-15068# Naval Postgraduate School, Monterey, CA. STRUCTURAL CONSIDERATIONS FOR AIRCRAFT PAYLOAD MODIFICATION: P-3C ZERO FUEL WEIGHT INCREASE M.S. Thesis

STEVEN D. CULPEPPER Mar. 1991 76 p

(AD-A242690) Avail: NTIS HC/MF A05 CSCL 01/3

The Navy is considering the feasibility of increasing the patrol aircraft P-3C zero fuel weight enabling avionics and payload growth. This analysis examines the consequences to the structural requirements of the center section wing box. Two solutions to the structures field equations are investigated: a simplified hand solution for preliminary feasibility calculations and a more precise solution for design analysis. Together, the solutions provide a necessary

check for the results. The simplified solution employs the Euler-Bernoulli assumption which generates a set of integrals expressed in terms of the assumed displacements. These integrals, when combined with simplified geometric shapes and symmetry, ultimately produce a decoupled matrix solution. The precise solution uses a PC based finite element method which simultaneously solves the field equations for basic elements to be linked together with the appropriate boundary conditions. For the current 135,000 pound gross weight 1 g load condition, the internal stresses calculated by finite element are in accord with those by simplified hand calculation. Extensions from this modeling will generate design criterion for the target 95,000 pound zero fuel weight aircraft as well as alternate flight or taxi conditions.

N92-15069# Wright Lab., Wright-Patterson AFB, OH. EVOLUTION AND DEVELOPMENT OF HYPERSONIC CONFIGURATIONS 1958-1990 Final Report, Jul. 1990 - Mar.

1991 ALFRED C. DRAPER and THOMAS R. SIERON Sep. 1991 128 p

(Contract AF PROJ. 2404)

(AD-A242768; WL-TR-91-3067) Avail: NTIS HC/MF A07 CSCL 01/3

This report traces the activities of the Flight Dynamics Laboratory in hypersonic configuration research. Early efforts concentrated on simple configurations and progressed to more sophisticated lifting body point designs as analysis and design techniques became available. Several flight technology demonstration programs pioneered the exploitation of this new challenging flight regime and provided an extensive data base for the development of the Space Shuttle. Hypersonic air-breathing cruise vehicles are shown to be dominated by inlet and nozzles integration with the airframe. A list of lessons learned is compiled to provide a useful reference for the designer in the early formulation of configurations concepts. GRA

**N92-15070\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### FLUTTER SUPPRESSION VIA PIEZOELECTRIC ACTUATION JENNIFER HEEG Sep. 1991 17 p

(NASA-TM-104120; NAS 1.15:104120) Avail: NTIS HC/MF A03 CSCL 01/3

Experimental flutter results obtained from wind tunnel tests of a two degree of freedom wind tunnel model are presented for the open and closed loop systems. The wind tunnel model is a two degree of freedom system which is actuated by piezoelectric plates configured as bimorphs. The model design was based on finite element structural analyses and flutter analyses. A control law was designed based on a discrete system model; gain feedback of strain measurements was utilized in the control task. The results show a 21 pct. increase in the flutter speed. Author

#### 06

#### **AIRCRAFT INSTRUMENTATION**

Includes cockpit and cabin display devices; and flight instruments.

#### A92-17596#

#### AN INTELLIGENT PILOT VEHICLE INTERFACE FOR A DAY/NIGHT ADVERSE WEATHER PILOTAGE SYSTEM (D/NAPS)

HOWARD R. SMITH (United Technologies Research Center, East Hartford, CT) and PATRICIA A. CASPER (Sikorsky Aircraft, Stratford, CT) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 159-163. refs

(AIAA PAPER 91-3729) Copyright

D/NAPS program will use artificial intelligence and integrate

with advanced pilotage sensors, controls, and displays in order to demonstrate the pilot cognitive decision aids. D/NAPS will incorporate lessons learned from the Defense Advanced Research Projects Agency (DARPA) and U.S. Air Force (USAF) Pilot's Associate program for fixed-wing aircraft. The primary purpose of D/NAPS is to use artificial intelligence technology to maximize combat helicopter mission effectiveness and survivability for day/night adverse weather operations. The Pilot-Vehicle Interface (PVI) is the key component of any system that offers pilot cognitive decision aiding, since the PVI is the intelligent interface that determines how and when to aid the pilot. This paper presents an overview of the Pilot's Associate and D/NAPS programs, and elucidates the requirements of an intelligent Pilot-Vehicle Interface. Author

A92-17597\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### SENSOR FUSION FOR SYNTHETIC VISION

M. PAVEL, J. LARIMER, and A. AHUMADA (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 164-173. refs

(AIAA PAPER 91-3730)

Display methodologies are explored for fusing images gathered by millimeter wave sensors with images rendered from an on-board terrain data base to facilitate visually guided flight and ground operations in low visibility conditions. An approach to fusion based on multiresolution image representation and processing is described which facilitates fusion of images differing in resolution within and between images. To investigate possible fusion methods, a workstation-based simulation environment is being developed.

Author

#### A92-17628#

#### PUTTING TEN POUNDS OF AVIONICS IN A ONE POUND PACKAGE (CAN WE DO IT AGAIN?)

J. D. SEALS (AT&T Bell Laboratories, Whippany, NJ) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 421-426. (AIAA PAPER 91-3766)

Each new generation of avionics is driven by the same requirements - provide a ten-fold improvement in performance density, halve the cost, and double the reliability. In the past, avionics designers have been able to meet these requirements through advances in device technology and faster clocking. Further advances in performance density will require accompanying improvements in interconnection, packaging, and thermal management. Multichip modules, 3D interconnections, conformal packaging, and liquid cooling could provide these needed improvements, but their reliability and compatibility with other avionics components is largely unknown. A program has been initiated to prototype and evaluate these and other promising interconnections. This paper describes some of the prototypes and presents some preliminary test results.

#### A92-18611 Technion - Israel Inst. of Tech., Haifa. ADAPTIVE SUPPRESSION OF BIODYNAMIC INTERFERENCE IN HELMET-MOUNTED DISPLAYS AND HEAD TELEOPERATION

S. J. MERHAV (Technion - Israel Institute of Technology, Haifa) and S. LIFSHITZ Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1173-1180. refs (Contract NAGW-1128; AF-AFOSR-88-0298)

This paper addresses errors caused by vibration or turbulence in airborne helmet displays and teleoperation. It is shown by analysis and computer simulations that a modified version of the least-mean-squares adaptive noise suppression algorithm facilitates the separation of the large voluntary head movements from the vibration-induced small nonvoluntary head motion. Thus, the effects

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of the biodynamic interference can be essentially removed. The results also indicate that errors in head-tracking teleoperated devices can essentially be suppressed. Extensive man-in-the-loop laboratory simulations that validate the method are described.

#### Author

#### A92-18937

#### INFRA-RED OFFERS NEW LANDING AID COMPETITION

BILL SWEETMAN Interavia Aerospace Review (ISSN 0020-6512), vol. 46, Dec. 1991, p. 62-66.

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An overview is presented of the development of civil enhanced visual systems (EVS), a forward looking FLIR/HUD combination that could be certificated for airliners within two years. EVS has evolved from FAA/USAF work in synthetic visual systems, the aim of which is to demonstrate redundant, all-weather landing guidance utilizing FLIR and millimeter-wave radar. One advantage of EVS over autoland is that it is an intuitive landing aid that makes all approaches visual, thus extending the pilot's performance rather than placing the pilot in the role of a monitor. R.E.P.

#### A92-19251

### ON-BOARD DATA ACQUISITION SYSTEM FOR EMBRAER'S CBA123

SERGIO D. PENNA (EMBRAER-Empresa Brasileira de Aeronautica, S.A., Sao Jose dos Campos, Brazil) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 595-604.

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The requirements of the onboard data acquisition system and alternatives proposed for a new 19-seat, twin-engine turboprop commuter aircraft are described. These requirements include light weight, small size, modular design, reduced cabling, and easily installed connectors. The onboard data acquisition system should be capable of accommodating a large number of analog channels with programmable gain, offset, and excitation voltage settings.

R.E.P.

#### A92-19252

#### A NEW 1553 ALL-BUS INSTRUMENTATION MONITOR

ALBERT BERDUGO and WILLIAM G. RICKER (Aydin Corp., Vector Div., Newtown, PA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 605-612. refs

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The present study discusses an airborne instrumentation monitor which acquires the information from up to eight dual-redundant buses, and formats the data for telemetry, recording, or real-time analysis according to the general requirements of IRIG-106-86, Chapter 8. An overview of these requirements is given, and the way in which the ALBUS-1553 handles specific Chapter 8 requirements is described. The ALBUS-1553 acquires all or selected 1553 messages which are formatted into IRIG-compatible serial data stream outputs. Data are time-tagged to microsecond resolution. The unit selectively transmits entire or partial 1553 messages under program control. This results in reduced transmission bandwidth if prior knowledge of 1553 traffic is known. The ALBUS also encodes analog voice inputs, discrete user-word inputs, and multiplexed analog (overhead) inputs. P.D.

#### A92-20025

### RETROFIT PROVIDES NAVIGATION ENHANCEMENT FOR OLDER AIRCRAFT

GEORGE NOREN and JOSEPH E. O'RENDY (Litton Aero Products, Moorpark, CA) ICAO Journal (ISSN 0018-8778), vol. 46, Nov. 1991, p. 24, 25.

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The options available to retrofit an older aircraft's earlier gimballed INS confronts the operator with two alternatives: a current

laser INS can be installed in place of an older INS, or the avionics compartment can be rewired to accommodate a flight management system. Consideration is given to a ring laser gyro strapdown INS, the LTN-92, which meets analog, digital, and Arinc 429 requirements in a standard size unit. For future growth, this INS has provision for a GPS processor card and Arinc 429 bus to provide this improvement when GPS becomes a commercially certifiable method of navigation update. R.E.P.

N92-14047# Aeronautical Systems Div., Wright-Patterson AFB, OH.

#### EVOLUTION OF AVIONIC SYSTEMS ARCHITECTURE, FROM THE 1950'S TO THE PRESENT

GARY L. LUDWIG *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 7 p Sep. 1991

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The evolution of the avionic systems architectures in the U.S. Air Force fighter aircraft is described, beginning with the system design typical of the Century Series aircraft (the F-100, F-101, etc.) and progressing on through the long list of fielded aircraft to the front-line fighters of today and beyond to the system currently under development at the Aeronautical Systems Division. In parallel with this description, the forcing functions and catalysts for change of avionic systems architecture are also noted. In this regard, the rapid shift to digital avionics made possible by the transistor and the integrated circuit, wafer-scale integration, and high-density mass memory devices has rapidly driven the evolution of avionic system architecture. Attendant with such technology advancements, pilot interface associated with each new generation of avionic subsystem has also continued to mature and this also has had a major impact on system design. With the ever-increasing capabilities of weapons systems, pilot workload has increased dramatically. The need for simplification, integration, and automation of operator functions has become abundantly clear. The evolution of system design features intended to ease the operator's burden have greatly influenced system design, and these impacts are also reviewed. In conclusion, a quick glimpse at future means of supporting the pilot is provided, and the implications on future avionic system design are reviewed. Author

**N92-14048**# Aeronautical Systems Div., Wright-Patterson AFB, OH.

#### AVIONICS STANDARDIZATION IN THE USAF: 1980 TO 1990

NANCY L. CLEMENTS *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 9 p Sep. 1991

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A review of avionics standardization from 1980-1990 is presented. Background, definitions, and anticipated benefits of avionics standardization are presented followed by the current extent of standards application and associated cost avoidance summaries. Lessons learned from the past 10 years are highlighted along with efforts underway to define a set of standardization, application, and implementation criteria designed to identify future avionics standardization initiatives and quantify anticipated benefits. Author

**N92-14049#** Boeing Military Airplane Development, Seattle, WA. Avionics Technology Div.

## HISTORICAL PERSPECTIVE ON THE EVOLUTION OF AVIONICS STANDARDS

JOHN C. RUTH *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 12 p Sep. 1991

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An Avionics Laboratory major program, the Digital Avionics Information System (DAIS), played a key role in the evolution of interface standards from the late 1960's to the middle 1980's. The DAIS program considered interface standards in its basic concept and the cornerstones of the DAIS concept were: (1) A digital multiplex distribution system; (2) Functional software coded in a Higher Order Language; (3) A functional interface standard
for processors in the form of a common instructional set architecture; and (4) A glass cockpit with interactive displays. The DAIS hypothesis was that significant ownership savings could be obtained on an aircraft and other weapon systems if some type of standard interfaces were established. Commonality of hardware was not the driving issue, but standards which defined the key interfaces and did not inhibit creative and innovative technology upgrades were imperative. The DAIS program endorsed many of the standards, 1553, 1589, 1750, and 1760, by which avionics designers now design highly integrated systems. Author

N92-14050# Ministry of Defence, Paris (France). Integration Div.

### **AVIONICS STANDARDIZATION IN EUROPE**

L. GUIBERT In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 15 p Sep. 1991

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Avionics standardization in Europe has relied upon common standards, such as Stanags. That approach is not rigid enough to ensure real interoperability, as will be demonstrated with the Link 16 example. It is foreseen that one of the major challenges for future avionics standardization will be the modularity. For some reasons, there must be international commonality in order to obtain minimization of costs. One important issue is the applicability of modular avionics on board European aircraft. This has been studied in France with relation to the Rafale. The results of that study will be discussed in some details. Another issue is the standardization of Instruction Set Architectures (ISA) in the field of data processing. That concept helps to solve some problems, such as software interchangeability and reconfigurability, but it also has drawbacks. A solution to the problem which does not imply common ISAs is predicted in France: the software bus. That concept, related to the Real Time Ada Extension program is proposed. It is clearly understood in Europe that modular avionics will gain maximum advantage if its F31 specifications are common to the different nations and services within NATO. This enforces the need for cooperation at both governmental and industrial levels. Europe has launched two multinational programs in order to define and validate a common avionics architecture for application in the next century: the ASAAC and the EUCLID CEPA 4. The scope and content of the first phase of these programs will be described.

Author

N92-14051# Thomson-CSF, Malakoff (France). Radar and Counter-Measures Div.

#### MIXED APPROACH TOWARDS MODULAR AVIONICS CONFLICTING REQUIREMENTS

J. P. LACROIX In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 10 p Sep. 1991 Copyright Avail: NTIS HC/MF A10; Non-NATO Nationals requests

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New development efforts like PAVE-PILLAR and PAVE-PACE in the US, EUCLID CEPA 4 in Europe, aim at architecture selection or standards recommendations in order to satisfy at least three requirement domains: LCC (life cycle cost) requirements; performance requirements, and availability requirements. A tool is described (graphic capture and simulation) which aims to bring some methodological help for designing modular integrated avionics systems, by allowing a more accurate analysis of their dynamical behavior. The refinement of the system modelization is tightly dependent on the performance of the simulation package.

Author

N92-14052# Ministry of Defence, London (England). AVIONICS SOFTWARE EVOLUTION

JOHN A. TURTON In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 17 p Sep. 1991

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The critical software related aspects are reviewed, where thorough planning and implementation of philosophies and principles are needed, in order to be able to develop software based avionic systems to meet target timescales and budgets. Some of the critical software technologies are identified that will facilitate this process, both today and in the near future. The implications are described for software resulting from the currently emerging modular avionic architectures. A central theme is that the system and software generation process should be placed on as formal a theoretical basis as possible. This is in order to be able to deal effectively with the complexity of the software based avionic systems that are just around the corner. Author -

N92-14053# Aeronautical Systems Div., Wright-Patterson AFB, OH.

#### COMMON AVIONICS BASELINE: THE PRODUCT OF THE JOINT INTEGRATED AVIONICS WORKING GROUP

CHRISTOPHER L. BLAKE In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 12 p Sep. 1991 Copyright Avail: NTIS HC/MF A10; Non-NATO Nationals requests

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The JIAWG CAB is expected to have enormous influence on the entire next generation of avionic systems. It is imperative that good standardization decisions, based on a credible data base of design, test, and analysis, be used as the basis for CAB definition. Premature publication of specifications and standards whose content is not well founded and likely to change could cause resources to be wasted by the industry and could fatally undermine the credibility of this DOD avionics commonality thrust. The CAB development is concurrent with the development phases of the Light Helicopter and Advanced Tactical Fighter programs from which the data needed to close remaining technical issues will be derived. The JIAWG process provides a systematic way to define technical issues and alternative solutions and to draw on all valid data sources in establishing the preferred resolution of each issue. This process will be tightly coordinated with the weapon system programs to ensure specifications and standards incorporate adequate and current data from analysis and testing to complete each version of the CAB as part of planned weapon system development milestones. Author

N92-14054# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Systems Engineering Branch.

AVIONICS SYSTEMS DEVELOPMENT: TECHNOLOGICAL TRENDS, CONFLICTS, AND COST ISSUES IN A CHANGING EUROPEAN ENVIRONMENT

HELMUT RAPP In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 15 p Sep. 1991

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Presented here is an overview of German research and development projects generally known as modular avionics and their relationship to international initiatives. Growing system software complexity as well as rising software problems and cost have forced software development into rigid development methods and high order languages, and towards increasing standardization. Focussed upon are equipment standards that allow technology growth, maximize competition, and promote reusability of designs, and the avionics system software evolution and the experiences gained in the German TORNADO and F-4F upgrade programs.

Author

N92-14055# Aeronautical Systems Div., Wright-Patterson AFB, OH.

AVIONICS MODERNIZATION/UPGRADES IN THE LATE 1990S RONALD S. VOKITS In AGARD, The Conflicting Forces Driving Future Avionics Acquisition 5 p Sep. 1991

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A number of issues relative to avionics upgrading are briefly discussed. Capability and supportability improvements; maintenance philosophy; availability, diagnostics, software, and packaging improvements; mixing of old and new technologies; standards; life cycles; and predictions are among the topics covered. Author

### 06 AIRCRAFT INSTRUMENTATION

**N92-14056#** Aeronautical Systems Div., Wright-Patterson AFB, OH. Integrated Engineering and Technical Management Div. **AVIONICS RELIABILITY, DURABILITY, AND INTEGRITY: CAN THEY BE INDEPENDENT OF APPLICATION?** 

HAROLD W. UNDERWOOD *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 22 p Sep. 1991

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The development of avionics through the application of traditional MIL-STD-785, Reliability Program for Systems and Equipment Development and Production development processes for avionic reliability has been proven to have several advantages. disadvantages, and limitations. This process is contrasted to the Avionics Integrity process which is based upon the knowledge of how the equipment is to be used, the actual environments of the operating equipment, and the application of fatigue theory and life laws to design. The process is based upon a detailed understanding of the characteristics of the parts, materials, and associated processes used in its manufacture, and the tailoring of the process controls, inspection, and test requirements. The outcome of the process will be avionics with a minimum life that is dependent upon the operational stresses applied. Additionally, a number of conflicts associated with the use of standard environments, standard parts, the use of redundancy, who is responsible for reliability, MIL-SPEC design criteria, mean time between failure as a metric, and warranties are also addressed. Author

**N92-14058**# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Systems Integration Div.

AVIONICS TECHNOLOGY BEYOND 2000

LESTER MCFAWN and D. R. MORGAN *In* AGARD, The Conflicting Forces Driving Future Avionics Acquisition 27 p Sep. 1991

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If current trends continue, military avionics will face a very difficult situation at the turn of the century. This situation is predicted despite the impressive strides made in avionics performance, reduced weight per function, reduced cost per function, and a steady improvement in hardware reliability over the past 20 years. are unable to achieve a reasonably balanced we If affordability/availability/performance capability triad, there will be no other option than to substantially reduce either the number of weapon systems or their war-fighting capability. The basic architectural framework and modular avionics strategy needed to achieve this triad will soon be in place. Most of the needed enabling technologies are under development. The next step will be to carefully exploit, integrate, and validate these technologies in bold, innovative ways. Dramatic change will be needed in the way we integrate and share sensor functions; in the way we develop and support software; and in the design environments we use. Projected factors that will fundamentally impact future avionics systems and the implications of these factors are discussed along with avionics architecture, 21st century avionics software, and the future avionic system design environment. Author

## 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.

#### A92-17503

#### NUMERICAL SIMULATION FOR VARIOUS FLOWFIELDS OF AERO-ENGINE COMPONENTS

KOJI MATSUNAGA, YASUNORI ANDO, ATSUSHIGE TANAKA, and HIDEMI TOH Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 31, July 1991, p. 230-237. In Japanese. refs Advances in aero-engine performance and economy are achieved by a fusion of many individual efforts in technology. Significant advances in the evolution and rationalization of aerodynamic technology appear in the development and utilization of CFD. CFD demonstrates valuable applications and is an essential complement to testing and experimentation. A brief review is presented of the current status and the future of CFD on the aero-engine development including: (1) 3D compressible Navier-Stokes computation for turbine-vane configurations; (2) incompressible Navier-Stokes computation for gas turbine combustor; and (3) Euler and Navier-Stokes computations for some ducts, stator/downstream strut interaction and swan-neck duct.

Author

#### A92-17828#

## HYPERSONIC AIRBREATHING PROPULSION ACTIVITIES FOR SAENGER

R. LEDERER, R. R. SCHWAB (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany), and N. VOSS (MBB GmbH, Ottobrunn, Federal Republic of Germany) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 10 p. Research supported by BMFT. refs (AIAA PAPER 91-5040) Copyright

The airbreathing propulsion technology concept for the German Saenger Space Transportation System lower stage is presented. Attention is given to the two principal components of the propulsion system, the ram combustor and the exhaust nozzle. Examples of decisive design considerations such as internal performance, overall performance, weight, cooling, and airframe integration are provided. R.E.P.

#### A92-17848#

#### HYDROGEN EXHAUST GAS DISPOSITION BY AFTERBURNING

G. D. GARRARD and C. S. BARTLETT (Sverdrup Technology, Inc., Arnold AFB, TN) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 10 p. refs (AIAA PAPER 91-5075)

A review of an ongoing program to provide an exhaust gas afterburning aerothermodynamic design database is presented. To provide a useful propulsion system operation time over the facility operating envelope of Mach number and altitude for efficient NASP propulsion system testing, a hydrogen disposition system (HDS) will be employed. Without the HDS, propulsion system operation times could be restricted to prevent dangerous levels of air and hydrogen from forming in the exhaust system. A successful HDS system will lower the hydrogen level in the exhaust system to under the flammability level. The HDS concept selection process resulting in the recommendation to burn the flammable hydrogen and air mixture with piloted flameholders is discussed. R.E.P.

#### A92-17849#

## SCRAMJET RESEARCH AT THE NATIONAL AEROSPACE LABORATORY

HIROSHI MIYAJIMA (National Aerospace Laboratory, Kakuda Research Center, Japan) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 10 p. refs (AIAA PAPER 91-5076) Copyright

A review of research conducted on scramjet engines at the National Aerospace Laboratory of Japan is presented. An initial configuration was adopted similar to that of the NASA Langley fixed-geometry, airframe-integrated modular scramjet. Results of component tests and numerical simulations, subscale engine design and fabrication, and special features of the ramjet test facility currently under construction are discussed. R.E.P.

#### A92-18198

#### AERODYNAMIC DAMPING OF BLADE VIBRATIONS IN TURBOMACHINES [AERODINAMICHESKOE DEMPFIROVANIE KOLEBANII LOPATOK TURBOMASHIN]

GEORGII S. PISARENKO and ARKADII A. KAMINER Kiev, Izdatel'stvo Naukova Dumka, 1991, 304 p. In Russian. refs Copyright Results of a study of the aerodynamic damping of blade vibrations in turbomachines are reported, with allowance made for factors determining the interaction of vibrating blades with the flow. In particular, attention is given to methods for determining the characteristics of aerodynamic damping of blade vibrations, principles governing the design of models used in experimental studies of aerodynamic damping, modeling of nonstationary aerodynamic processes, and equipment used in aerodynamic damping studies.

#### A92-18292

#### A PROBABILISTIC METHOD FOR MONITORING THE REMAINING LIFE OF AIRCRAFT GAS TURBINE ENGINE COMPONENTS USING THE TEMPERATURE LIMIT CRITERION [VEROIATNOSTNYI METOD KONTROLIA RASKHODOVANIIA RESURSA DETALEI AGTD PO KRITERIIU PREDEL'NOI TEMPERATURY]

A. N. VETROV, A. G. KUCHER, and N. A. SNEGIREV (Kievskii Institut Inzhenerov Grazhdanskoi Aviatsii, Kiev, Ukraine) Problemy Prochnosti (ISSN 0556-171X), Oct. 1991, p. 54-58. In Russian. refs

Copyright

A method is proposed for predicting the remaining life of aircraft engine components is proposed which is based on the probabilistic comparison of the the maximum in-flight temperatures of the components with the temperature limits of their materials. The maximum temperature and temperature limit distributions are described by extreme-value laws whose parameters can be best estimated by the least squares method. A series of integral relations for the gamma-percent remaining life are obtained which require the use of numerical methods. V.L.

#### A92-19275

## AN INTEGRATED REAL-TIME TURBINE ENGINE FLIGHT TEST SYSTEM

MIKE MORO (Allied-Signal Aerospace Corp., Garrett Engine Div., Phoenix, AZ) and PAUL J. FRIEDMAN (Loral Instrumentation, San Diego, CA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 791-805. refs

Copyright

Commercial off-the-shelf telemetry systems for 'quick-look' to ensure data integrity on board the Boeing 720 test platform are addressed. Particular attention is given to a ground station based on a distributed architecture which designed to serve multiple engineering disciplines through acquisition subsystem serving data to independent color graphics workstations via an Ethernet local network. O.G.

#### A92-19696

## MULTIAXIAL LOAD SPECTRA IN A COOLED GAS TURBINE BLADE UNDER IN-SERVICE CONDITIONS

A. FISCHERSWORRING-BUNK (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 1. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 423-428. refs

Copyright

The computed cyclic inelastic stress-strain response of a cooled turbine blade of a jet engine under in-service loading conditions is described covering the aspects of multiaxiality, associated nonproportionality, superimposed hydrostatic pressure and thermomechanical phase relationship. Stress coefficients are presented to describe multiaxiality. A normalized stress function is used to synthesize part of the resulting stress characteristics. All the histories are discussed in the context of related crack initiation life predictive techniques based on parametric relationships, giving emphasis to the aspect of multiaxiality. Author

#### A92-20734

#### EVALUATION OF A BOUNDED HIGH-RESOLUTION SCHEME FOR COMBUSTOR FLOW COMPUTATIONS

BERTHOLD NOLL (Karlsruhe, Universitaet, Federal Republic of Germany) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 64-69. Research supported by DFG. refs Copyright

The present paper is concerned with the application of a high-resolution scheme for a finite volume discretization method. The capability of the chosen scheme is evaluated for the numerical simulation of three-dimensional flowfields. Special emphasis lies in the calculation of the processes in the mixing zone of gas turbine combustors. Thus, numerical results are compared with detailed measurements of velocity and temperature in a model mixing zone. The velocity field as well as the temperature field strongly depend on the scheme used for the discretization of the momentum and energy equations. The proposed high-resolution scheme and the well-known QUICK scheme yield similar results, which are superior to those obtained with the simple UPWIND scheme. For the simulation of turbulent transport, the standard k, epsilon model is employed. The effect of numerical diffusion caused by the usual UPWIND discretization of the convective transport of k and epsilon is assessed by the application of the high-resolution scheme of the discretization of the k and epsilon equations. As a result, it is found that the velocity and temperature fields are insensitive to the scheme that is applied for the discretization of the k and epsilon equations. Author

**N92-13938\*#** Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Cincinnati, OH.

### **RECENT PROGRESS IN INVERSE METHODS IN FRANCE**

PIERRE-FRANCOIS BRY, OLIVIER-PIERRE JACQUOTTE, and MARIE-CLAIRE LEPAPE (Office National d'Etudes et de Recherches Aeronautiques, Paris, France) *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 123-144 1991

Avail: NTIS HC/MF A99 CSCL 21E

Given the current level of jet engine performance, improvement of the various turbomachinery components requires the use of advanced methods in aerodynamics, heat transfer, and aeromechanics. In particular, successful blade design can only be achieved via numerical design methods which make it possible to reach optimized solutions in a much shorter time than ever before. Two design methods which are currently being used throughout the French turbomachinery industry to obtain optimized blade geometries are presented. Examples are presented for compressor and turbine applications. The status of these methods as far as improvement and extension to new fields of applications is also reported. Author

**N92-13939\***# Shanghai Inst. of Mechanical Engineering (China). Lab. of Turbomachinery Aerodynamics.

#### RESEARCH ON INVERSE, HYBRID AND OPTIMIZATION PROBLEMS IN ENGINEERING SCIENCES WITH EMPHASIS ON TURBOMACHINE AERODYNAMICS: REVIEW OF CHINESE ADVANCES

GAO-LIAN LIU *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 145-163 1991 Avail: NTIS HC/MF A99 CSCL 21E

Advances in inverse design and optimization theory in engineering fields in China are presented. Two original approaches, the image-space approach and the variational approach, are discussed in terms of turbomachine aerodynamic inverse design. Other areas of research in turbomachine aerodynamic inverse design include the improved mean-streamline (stream surface) method and optimization theory based on optimal control. Among the additional engineering fields discussed are the following: the inverse problem of heat conduction, free-surface flow, variational cogeneration of optimal grid and flow field, and optimal meshing theory of gears. Author

#### N92-13956\*# Fiat Aviazione S.p.A., Turin (Italy). RESEARCH ON INVERSE METHODS AND OPTIMIZATION IN ITALY

FRANCESCO LAROCCA *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 371-390 1991

Avail: NTIS HC/MF A99 CSCL 21E

The research activities in Italy on inverse design and optimization are reviewed. The review is focused on aerodynamic aspects in turbomachinery and wing section design. Inverse design of blade rows and ducts of turbomachinery in subsonic and transonic regime are illustrated by the Politecnico di Torino and turbomachinery industry (FIAT AVIO). Author

N92-13973\*# Tsinghua Univ., Bejing (China). Dept. of Thermal Engineering. DESIGN OF TRANSONIC COMPRESSOR CASCADES USING

## DESIGN OF TRANSONIC COMPRESSOR CASCADES USING HODOGRAPH METHOD

ZUOYI CHEN and JINGRONG GUO *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 593-598 1991

Avail: NTIS HC/MF A99 CSCL 21E

The use of the Hodograph Method in the design of a transonic compressor cascade is discussed. The design of the flow mode in the transonic compressor cascade must be as follows: the flow in the nozzle part should be uniform and smooth; the location of the sonic line should be reasonable; and the aerodynamic character of the flow canal in the subsonic region should be met. The rate through cascade may be determined by the velocity distribution in the subsonic region (i.e., by the numerical solution of the Chapygin equation). The supersonic sections A'C' and AD are determined by the analytical solution of the Mixed-Type Hodograph equation. Author

**N92-13977**# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

#### AERODYNAMICS

J. D. DELAURIER, G. W. JOHNSTON, D. W. ZINGG, W. D. MCKINNEY, C. HAYBALL, G. SAARENVIRTA, J. D. LOWE, B. WOODCOCK, S. HULSHOFF, H. MURTY et al. *In its* Activities of the University of Toronto Institute for Aerospace Studies p 54-58 1989

#### Avail: NTIS HC/MF A06

A brief review of aerodynamic investigations currently underway at the Institute for Aerospace Studies is provided. An extensive investigation of airship dynamics and turbulence response has resulted in the development of a numerical analysis of airship dynamic stability and stochastic response. Research on the performance and detailed design of a remotely piloted microwave powered aircraft is underway. A 12-m span airframe is currently being constructed to assist in the development of an automatic flight control system. The aerodynamics of flapping wing flight are being studied to provide understanding of the energetics and efficiency of animal flight. A two phase program has been initiated to study finite amplitude response and flutter of two dimensional airfoils involving the computation of steady and unsteady transonic flows using nonlinear full potential equations. A number of studies of propeller aerodynamics are underway including: development of a generalized incompressible 3-D propeller analysis code; an experimental unsteady propeller loading study; application of modern computational methods to the work of Theodorsen on propeller efficiency; development of a 3-D undsteady Euler code to study propeller wing interaction at transonic speed; and investigation of the modified viscous boundary flow found on rotating propeller blades. Airfoil flow on trailing edges and on leading edge slat airfoil combinations are currently being studied. A research duct facility has been built to study the destruction of toxic hydrocarbon gases by irradiated ozone. Finally, an evaluation of various turbulence models for the computation of 3-D internal CISTI flows is in progress.

N92-14059# Innovative Textile Applications Co., Grand Junction, CO.

UNIVERSAL WEAVING FOR TURBINE ENGINE COMPOSITE PREFORMS Final Report, Jul. 1990 - Mar. 1991

KONRAD L. KRAULAND May 1991 47 p

(Contract F33615-90-C-2066)

(AD-A237667; WL-TR-91-2051) Avail: NTIS HC/MF A03 CSCL 11/5

The 3-D weaving/braiding technology being pursued at ITAC has the potential to result in techniques for manufacturing low cost, high volume, near net shape, multiaxially reinforced (through the thickness) fibrous preforms, utilizing a cartesian plane, weaving/braiding for high temperature composite applications. These techniques lend themselves to the manufacture of hybrid preforms; fiber assemblies that contain more than one shape or fiber architecture. With this tool, designers may optimize the fiber structure and shape of a preform along the length of composite parts to maximize performance. A low cost hand loom has been designed and built to demonstrate concepts empirical to this technology, laying the ground work for a fully automated 3-D cartesian weaving machine. GRA

N92-14060# National Research Council of Canada, Ottawa (Ontario). Engine Lab.

## RUB INDUCED ROTOR/STATOR VIBRATION ANALYSIS ON CF700 ENGINE

BULENT TUDES (Turkish Air Force Academy, Istanbul.) Jan. 1991 101 p Sponsored by Dept. of National Defence (NRC-TR-ENG-007; CTN-91-60273) Copyright Avail: NTIS HC/MF A06

This report presents studies carried out on rub-induced rotor/stator vibrations on a CF700 gas turbine engine. The objectives of these studies were to develop signature analysis methodologies and condition monitoring techniques for the early detection of rub-induced instabilities. Spectral analysis was carried out to identify the changes in the levels at blade passing frequencies and other dominant peaks. Both amplitude and phase modulation techniques were employed to identify the rub-induced vibrations and derive parameters that could extract the characteristic features of the signals describing the changes due to several types of rubs. Signals acquired from displacement transducers were too low for any further analysis, as the casing of the engine was much too stiff to yield an enhanced signal.

Author (CISTI)

**N92-14063\***# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

# THE AERODYNAMIC EFFECT OF FILLET RADIUS IN A LOW SPEED COMPRESSOR CASCADE Thesis - Von Karman Inst. for Fluid Dynamics

BRIAN P. CURLETT Nov. 1991 49 p

(NASA-TM-105347; E-6717; NAS 1.15:105347) Avail: NTIS HC/MF A03 CSCL 21/5

The aerodynamic effects of fillet size in a low speed compressor cascade were experimentally studied. Two blade profiles were used during the experiment, namely a controlled diffusion blade and a double circular arc blade. Cascades were tested with three fillet radii and two boundary layer thicknesses over a large range of incidence angles. The cascade performance was determined by extensive downstream flow measurements using a two head, 5 hole pressure probe. Results differ significantly between the two types of blades tested. As fillet radius increases secondary flows and total pressure losses were found to increase for the controlled diffusion blades; whereas, for the double circular arc blades the losses decrease, particularly at high incidence angles. Author

N92-14064# Systems Control Technology, Inc., Palo Alto, CA. TURBINE ENGINE DIAGNOSTICS SYSTEM STUDY Final Report

BARBARA K. MCQUISTON and RONALD L. DEHOFF Oct. 1991 91 p

(Contract DTFA01-87-C-00014)

(DOT/FAA/CT-91/16) Avail: NTIS HC/MF A05

The results of a system study for the Turbine Engine Diagnostics (TED) program are presented. This research project was initiated to develop a method of approach and prototype design for a system capable of predicting the failure of rotating parts in turbine engines. Systems Control Technology (SCT) Inc. was contracted by the Federal Aviation Administration (FAA) and used an innovative approach that assimilated data from multiple sources for determining trends in engine performance and health. SCT initially performed an extensive technical literature search and industry survey to augment the present understanding of current technology in the industry for computerized diagnostics systems and measurement sensor technology. The result of this study is a proposed system with a method of approach that minimizes the technical and financial risk of turbine engines, while at the same time it optimizes the safety factors needed to accurately predict component failures. This proposed system is detailed. The abstracts from the literature search are included. Author

### 08

### AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

#### A92-17837\*# Princeton Univ., NJ. A GEOMETRIC APPROACH TO REGULATOR AND TRACKER DESIGN FOR AN AEROSPACE PLANE

MARK A. VAN BUREN and KENNETH D. MEASE (Princeton University, NJ) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 17 p. refs (Contract NAG1-907)

(AIAA PAPER 91-5054) Copyright

The paper presents a nonlinear design approach drawing from singular perturbations, feedback linearization, and variable structure control, that leads to regulators with automatic gain scheduling which exhibit similar dynamic behavior over the entire flight envelope of the aerospace plane. Additionally, design approach provides for a systematic way to counter disturbance effects as well as modeling uncertainties. The unifying feature of the three nonlinear feedback control methodologies is that they all have a geometric interpretation. First, the translational dynamics are decomposed into reduced-order slow and fast dynamics by way of a formal singular perturbation analysis. After feedback linearization the fast dynamics are robustly stabilized via a variable structure control approach. The slow dynamics are stabilized using conventional proportional-integral compensation based on the nominal slow dynamics. A number of sample command and disturbance responses at opposite ends of the flight envelope are presented for a nonlinear aerospace plane model. Author

**A92-17838\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### CONTROL CONCEPT FOR MANEUVERING IN HYPERSONIC FLIGHT

DAVID L. RANEY and FREDERICK J. LALLMAN (NASA, Langley Research Center, Hampton, VA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs (AIAA PAPER 91-5055) Copyright

This research investigates an approach to provide precise, coordinated maneuver control during excursions from a hypersonic cruise flight path while observing the necessary flight condition constraints. The approach achieves specified guidance commands by resolving altitude and cross-range errors into a load factor and bank angle command through a coordinate transformation which acts as an interface between outer loop guidance controls and inner loop flight controls. This interface, referred to as a 'resolver', applies constraints on angle-of-attack and dynamic pressure perturbations while prioritizing altitude regulation over crossrange. An unpiloted test simulation, in which the resolver was used to

### 08 AIRCRAFT STABILITY AND CONTROL

drive inner-loop flight controls, produced time histories of responses to guidance commands at Mach numbers of 6, 10, 15, and 20. It is shown that angle-of-attack and throttle perturbation constraints, combined with high-speed flight effects and the desire to maintain constant dynamic pressure, significantly impact the maneuver envelope for a hypersonic vehicle. Turn rate, climb rate, and descent rate limits are expressed in terms of these constraints. Author

#### A92-17839\*# McDonnell Aircraft Co., Saint Louis, MO. AEROSERVOELASTIC STABILIZATION TECHNIQUES FOR HYPERSONIC FLIGHT VEHICLES

PETER Y. CHENG, SAMUEL Y. CHAN (McDonnell Aircraft Co., Saint Louis, MO), THOMAS T. MYERS, DAVID H. KLYDE, and DUANE T. MCRUE (Systems Technology, Inc., Hawthorne, CA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 10 p. Previously announced in STAR as N91-30156. refs

(Contract NAS1-18763)

(AIAA PAPER 91-5056) Copyright

The potential of Hybrid Phase Stabilization (HPS), particularly for highly unstable aircraft, using a hypersonic flight vehicle (HSV) as a relevant example, is discussed. The development of HPS is presented and the result is compared with that generated using a conventional gain stabilization technique. Since HPS was not addressed in the MIL-spec requirements, a preliminary residual response metric was developed to provide guidance in assessing HPS. Author

#### A92-17840\*# Arizona State Univ., Tempe. DYNAMICS AND CONTROL OF HYPERSONIC VEHICLES -

## THE INTEGRATION CHALLENGE FOR THE 1990'S

DAVID K. SCHMIDT, HARVEY MAMICH, and FRANK CHAVEZ (Arizona State University, Tempe) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 11 p. refs (Contract NAG1-1341)

(AIAA PAPER 91-5057) Copyright

The dynamic characteristics of hypersonic vehicles are reviewed, with special attention to the interactions between the airframe, engine, and structural dynamics. Based on a preliminary investigation of the dynamics of a generic vehicle configuration similar to the X-30 with Scramjet propulsion, an assessment of these interactions is presented. The control effectors include aerodynamic pitch-control surfaces, as well as engine fuel flow and diffuser area ratio. The study configuration is statically instable in pitch, and exhibits strong airframe/engine/elastic coupling in the attitude dynamics and engine responses. This strong coupling will require a highly integrated airframe-engine control system, and the performance of the attitude control system will be contingent upon the ability to adequately deal with the structural aeroelastic response and engine dynamics.

#### A92-18463

#### **REGULATION OF RELAXED STATIC STABILITY AIRCRAFT**

HARRY G. KWATNY, JORDAN BERG (Drexel University, Philadelphia, PA), and WILLIAM H. BENNETT (Techno-Sciences, Inc., Greenbelt, MD) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. 36, Nov. 1991, p. 1315-1323. refs (Contract F33615-88-C-3606)



The authors formulate and solve a regulator problem for nonlinear parameter-dependent dynamics. It is shown that the problem is solvable except at parameter values associated with bifurcation of the equilibrium equations and that such bifurcations are inherently linked to the system zero dynamics. These results are applied to the study of the regulation of the longitudinal dynamics of aircraft. It is shown how bifurcation points arise in these problems and why they affect solvability of the regulator problem. The relationships between bifurcation, system zeros, and dynamic and static stability are illustrated.

#### A92-18601

## RETROSPECTIVE ESSAY ON NONLINEARITIES IN AIRCRAFT FLIGHT CONTROL

DUNSTAN GRAHAM (Graham-Metsys, Inc., Pocono Pines, PA) and DUANE MCRUER (Systems Technology, Inc., Hawthorne, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1089-1099. refs Copyright

A development history is presented of treatments of the peculiar and potentially destructive behavior manifested in aircraft nonlinear mechanics. With the exception of limiters and such mechanical features as preloading, the effort to define and employ beneficial nonlinearities has been largely unsuccessful. No general theory of nonlinear systems is possible, and analytical methods for the treatment of specific nonlinear effects have undergone very meager development. Discrete nonlinearities are noted to be essential between system architectures, in envelope restrictors, and in redundancy management. O.C.

#### A92-18608

### DYNAMICS OF HANG-GLIDERS

GUIDO DE MATTEIS (Roma I, Universita, Rome, Italy) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1145-1152. Previously cited in issue 21, p. 3274, Accession no. A89-49069. refs Copyright

#### A92-18610

#### AUTONOMOUSLY AIDED STRAPDOWN ATTITUDE REFERENCE SYSTEM

S. J. MERHAV (Technion - Israel Institute of Technology, Haifa) and M. KOIFMAN (Israel Annual Conference on Aviation and Astronautics, 31st, Tel Aviv, Israel, Feb. 21, 22, 1990, Collection of Papers, p. 141-152) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1164-1172. Research supported by Ministry of Defence of Israel and Precision Instrument Industries. Previously cited in issue 18, p. 3069, Accession no. A91-43095. refs

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#### A92-18615\* Clemson Univ., SC. PARAMETER INSENSITIVE CONTROL UTILIZING EIGENSPACE METHODS

ROBERT E. FENNELL (Clemson University, SC), WILLIAM M. ADAMS, JR. (NASA, Langley Research Center, Hampton, VA), and DAVID M. CHRISTHILF (Lockheed Engineering and Sciences Co., Hampton, VA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1208-1214. Previously cited in issue 21, p. 3493, Accession no. A88-50204. refs

(Contract N00014-86-K-0693; NAS1-18107) Copyright

#### A92-18620 Princeton Univ., NJ. APPLICATION OF STOCHASTIC ROBUSTNESS TO AIRCRAFT CONTROL SYSTEMS

ROBERT F. STENGEL (Princeton University, NJ) and LAURA R. RAY Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1251-1259. Research sponsored by FAA. Previously cited in issue 23, p. 3619, Accession no. A89-52598. refs (Contract NGL-31-001-252)

(Contract NGL-31-001-252) Copyright

#### A92-18621

#### STRUCTURE/CONTROL DESIGN SYNTHESIS OF ACTIVE FLUTTER SUPPRESSION SYSTEM BY GOAL PROGRAMMING

SHINJI SUZUKI (Tokyo, University, Japan) and SEIJI MATSUDA (Nissan Motors Co., Ltd., Tokyo, Japan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1260-1266. Previously cited in issue 21, p. 3330, Accession no. A90-47587. refs

Copyright

A92-18622\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### APPLICATION OF AEROSERVOELASTIC MODELING USING MINIMUM-STATE UNSTEADY AERODYNAMIC APPROXIMATIONS

SHERWOOD T. HOADLEY (NASA, Langley Research Center, Hampton, VA) and MORDECHAY KARPEL (Technion - Israel Institute of Technology, Haifa) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1267-1276. Previously cited in issue 12, p. 1786, Accession no. A89-30678. refs Copyright

#### A92-18623

## ROLL-PERFORMANCE CRITERIA FOR HIGH AUGMENTED AIRCRAFT

MARIO INNOCENTI (Auburn University, AL) and AJAY THUKRAL Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1277-1286. Previously cited in issue 21, p. 3275, Accession no. A89-49092. refs Copyright

#### A92-18624

## NONLINEAR CONTROL OF A TWIN-LIFT HELICOPTER CONFIGURATION

P. K. A. MENON, J. V. R. PRASAD, and D. P. SCHRAGE (Georgia Institute of Technology, Atlanta) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1287-1293. Research supported by U.S. Army. Previously cited in issue 21, p. 3491, Accession no. A88-50162. refs Copyright

A92-18625\* Army Aviation Systems Command, Moffett Field, CA.

#### HELICOPTER AIR RESONANCE MODELING AND SUPPRESSION USING ACTIVE CONTROL

M. D. TAKAHASHI (U.S. Army, Aviation Research and Technology Activity, Moffett Field, CA) and P. P. FRIEDMANN (California, University, Los Angeles) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1294-1300. refs

(Contract NAG2-209; NAG2-477)

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A coupled rotor/fuselage helicopter analysis with the important effects of blade torsional flexibility, unsteady aerodynamics, and forward flight is presented. Using this mathematical model, a nominal configuration is selected with an air resonance instability throughout most of its flight envelope. A multivariable compensator is then designed using two swashplate inputs and a single-body roll rate measurement. The controller design is based on the linear quadratic Gaussian technique and the loop transfer recovery method. The controller is shown to suppress the air resonance instability throughout a wide range of helicopter loading conditions and forward flight speeds. Author

#### A92-18626

**TIME-PERIODIC CONTROL OF A MULTI-BLADE HELICOPTER** STEVEN G. WEBB (U.S. Air Force Academy, Colorado Springs, CO), ROBERT A. CALICO, and WILLIAM E. WIESEL (USAF, Institute of Technology, Wright-Patterson AFB, OH) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov. Dec. 1991, p. 1301-1308. Previously cited in issue 23, p. 3617, Accession no. A89-52548. refs

### A92-19103

#### ENHANCED AUTOPILOT DESIGN THROUGH HARDWARE-IN-THE-LOOP SIMULATION

JEFFERY C. LUCAS (Nichols Research Corp., Huntsville, AL) IN: 1990 Annual Summer Computer Simulation Conference, 22nd, Calgary, Canada, July 16-18, 1990, Proceedings. San Diego, CA, Society for Computer Simulation, 1990, p. 1019-1023. (Contract DAAH01-88-D-0002) Copyright The recent U.S. Army Precision Deep Attack Missile System (PDAMS) program is discussed. The objective of the program was to demonstrate the feasibility of using electronic inertial image stabilization from a daylight ATV camera in terminal guidance. The program included the design fabrication, and testing of a missile in a near-tactical environment. This paper examines the necessity of a hardware-in-the loop simulation to enhance the autopilot design and to provide a comparison with digital simulation. C.D.

#### A92-19107

## A MULTIDIMENSIONAL TERRAIN MODEL FOR LOW ALTITUDE TRACKING SCENARIOS

J. A. SAFFOLD and M. T. TULEY (Georgia Institute of Technology, Atlanta) IN: 1990 Annual Summer Computer Simulation Conference, 22nd, Calgary, Canada, July 16-18, 1990, Proceedings. San Diego, CA, Society for Computer Simulation, 1990, p. 1113-1118. refs

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A model that circumvents many of the shortfalls of current approaches for computation of multipath interference is developed. Current approaches utilize equiphase and flat-earth assumptions within the first Fresnel zone to compute coherent multipath field contributions. This paper describes (specular) а two-dimensional terrain representation used to determine the multipath field reflection coefficients for a low altitude scenario. The computed indirect multipath field is combined with the direct field to form a complex interference pattern. The terrain model uses a facet representation with distributed height and slope to describe the contribution of coherent (specular) and noncoherent (diffuse) multipath fields. The multidimensional terrain representation provides a more realistic model of the low altitude electromagnetic environment. Author

#### A92-19273

## THE APPLICATION OF NEURAL NETWORKS TO DRONE CONTROL

DAN GREENWOOD (Netrologic, Inc., San Diego, CA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 775-781. refs

Copyright

The FAA Sponsored a six months research program to investigate the application of neural networks to controlling aircraft. It was found that properly configured neural networks offer powerful new computationally robust methods to generate command vectors corresponding to collision free routes. Methods using neural networks which capture the expertise employed by controllers in resolving conflicts were formed. This paper shows that many of the neural network techniques applied to ATC can also be applied to drone control. Two different networks are presented: a multi-layer feed-forward network using back-propagation and a method using a potential field where a gradient measure is employed to maintain the aircraft separation in real time.

**A92-20204\*** National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

PERFORMANCE IMPROVEMENTS OF AN F-15 AIRPLANE WITH AN INTEGRATED ENGINE-FLIGHT CONTROL SYSTEM LAWRENCE P. MYERS and KEVIN R. WALSH (NASA, Flight Research Center, Edwards, CA) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 812-817. Previously cited in issue 15, p. 2408, Accession no. A88-38747. refs Copyright

A92-20207 Embraer S.A., Sao Jose dos Campos (Brazil). ANALYSIS OF AIRCRAFT PERFORMANCE DURING LATERAL MANEUVERING FOR MICROBURST AVOIDANCE

DENISE A. DE MELO (Embraer - Empresa Brasileira de Aeronautica, S.A., Sao Jose dos Campos, Brazil) and R. J. HANSMAN, J.R. (MIT, Cambridge, MA) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 837-842. Research supported

by Embraer - Empresa Brasileira de Aeronautica, S.A. and MIT. Previously cited in issue 06, p. 767, Accession no. A90-19920. refs

(Contract NGL-22-009-640; NAG1-690) Copyright

#### A92-20483

## A LOW-ALTITUDE BREAKTHROUGH SYSTEM USING OPTIMAL PATH TERRAIN FOLLOWING

JINWEN AN and SHUNDA XIAO (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 9, Dec. 1991, p. 1-9. In Chinese. refs

A new scheme for an automatic terrain-following system is designed using a linear programming algorithm and an output predictive control algorithm of the modern control theory. As a result, the algorithm of the automatic optimal terrain-following scheme is simplified, and the accuracy of the aircraft following optical flight path is improved. A parallel data processing multiprocessor system is designed. Simulation results show that the accuracy of path tracking of this system is quite high, with the altitude error being not greater than 3 m. I.S.

N92-14065# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel

## KNOWLEDGE BASED SYSTEM APPLICATIONS FOR GUIDANCE AND CONTROL

FRANCO CANEPA (Alenia, Torino, Italy ) Jul. 1991 18 p Presented at the 51st Symposium, Madrid, Spain, 18-21 Sep. 1990

(AGARD-AR-284; ISBN-92-835-0624-3; CP-474; AD-A241357) Copyright Avail: NTIS HC/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An evaluation of the technical papers contributed as part of the Guidance and Control Panel's symposium on knowledge based system applications is presented. The objectives of the symposium are outlined and each of the five sessions comprising the symposium is briefly summarized. These sessions addressed representative guidance and control applications, design concepts and synthesis techniques, related methods and techniques, information processing and system architecture, and mechanization and integration issues. General conclusions related to integration between artificial intelligence (Al) technologies and between Al and conventional technologies are given. All papers presented at the symposium were compiled as conference proceedings AGARD-CP-474. M.G.

N92-14066\*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

RAPID NEAR-OPTIMĂL AEROSPACE PLANE TRAJECTORY GENERATION AND GUIDANCE Final Report, 1 Dec. 1988 - 31 Aug. 1991

A. J. CALISE, J. E. CORBAN, and N. MARKOPOULOS Nov. 1991 38 p

(Contract NAG1-922)

(NASA-CR-189469; NAS 1.26:189469) Avail: NTIS HC/MF A03 CSCL 01/3

Effort was directed toward the problems of the real time trajectory optimization and guidance law development for the National Aerospace Plane (NASP) applications. In particular, singular perturbation methods were used to develop guidance algorithms suitable for onboard, real time implementation. The progress made in this research effort is reported. Author

N92-15072# Technische Univ., Brunswick (Germany, F.R.). Fakultaet fuer Maschinenbau und Elektrotechnik.

PROJECT OF AN ADAPTIVE MULTIAXIAL AUTOPILOT WITH LEARNING PILOT CONTROL Ph.D. Thesis [ENTWURF EINES SELBSTEINSTELLENDEN MEHRACHSIGEN FLUGREGLERS MIT LERNENDER VORSTEUERUNG]

### ULRICH LINDEMANN 1991 116 p In GERMAN (ETN-92-90592) Avail: NTIS HC/MF A06

The autopilot was implemented in the form of several computing programs in the digital computer of research aircraft. It was successfully tested in flight trial. The coefficients of a discrete model transfer function were identified from the dynamic behavior of the aircraft. The identification assessed the relation between the autocorrelation of the test signal and the cross correlation of test signal and aircraft behavior. This process proved efficient. A universal applicable software package was developed during the flight trial of the autopilot, which allowed for the testing of control algorithms in real time conditions in the aircraft. ESA

**N92-15073**# Aeronautical Research Labs., Melbourne (Australia).

F/A-18 STABILATOR: EQUIVALENT SET OF POINT FORCES REQUIRED FOR PNEUMATIC BAG LOAD CASE SIMULATION SIMON C. DARCY Oct. 1990 44 p

(AD-A242637; ARL-STRUC-TM-571; DODA-AR-006-123) Avail: NTIS HC/MF A03 CSCL 01/3

In preparation for a fatigue test on the F/A-18 rear empennage, a method has been developed to determine actuator loads for the horizontal stabilators. A computer program called STABAG has been written which implements the method to enable automated computation of actuator loads corresponding to input spectrum points. This report describes the program and serves as an operating manual for it. GRA

N92-15074#Naval Air Development Center, Warminster, PA.Air Vehicle and Crew Systems Technology Dept.NEURAL NETWORK AND FUZZY LOGIC TECHNOLOGY FOR

#### NEURAL NETWORK AND FUZZY LOGIC TECHNOLOGY FOR NAVAL FLIGHT CONTROL Interim Report, Sep. 1990 - Jul. 1991

MARC L. STEINBERG and ROBERT D. DIGIROLAMO 6 Aug. 1991 44 p Sponsored by Office of Naval Technology (AD-A242650; NADC-91080-60) Avail: NTIS HC/MF A03 CSCL 01/4

Neural networks and fuzzy logic have the potential to overcome some of the most difficult problems that occur in the design and implementation of modern flight control systems (FCS). Ultimately, this may yield significant gains in performance, robustness, cost survivability, and reliability. However, it is still uncertain what neural network and fuzzy logic functions are both technologically feasible and suitable for flight control system implementation. In this report, an ongoing comprehensive program to develop and assess this technology for Naval FCS applications is described. Currently, this program is focused on the development of a neural network FCS design tool, a neural network flight control law emulator, a fuzzy logic automatic carrier landing system, and a neural network flight control configuration management system. For each project, some initial results are given. Also, several new and planned projects are discussed. These include learning augmented adaptive control, neural network augmented nonlinear control, optical neurons, and neural augmentation of conventional control systems. GRA

**N92-15075\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### FORMULATION OF A STRATEGY FOR MONITORING CONTROL INTEGRITY IN CRITICAL DIGITAL CONTROL SYSTEMS

CELESTE M. BELCASTRO, ROBERT FISCHL, and MOSHE KAM (Drexel Univ., Philadelphia, PA.) Nov. 1991 16 p (NASA-TM-104158; NAS 1.15:104158) Avail: NTIS HC/MF A03 CSCL 01/3

Advanced aircraft will require flight critical computer systems for stability augmentation as well as guidance and control that must perform reliably in adverse, as well as nominal, operating environments. Digital system upset is a functional error mode that can occur in electromagnetically harsh environments, involves no component damage, can occur simultaneously in all channels of a redundant control computer, and is software dependent. A strategy is presented for dynamic upset detection to be used in the evaluation of critical digital controllers during the design and/or

•

validation phases of development. Critical controllers must be able to be used in adverse environments that result from disturbances caused by an electromagnetic source such as lightning, high intensity radiated field (HIRF), and nuclear electromagnetic pulses (NEMP). The upset detection strategy presented provides dynamic monitoring of a given control computer for degraded functional integrity that can result from redundancy management errors and control command calculation error that could occur in an electromagnetically harsh operating environment. The use is discussed of Kalman filtering, data fusion, and decision theory in monitoring a given digital controller for control calculation errors, redundancy management errors, and control effectiveness.

Author

**N92-15076\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### TRIM DRAG REDUCTION CONCEPTS FOR HORIZONTAL TAKEOFF SINGLE-STAGE-TO-ORBIT VEHICLES

JOHN D. SHAUGHNESSY and IRENE M. GREGORY Dec. 1991 32 p

(NASA-TM-102687; NAS 1.15:102687) Avail: NTIS HC/MF A03 CSCL 01/3

The results of a study to investigate concepts for minimizing trim drag of horizontal takeoff single-stage-to-orbit (SSTO) vehicles are presented. A generic hypersonic airbreathing conical configuration was used as the subject aircraft. The investigation indicates that extreme forward migration of the aerodynamic center as the vehicle accelerates to orbital velocities causes severe aerodynamic instability and trim moments that must be counteracted. Adequate stability can be provided by active control of elevons and rudder, but use of elevons to produce trim moments results in excessive trim drag and fuel consumption. To alleviate this problem, two solution concepts are examined. Active control of the center of gravity (COG) location to track the aerodynamic center decreases trim moment requirements, reduces elevon deflections, and leads to significant fuel savings. Active control of the direction of the thrust vector produces required trim moments, reduces elevon deflections, and also results in significant fuel savings. It is concluded that the combination of active flight control to provide stabilization, (COG) position control to minimize trim moment requirements, and thrust vectoring to generate required trim moments has the potential to significantly reduce fuel consumption during ascent to orbit of horizontal takeoff SSTO vehicles. Author

### 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.

#### A92-17818#

### THRUST NOZZLE TEST FACILITY AT DLR COLOGNE

H. G. HUNGENBERG, K. H. STURSBERG, and H. B. WEYER (DLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 11 p. Research sponsored by BMFT. refs

(AIAA PAPER 91-5024) Copyright

DLR Cologne has built a thrust nozzle test facility for high temperature model tests on nozzles of hypersonic vehicles like Saenger. The facility has been designed to simulate the aerothermodynamic flow field conditions within a ramjet at flight Mach numbers of about 3.5 to 7. The high-temperature-ramcombustor intake conditions will be generated by precombustors and the low pressure exhaust conditions will be provided by a diffuser working against atmospheric pressure. The total temperature up to 3000 K will be achieved by hydrogen

combustion. When fully operational, the facility will have the capability to measure flow parameters with laser diagnostics and thrust coefficients with a strain-gage balance. Author

A92-17819\*# Purdue Univ., West Lafayette, IN.

A QUIET-FLOW LUDWIEG TUBE FOR EXPERIMENTAL STUDY OF HIGH SPEED BOUNDARY LAYER TRANSITION

STEVEN P. SCHNEIDER (Purdue University, West Lafayette, IN) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. Previously announced in STAR as N91-25107. refs

(Contract NAG1-1133; NAG1-1201)

(AIAA PAPER 91-5026) Copyright

Laminar-turbulent transition in high speed boundary layers is a complicated problem which is still poorly understood, partly because of experimental ambiguities caused by operating in noisy wind tunnels. The NASA Langley experience with quiet tunnel design has been used to design a quiet flow tunnel which can be constructed less expensively. Fabrication techniques have been investigated, and inviscid, boundary layer, and stability computer codes have been adapted for use in the nozzle design. Construction of such a facility seems feasible, at a reasonable cost. Two facilities have been proposed: a large one, with a quiet flow region large enough to study the end of transition, and a smaller and less expensive one, capable of studying low Reynolds number issues such as receptivity. Funding for either facility remains to be obtained, although key facility elements have been obtained and are being integrated into the existing Purdue supersonic facilities. Author

A92-18100

### HEAVY METAL

DOUGLAS BARRIE Flight International (ISSN 0015-3710), vol. 140, Dec. 18, 1991, p. 18, 20, 22, 23.

Copyright

The philosophy and application behind the extensive use of ground rigs for development of the European Fighter Aircraft is explained as providing an incremental development loop. The ground rig permits the exploration and testing of components and their parameters as they become available, within both an integrated and an isolated test environment. Utilizing a complicated ground rig, with the potential to test the flight-control software and control surfaces, allows the software developers to examine the systems' performance in a near-real, safe environment.

R.E.P.

#### A92-18375

DRAG BALANCE FOR HYPERVELOCITY IMPULSE FACILITIES

J. M. SIMMONS (Queensland, University, St. Lucia, Australia) and S. R. SANDERSON AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2185-2191. Research supported by Australian Research Council. refs

Copyright

A new technique is described for measuring drag with 100-microsec rise time on a nonlifting model in a free piston shock tunnel. The technique involves interpretation of the stress waves propagating within the model and its support. A finite element representation and spectral methods are used to obtain a mean square optimal estimate of the time history of the aerodynamic loading. Thus, drag is measured instantaneously and the previous restriction caused by the mechanical time constant of balances is overcome. The effectiveness of the balance is demonstrated by measuring the drag on a cone with 15-deg semivertex angle in nominally Mach 5.6 flow with stagnation enthalpies from 2.6 to 33 MJ/kg. Measurement repeatability of about 10 percent is achieved.

#### A92-20650

## CONTROL SYSTEM DESIGN FOR THE FREE DROP TEST OF EXTERNAL STORES IN A WIND TUNNEL

C. T. CHI, C. F. HSU, C. Y. HSIAO (Feng Chia University, Taichung, Republic of China), and R. C. CHANG (Chung-Shan Institute of Science and Technology, Taichung, Republic of China) IAF, International Astronautical Congress, 42nd, Montreal, Canada, Oct. 5-11, 1991. 8 p. refs

(IAF PAPER ST-91-002) Copyright

The trajectory of a store which is released from a flying vehicle can be determined by dynamic free drop wind tunnel test. This paper describes a simple, effective, and reliable control system design for the test project conducted at the Low Speed Wind Tunnel of AIDC. The system was designed based on the following guidelines: Self-contained, safety-guaranteed, user-friendly, and using PLC and pneumatic power. The system is separated into the pneumatic and the electric subsystems. Experiment results show that its performance is well accepted. Author

N92-13982# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

### FLIGHT SIMULATION

L. D. REID, S. ADVANI, W. O. GRAF, R. J. SOOSAAR, P. R. GRANT, P. A. ROBINSON, D. M. CHISHOLM, A. HOPPE, J. KIRDEIKIS, R. A. ROMANO et al. *In its* Activities of the University of Toronto Institute for Aerospace Studies p 78-79 1989 Avail: NTIS HC/MF A06

A brief description is provided of several University of Toronto Institute for Aerospace Studies (UTIAS) programs designed to investigate human factors and system optimization involved in flight simulation. A program of study has been undertaken to determine the critical amplitudes required to provide sensations of motion in the flight simulator sickness that are congruent with the expected motion of an aircraft. An electrogastrogram system designed to measure stomach activity associated with simulator sickness has been developed and tested. A program to evaluate nonlinear motion drive algorithms for flight simulators has been completed. The modelling of atmospheric disturbances, especially atmospheric turbulence and wind gradients associated with thunderstorms, is under study. Implementation of software for Instrument Flight Rule (IFR) flight test evaluations of a Bell 205 Helicopter simulator developed earlier, is currently underway. A generic spin simulator for simulation of light aircraft flight when airframe spin data is unavailable has been implemented on the flight simulator. An expert system for the purpose of tuning motion drive algorithms is to be developed.

**N92-14027**# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).

# A TAXI AND RAMP MANAGEMENT AND CONTROL SYSTEM (TARMAC)

U. VOELCKERS In Communications Gillies, Inc., Electronic Systems in Transportation p 94-98 Sep. 1989

Avail: Transportation Development Centre, 200 Rene Levesque Blvd. West, West Tower, Ste 601, Montreal, PQ H2Z 1X4 Canada

The development of safe and efficient low visibility ground operations has become very important with the increasing use of sophisticated systems such as Cat Illa/b which allow all-weather approaches and landings. The high traffic rate at major airports has made improved ground operations important even for good weather. This paper outlines a general concept for a new airport ground movement control system (GMCS) currently under development at the German Aerospace Research Establishment (DLR). The GMCS system should provide complete information on the position, identity, and progress of aircraft and other vehicles operating in the movement area as well as supplying information on the positions of stationary hazards. Digital data should be used in approach, departure, and flow control. Communications with aircraft should be mainly via digital data and voice communications should be minimized. The system should provide the pilot with detailed guidance information. It should include automatic conflict avoidance and resolution. The system should be of modular design so that it can adapt to any airport structure and any traffic volume. It should have all-weather functionality, comply with International Civil Aviation Organization (ICAO) regulatory documents, and function as an integral part of air traffic control systems. CISTI

### 09 RESEARCH AND SUPPORT FACILITIES (AIR)

**N92-14999#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Aerothermodynamics Section.

## SIMOUN AND SCIROCCO WIND TUNNEL NOZZLE VISCOUS

D. GIORDANO, L. MARRAFFA, and G. RUSSO (Centro Italiano Ricerche Aerospaziali, Naples.) In its Aerothermodynamics for Space Vehicles p 197-207 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

The results obtained during a first study phase about the flow fields in the SIMOUN and Scirocco wind tunnel nozzles are presented. The geometrical configurations analyzed here are conical with circular section of Scirocco and contoured with semicircular section for SIMOUN. Air is the working fluid and it was assumed to behave as an ideal gas in chemical and thermal equilibrium. Two dimensional and three dimensional results were produced by SPEAR/3D, a computer program which solves the parabolized Navier-Stokes equations. Isoline contours and transversal profiles of flow field parameters are shown to give an understanding of the flow patterns which settle on the nozzles under different operating conditions. The flow field characteristics and the limitations deriving from the assumptions on which the calculations were based are discussed; accordingly, future developments of the study are envisaged. ESA

N92-15001# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).

#### SHORT TIME FORCE MEASUREMENT SYSTEM

JOSEF MERTENS and KLAUS KOENIG *In* ESA, Aerothermodynamics for Space Vehicles p 223-227 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

The development of the SFS (Short time Force and moment measurement System) is considered. It enables measurement of aerodynamic forces and moments at testing times of less than 10 ms. This is required for measurements in high enthalpy shock tunnels to simulate reentry flight. Measurement is done using distributed accelerometers. The one year development program will comprise: development of software for modal analysis, correction and evaluation, development of a suited suspension system, development of calibration methods, test loading of a generic model with a precise load on a shock tube's endwall.

ESA

#### N92-15002# Naples Univ. (Italy).

#### INFRARED MEASUREMENTS OF AERODYNAMIC HEATING IN HYPERSONIC WIND TUNNEL

L. DELUCA, G. CARDONE, G. M. CARLOMAGNO, T. ALZIARYDEROQUEFORT, and D. AYMERDELACHEVALERIE (Centre d'Essais Aeronautique Toulouse, Poitiers, France) /n ESA, Aerothermodynamics for Space Vehicles p 229-234 Jul. 1991 Sponsored by Centro Italiano Ricerche Aerospaziali and Avions Marcel Dassault-Breguet Aviation

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Significant results referring to flow visualizations and heat transfer measurements performed by means of an infrared scanning radiometer in a blowdown hypersonic wind tunnel on delta wing and ellipsoids models are discussed. Tests are carried out within the European Community space program Hermes to develop the first European space shuttle. Comparisons of infrared data with oil film flow visualizations, thermocouple measurements and numerical results are presented.

**N92-15003#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Div. de Thermophysique.

#### HEAT TRANSFER MEASUREMENTS IN ONERA SUPERSONIC AND HYPERSONIC WIND TUNNELS USING PASSIVE AND ACTIVE INFRARED THERMOGRAPHY

D. L. BALAGEAS, D. BOSCHER, A. A. DEOM, and G. GARDETTE *In* ESA, Aerothermodynamics for Space Vehicles p 235-240 Jul. 1991 Previously announced in IAA as

A91-45632 Sponsored in part by Direction des Recherches, Etudes et Techniques; CEA; and Cryospace Co. Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Over the past few years, a major intellectual and technical investment has been made at ONERA to use data acquisition systems and data reduction procedures using an infrared camera as a detector under routine wind tunnel conditions. This allows a really quantitative mapping of heat tranfer rate distributions in models in supersonic and hypersonic flows. Sufficient experience has been required, and an overview of the following is given: the systems and data reduction procedures developed for both passive and active methods; typical results obtained various configurations such as supersonic axisymmetrical flow around an ogival body (passive and active thermography), heat flux modulation in the reattachment zone of a flap in hypersonic regime, transitional heating in very slightly blunted spheroconical bodies in hypersonic flows, and materials testing in high enthalpy hypersonic flow (passive thermography). FSA

N92-15009# Stuttgart Univ. (Germany, F.R.). Inst. fuer Raumfahrtsysteme.

#### THE IRS PLASMA WIND TUNNELS FOR THE INVESTIGATION OF THERMAL PROTECTION MATERIALS FOR REENTRY VEHICLES

M. AUWETER-KURTZ, H. HABIGER, S. LAURE, E. W. MESSERSCHMID, W. ROECK, and N. TUBANOS *In* ESA, Aerothermodynamics for Space Vehicles p 283-293 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

The plasma wind tunnels PWK1 and PWK2 were designed to test thermal protection materials for space vehicles. They are suitable for the qualification of ablative materials as well as for heat resistant ceramics such as C-C or C-SiC. In either case, a steady state heating environment including transient conditions at the surface of space transportation systems during the early reentry phase are simulated as close to reality as possible. Such plasma wind tunnels represent the only possible way to investigate candidate materials with respect to their surface chemistry associated with erosion or ablation behavior. In these facilities, the emphasis is on reproducing the specific enthalpy of the flow, the wall temperature and heat flux respectively as well as the chemical composition with respect to the main and most reactive components on the surface of the tested specimens rather than aerodynamic similarities. The plasma wind tunnels are characterized in terms of specific enthalpy, pressure, heat flux, and mass flow. The simulation requirements are discussed with respect to the erosion mechanisms of modern heat shield materials. It is shown that the environment of the nose cap and at the leading edge of Hermes during the first phase of reentry, including the points of maximum temperature, can be simulated as well as the conditions during the reentry of the space probe Rosetta. ESA

N92-15021# Technische Hochschule, Aachen (Germany, F.R.). Shock Wave Lab.

#### HIGH ENTHALPY TESTING IN THE AACHEN (FED. REPUBLIC OF GERMANY) SHOCK TUNNEL TH 2

H. OLIVIER, M. VETTER, and H. GROENIG In ESA, Aerothermodynamics for Space Vehicles p 377-384 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

A simple experimental method is described to determine the free stream conditions and the stagnation enthalpy in a high enthalpy shock tunnel. The main advantage of this method is that it only uses values which are measured within the test section. If measured or computed values of the nozzle reservoir are used to determine the free stream conditions by a nozzle calculation, a lot of uncertainties enter the problem. The performed experiments and the comparisons with numerical results show that the achieved accuracy of the experimental values for high enthalpy conditions is very good. Tests at the same flow conditions have shown that the repeatability margins, typically of the pressure coefficient, are

within 5 percent, and for the Stanton number within 10 percent. The error margins are in the same range.

N92-15043# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

## REVIEW OF THE EUROPEAN HYPERSONIC WIND TUNNEL PERFORMANCE AND SIMULATION REQUIREMENTS

J. MUYLAERT, T. VOIRON, P. SAGNIER, D. LOURME, O. PAPIRNYK, K. HANNEMANN, K. BUETEFISCH, and GEORG KOPPENWALLNER (Hyperschall-Technologie-Goettingen, Germany, F.R.) *In its* Aerothermodynamics for Space Vehicles p 559-574 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Hypersonic wind tunnel testing is required in many stages during the development of an aerospace vehicle. In order to reproduce the physical phenomena in a scale experiment similarity parameters must be considered. The simultaneous duplication of all simulation parameters is not possible in ground based facilities. The facilities can be grouped as follows: the classical hypersonic wind tunnels; the high enthalpy facilities; and the low density wind tunnels. A review of all the facilities within the Hermes project is given. Their simulation capabilities, flow quality, and measurement techniques are outlined. In addition, two major new high enthalpy facilities in Europe, the F4 and the High Enthalpy wind tunnel Gottingen (HEG) are presented. In order to improve the level of understanding in hypersonic testing, a standard model is recommended. ESA

#### N92-15077\*# Vigyan Research Associates, Inc., Hampton, VA. THE NASA LANGLEY RESEARCH CENTER 0.3-METER TRANSONIC CRYOGENIC TUNNEL MICROCOMPUTER CONTROLLER SOURCE CODE

W. ALLEN KILGORE and S. BALAKRISHNA Dec. 1991 66 p (Contract NAS1-18585)

(NASA-CR-189556; NÁS 1.26:189556) Avail: NTIS HC/MF A04 CSCL 14/2

The 0.3 m Transonic Cryogenic Tunnel (TCT) microcomputer based controller has been operating for several thousand hours in a safe and efficient manner. A complete listing is provided of the source codes for the tunnel controller and tunnel simulator. Included also is a listing of all the variables used in these programs. Several changes made to the controller are described. These changes are to improve the controller ase of use and safety.

Author

## 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.

### A92-17349

## SOLVING THE STRUCTURES PROBLEM FOR HYPERSONIC VEHICLES

Aerospace Engineering (ISSN 0736-2536), vol. 11, Dec. 1991, p. 15-18.

Copyright

An overview is presented of the requirements and development work conducted on lightweight, high-strength, temperature resistant structures for a fully reusable, SSTO vehicle such as the NASP. Attention is given to the enhancement of advanced heat-resistant monolithic and composite materials, and the reduction of shock wave effects in localized areas where aerothermal loadings are greatly magnified. Some concepts are studied for possible application to cooling areas of extreme temperature such as the cowl leading edge on a hypersonic vehicle's airbreathing propulsion system. R.E.P.

#### A92-17802#

### 'SPACEPLANES' R&D STATUS OF JAPAN

TATSUO YAMANAKA (National Aerospace Laboratory, Chofu, Japan) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs

(AIAA PAPER 91-5002) Copyright

Activities related to the development of aerospace planes are discussed with attention given to basic problems and requirements facing the fledgling industry. Among the programs in progress discussed are the Highly Maneuverable Experimental Space (Himes) vehicle, the Orbital Reentry Experiment (OREX), the Japanese Experimental Module (JEM), and the Advanced Technology for Aerospace Study (ATAS) program. The H-2 Orbiting Plane (HOPE) is also described in terms of conceptual and aerodynamic studies as well as structural and avionic considerations for a 20-ton HOPE vehicle. Test facilities and programs for SSTO and TSTO engine concepts are discussed in the light of studying aerospace-planes' systems. Specifications are given for five engines - two are rocket-mode engines - that correspond to specific mission requirements. C.C.S.

**A92-17820\*#** NASP Joint Program Office, Wright-Patterson AFB, OH.

#### CONDUCTING THE NASP GROUND TEST PROGRAM

WILLIAM SULLIVAN (National Aero-Space Plane Joint Program Office, Wright-Patterson AFB, OH) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 7 p. (AIAA PAPER 91-5029)

The National Aero-Space Plane program has recently entered a new phase of the program known as Phase 2D. During this period, five aerospace companies and the Government have formed a National Team. This team has focused on developing a single experimental (X-30) vehicle design and are pursuing a technology validation and demonstration program to prove out the design concepts and design tools. This paper presents an overview of the Phase 2D ground testing being conducted to validate the X-30 design and to demonstrate the critical technologies needed to build and fly a research vehicle during Phase 3 of the program. The Phase 2D exit criteria are discussed to identify how they provide top-level guidance for developing the ground test program. An overview of major test facility modifications being performed in support of the test program is also presented. Emphasis is placed on propulsion and structures testing since these are felt to be the primary areas requiring technologies beyond the current state-of-the-art. Also discussed is the use of uncertainty analysis as a method to account for uncertainties in test data.

Author

#### A92-17824#

## APPLICATION OF THE STAPAT II CODE TO HYPERSONIC VEHICLE AEROTHERMODYNAMICS

BRET L. BOMAN (McDonnell Aircraft Co., Saint Louis, MO) and CHARLES A. BABISH, III (USAF, Wright Laboratory, Wright-Patterson AFB, OH) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs (AIAA PAPER 91-5035)

Attention is given to the STAPAT II computer code and its application to computing the laminar, transitional, and turbulent real-gas aerothermodynamics of hypersonic aerospace vehicles. Two of the more unique and significant computational techniques formulated for incorporation into STAPAT II during its development are presented: one for coupling aerodynamic heating with wall heat transfer, the other for modeling embedded shock waves. Simulations were run to demonstrate STAPAT II's application to hypersonic vehicle aerothermodynamics. Wind tunnel models and full-scale configurations of a NASP blended wing body and the space shuttle were simulated. STAPAT II predictions compared well with data from both wind tunnel and flight tests, and with results from CFD calculations. A flight simulation involving a

full-scale multipane crew window system was also run to demonstrate the thermal analysis features of STAPAT II. Transparency system temperature solutions exhibited correct trends and values. P.D.

A92-17825\*# Lockheed Engineering and Sciences Co., Hampton, VA.

#### A COMPARISON OF COOLING METHODS FOR THE AIRFRAME NOZZLE OF A SINGLE-STAGE-TO-ORBIT AIRCRAFT

STUART C. JONES (Lockheed Engineering and Sciences Co., Hampton, VA) and DENNIS H. PETLEY (NASA, Langley Research Center, Hampton, VA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991, 12 p. refs (AIAA PAPER 91-5036) Copyright

A comparison is made between two different cooling schemes, including a complete system thermal analysis and weight accounting for each. A hydrogen-direct system operates at a higher pressure (34.5 Mpa) and greater temperature rise in the coolant. There is no temperature limit on the coolant itself and high injector temperatures may be achieved, but the pressure lines must be routed over great distances (10 m). The system is simple, and the coolant is almost weightless. In contrast, an indirect system operates at a lower pressure (3.8n MPa) and the liquid coolant has a much greater thermal capacity. The greater thermal capacity causes much less of a temperature rise in the coolant. The chosen coolant is Syltherm 800. This nontoxic fluid is compatible with any metal, including titanium. The loop requires a separate fuel/coolant heat exchanger and coolant pump. The indirect system offers some distinct safety advantages but is heavier than the direct hydrogen coolant system. Author

A92-17830\*# NASP Joint Program Office, Wright-Patterson AFB, OH.

#### A CONFIGURATION DEVELOPMENT STRATEGY FOR THE NASP

CURTIS D. SNYDER (National Aero-Space Plane Joint Program Office, Wright-Patterson AFB, OH) and S. Z. PINCKNEY (Lockheed Engineering and Sciences Co., Wright-Patterson AFB, OH) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 9 p. Previously cited in issue 24, p. 4216, Accession no. A91-56156. refs

(AIAA PAPER 91-5044)

### A92-17834#

#### THE VALUE OF SUB-SCALE FLIGHT TESTS IN THE **DEVELOPMENT OF NASP VEHICLES**

PETER K. SHIH (General Dynamics Corp., Convair Div., San Diego, CA) and RICHARD D. NEUMANN (Science Applications International Corp., Dayton, OH) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs (AIAA PAPER 91-5048) Copyright

A low-cost approach for hypersonic sub-scale flight test programs is presented. Simple-shaped vehicles are proposed for obtaining the qualitative technical data. This data will be used for CFD code validation and to enhance design analyses for NASP-type vehicles. Author

#### A92-17851\*# Aerospace Corp., El Segundo, CA. **OPERATIONAL DESIGN FACTORS FOR NASP DERIVED** VEHICLES

R. A. HICKMAN and J. D. ADAMS (Aerospace Corp., El Segundo, AIAA, International Aerospace Planes Conference, 3rd, CA) Orlando, FL, Dec. 3-5, 1991. 11 p. Research sponsored by National Aero-Space Plane Joint Program Office. refs (AIAA PAPER 91-5081) Copyright

The factors that significantly affect the operability of aerospace planes are identified and considered in terms of the development of the National Aerospace Plane (NASP). The aircraftlike vehicle can be affected by variables related to the structure, propulsion, and mechanical elements of the design. The requirements to control the factors are listed including robustness, fuels and propellants, maintainability, autonomy, and development testing. The details of

the requirements indicate critical factors such as the strength-to-weight ratios of the materials, propellant-system components that can withstand 5000 consecutive cycles, and low vehicle-failure probabilities. The NASP program is concluded to require: (1) models for quantitative operational assessments; (2) a modular design for the NASP structure; (3) computer-technology integration; and (4) technologies to support and normalize cryogenic operations. C.C.S.

#### A92-19061

#### AUTOMATED TRAJECTORY SYNTHESIS FOR HYPERSONIC VEHICLES USING ENERGY MANAGEMENT AND **VARIATIONAL CALCULUS TECHNIQUES**

N. VENUGOPAL, R. V. GRANDHI, W. L. HANKEY, and P. J. BELCHER (Wright State University, Dayton, OH) Acta Astronautica (ISSN 0094-5765), vol. 25, Nov. 1991, p. 669-678. refs (Contract F33615-87-C-1550)

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A generalized algorithm based on energy management techniques and calculus of variations is discussed for determining optimal trajectories of hypersonic vehicles. This method employs both techniques simultaneously such that they augment each other in obtaining the optimum path. A simulation algorithm consisting of guidance and control and numerical integration aspects is briefly described. A generic vehicle for maximizing the payload into orbit is used for testing the algorithm and the resulting optimal trajectories are presented. Author

#### A92-19257

#### IMPLEMENTATION AND USAGE OF THE RJ PROGRAM DATA ACQUISITION SYSTEM GROUND STATION

BARRY QUART (Bombardier, Inc., Canadair Aerospace Group, Montreal, Canada) and RICK MITCHELL (Loral Data Systems, Sarasota, FL) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 635-642.

Copyright

The Data Acquisition System Ground Station (DASGS), is a system developed by Loral Data Systems (Loral) for CANADAIR Aerospace Group. The system implements the latest technologies in telemetry front-end equipment, host computers, networking, and graphic workstations. The goal of the DASGS is to supply Canadair with a telemetry acquisition and processing system that can satisfy the Regional Jet (RJ) program requirements and provide future expandability to service their needs throughout the 1990's.

Author

N92-14087\*# Rockwell Space Operations Co., Houston, TX. Guidance and Navigation Analyst.

#### TESTING OF THE HIGH ACCURACY INERTIAL NAVIGATION SYSTEM IN THE SHUTTLE AVIONICS INTEGRATION LAB

RUSSELL L. STRACHAN and JAMES M. EVANS In NASA Goddard Space Flight Center, Flight Mechanics/Estimation Theory Symposium, 1991 p 301-320 Oct. 1991 Avail: NTIS HC/MF A21 CSCL 22/2

The description, results, and interpretation is presented of comparison testing between the High Accuracy Inertial Navigation System (HAINS) and KT-70 Inertial Measurement Unit (IMU). The objective was to show the HAINS can replace the KT-70 IMU in the space shuttle Orbiter, both singularly and totally. This testing was performed in the Guidance, Navigation, and Control Test Station (GTS) of the Shuttle Avionics Integration Lab (SAIL). A variety of differences between the two instruments are explained. Four, 5 day test sessions were conducted varying the number and slot position of the HAINS and KT-70 IMUs. The various steps in the calibration and alignment procedure are explained. Results and their interpretation are presented. The HAINS displayed a high level of performance accuracy previously unseen with the KT-70 IMU. The most significant improvement of the performance came in the Tuned Inertial/Extended Launch Hold tests. The HAINS exceeded the 4 hr specification requirement. The results obtained

from the SAIL tests were generally well beyond the requirements of the procurement specification. Author

**N92-14101#** Joint Publications Research Service, Arlington, VA. **JPRS REPORT: SCIENCE AND TECHNOLOGY. USSR: SPACE** 22 Nov. 1991 100 p Transl. into ENGLISH from various Russian articles

(JPRS-USP-91-007) Avail: NTIS HC/MF A05

This is a compilation of translated articles from Soviet publications. The general areas of discussion are as follows: manned mission highlights; space sciences; interplanetary sciences; space engineering; space applications; and space policy. Two articles of special interest are Small Solar Sail Spacecraft for Regatta Project, and History of EPOS Air Launched Spaceplane Project.

**N92-14103#** Joint Publications Research Service, Arlington, VA. **HISTORY OF EPOS AIR-LAUNCHED SPACEPLANE PROJECT** VYACHESLAV KAZMIN *In its* JPRS Report: Science and Technology. USSR: Space p 27-36 22 Nov. 1991 Transl. into ENGLISH from Krylya Rodiny (Moscow, USSR), no. 11, Nov. 1990 p 25-26, no. 12, Dec. 1990 p 16-17, and no. 1, Jan. 1991 p 4-5 Avail: NTIS HC/MF A05

Both stages of an aerospace system, with a calculated mass of 115 tons, were simply attached, winged, wide-fuselage craft for horizontal takeoff and landing and multiple use. The system was designed according to a tailless lifting body design. The carrier was a 52 ton powerful aircraft booster which would accelerate to Mach 6 and separate, launching from its back at an altitude of 28 to 30 km, a 10 ton manned orbital aircraft 8 m long with a 7.4 m wing span. Only 3.4 m of this was the outer wing, and the remaining large part of the bearing surface was the width of the fuselage. This little bird was named EPOS (Experimental Manned Orbital Aircraft). It was attached to a tank of rocket fuel for insertion into orbit at hypersonic speed. The development of EPOS attracted great attention for aviation designers.

**N92-14108\*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

LIMIT CYCLE VIBRATIONS IN TURBOMACHINERY

S. G. RYAN Dec. 1991 84 p

(NASA-TP-3181; M-676; NAS 1.60:3181) Avail: NTIS HC/MF A05 CSCL 13/9

The focus is on an examination of rotordynamic systems which are simultaneously susceptible to limit cycle instability and subharmonic response. Characteristics of each phenomenon are determined as well as their interrelationship. A normalized, single mass rotor model is examined as well as a complex model of the high pressure fuel turbopump and the Space Shuttle Main Engine. Entrainment of limit cycle instability by subharmonic response is demonstrated for both models. The nonuniqueness of the solution is also demonstrated.

N92-14975# Tsentralni Aerogidrodinamicheskii Inst., Moscow (USSR).

#### AEROTHERMODYNAMIC CONFIGURATION OF FIRST GENERATION AEROSPACE PLANES (OF BURAN-TYPE) AND FIRST FLIGHT RESULTS

V. YA. NEILAND *In* ESA, Aerothermodynamics for Space Vehicles p 13-22 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Some main factors influencing the Aerothermodynamics Configurations (ATC) of first generation aerospace planes, the problems to be solved during its selection, the phases of the ATC development, estimation methods for aerodynamic characteristics and heat fluxes, including laboratory experiments, numerical investigations and flight tests, are discussed. The circle of problems being considered is confined to the first generation aerospace planes of the type 'Buran'. Some data of fundamental importance concerning the convergence of aerothermodynamic characteristics preflight predictions with real flight test results are presented.

ESA

**N92-14977#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

#### ANALYSIS TOOLS OF ONERA AND DLR FOR THE AEROTHERMODYNAMICS OF REENTRY VEHICLES

P. BARILLOT, J. M. BOUSQUET, G. BRENNER, J. L. DACOSTA, D. DEVEZEAUX, P. NIEDERDRENK, R. RADESPIEL, P. SAGNIER, and J. SCHOENE (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) In ESA, Aerothermodynamics for Space Vehicles p 39-46 Jul. 1991 Previously announced in IAA as A91-53246

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Design analysis of space planes must include all flow phenomena occurring during the reentry phase of the flight. Aerodymanic and aerothermic tools must be able to treat hypersonic, supersonic and subsonic flow fields. In the frame of Hermes Technical Assistance (TA) for the National Center for Space Studies (CCNES), DLR and ONERA have improved their numerical tools in order to increase their capabilities. Euler codes are necessary to compute aerodynamic coefficients during the hyper/supersonic part of the flight. The Panel Method is used for subsonic flow. For aerothermal load calculations, engineering methods allow short term response. More sophisticated methods, such as coupled Euler/boundary layer solvers, are used to study critical design points, including nonequilibrium and wall catalycity phenomena. Navier-Stokes solvers are used to study separation phenomena. Examples of application are presented. They show the present capability of TA teams to perform aerothermodynamic evaluations for Hermes design. ESA

#### N92-14980# Alenia Spazio S.p.A., Naples (Italy). AEROTHERMODYNAMIC DEVELOPMENT OF THE CARINA RE-ENTRY VEHICLE: CFD ANALYSES AND EXPERIMENTAL TESTS

A. MARZANO, M. SOLAZZO, A. SANSONE, A. CAPUANO, and G. BORRIELLO *In* ESA, Aerothermodynamics for Space Vehicles p 67-72 Jul. 1991

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The CARINA (Italian acronym for unmanned reentry capsule) system is a microgravity payload carrier with reentry capability. In the frame of the design activities for the CARINA system, the aerothermodynamic characterization of the reentry vehicle is one of the most considerable efforts. Furthermore, the design aspects of such a vehicle are largely unexplored in Europe, requiring a technological program to support the development of the knowledge in this research area. After a tradeoff analysis and preliminary studies, a more in depth approach to the problem was planned. Two different driving lines are pointed out: the utilization of Computational Fluid Dynamics (CFD) tools and the contemporary development of an adequate experimental campaign. Test results, compared with the numerical predictions, are illustrated.

**N92-14984**# Societe Europeenne de Propulsion, Vernon (France).

## SUPERSONIC COMBUSTION STUDIES [ETUDES EN COMBUSTION SUPERSONIQUE]

H. ZELLER, D. SAUCEREAU, and M. DESAULTY (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel, France ) *In* ESA, Aerothermodynamics for Space Vehicles p 93-100 Jul. 1991 In FRENCH

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The potential advantage of the scramjet for space launch and research is discussed. Firsts results of theoretical and experimental studies on mixing, combustion, and supersonic boundary layer flow behavior are presented.

N92-15037# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).

THE INFLUENCE OF A RETARDING ROCKET ON PARAMETER LIMITS FOR REENTRY TRAJECTORIES

N. OREN In ESA, Aerothermodynamics for Space Vehicles p

#### ASTRONAUTICS 10

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505-507 Jul. 1991

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This simulation enables one to compute the influence of the spinning atmosphere on the recovery devices used in a returning spacecraft: retarding rocket, lifting panels and retarding parachute. The computer simulation determines location, velocity vector, and landing spot. Two articles on the subject were published by the author. The first dealt with the influence of lifting panels on a spacecraft trajectory and the second dealt with the influence of retarding rocket burn time on energy dissipation rate in a spacecraft trajectory. The influence of the retarding rocket burn time on the maximum values along the trajectory of five output parameters is shown. The following items are the five output parameters: maximum rate of heat dissipation; maximum skin temperature; maximum deceleration; and overall trajectory time. ESA

N92-15877\*# Tennessee Univ., Chattanooga. Mechanical Engineering-Mechanics.

#### REDESIGN OF FLIGHT SPACE SHUTTLE MAIN ENGINE NOZZLE G-15 SEAL AREA BASED ON THE THERMAL ANALYSIS AND FLOW MODELS

GARY H. MCDONALD In Alabama Univ., Research Reports: 1991 NASA/ASEE Summer Faculty Fellowship Program 5 p Oct. 1991

(Contract NGT-01-008-021)

Àvail: NTIS HC/MF A12 CSCL 21/8

The main objective is to understand the present sealing area response to environmental conditions of the supersonic turbulent combustion gases which has led to both stress rupture cracks and hot gas leakage. A review of the existing thermal analysis and flow modeling has been performed of the present design and seal alternatives have been suggested to possibly reduce or eliminate the hot gas flow recirculation problem and the associated seal cracking. Author

### 11

### CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

#### A92-17861#

#### AN EXPERIMENTAL INVESTIGATION OF THE COMBUSTION OF A HYDROGEN JET INJECTED PARALLEL IN A SUPERSONIC AIR STREAM

ROSEMARIE GUERRA, WINFRIED WAIDMANN, and CHRISTOPH (DLR, Institut fuer Chemische Antriebe LAIBLE und Verfahrenstechnik, Hardthausen am Kocher, Federal Fepublic of AIAA, International Aerospace Planes Conference, Germany) 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs

(AIAA PAPER 91-5102) Copyright

The paper describes a reliable method for the ignition of a hydrogen jet in a supersonic air stream. Ignition is achieved through radicals produced by precombustion of a fuel-rich mixture of hydrogen and oxygen. To avoid interference from the boundary layer, the hydrogen jet is injected parallel to the free stream through the base of a wedge centered in the test chamber. Results from measurements of OH spectra intensity and schlieren photography show that a 2D stable flame was established just downstream of the wedge base. After ignition was achieved, precombustion was no longer necessary for flameholding, except for cases of unvitiated cold air. Results of computations showed that water, which occurs at mass fractions less than 15 percent in the freestream, not only lowers the final temperature, but also shortens the reaction time.

15

## A92-18002

## HYPERSONIC MATERIALS

FRANK COLUCCI Aerospace Composites and Materials (ISSN 0954-5832), vol. 3, Nov.-Dec. 1991, p. 4-8.

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An overview is presented of the development work being conducted on titanium matrix composites and other materials for the air-breathing hypersonic NASP. Consideration is given to composites including, aluminum-lithium various alloy, а thermoplastic PEEK matrix, organic composites, refractory composites, and titanium metal matrices. R.F.P.

### A92-18898

#### **INERTIA-FRICTION WELDING OF AN ADVANCED RAPIDLY** SOLIDIFIED TITANIUM ALLOY

W. A. BAESLACK, III (Ohio State University, Columbus), D. PHILLIPS, C. ENGLISH, and A. P. WOODFIELD (GE Aircraft Journal of Materials Science Letters Engines, Cincinnati, OH) (ISSN 0261-8028), vol. 10, Dec. 1, 1991, p. 1401-1408. refs Copyright

Inertia-friction welding is shown to be capable of effectively yielding a fine weld-zone dispersoid structure in an erbium-containing rapidly-solidified Ti alloy. The dispersoid structure observed within the inner heat-and-diffusion zone (HDZ) originated in the solid-state dissolution of the original base-metal dispersoids; it is suggested that the dissolution of the base metal dispersoid structure was kinematically enhanced by the extremely high temperatures experienced in the inner HDZ, as well as the severe local deformation experienced at the weld interface. The weld's room-temperature strength and hardness were primarily dependent on the fine transformed-beta microstructure within the weld zone. O.C.

A92-19754\* Lockheed Engineering and Sciences Co., Hampton,

#### FATIGUE CRACK INITIATION AND SMALL CRACK GROWTH IN SEVERAL AIRFRAME ALLOYS

M. H. SWAIN (Lockheed Engineering and Sciences Co., Hampton, VA), J. C. NEWMAN, J.R., E. P. PHILLIPS (NASA, Langley Research Center, Hampton, VA), and R. A. EVERETT (NASA, Langley Research Center; U.S. Army, Aerostructures Directorate, Hampton, IN: Fatigue 90; Proceedings of the 4th International VA) Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 2. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 1079-1084. Previously announced in STAR as N90-18746. refs Copyright

The growth of naturally-initiated small cracks under a variety of constant amplitude and variable amplitude load sequences is examined for several airframe materials: the conventional aluminum alloys, 2024-T3 and 7075-T6, the aluminum-lithium alloy, 2090-T8E41 and 4340 steel. Loading conditions investigated include constant amplitude loading at R = 0.5, 0, -1 and -2 and the variable amplitude sequences FALSTAFF, Mini-TWIST, and FELIX/28. Crack growth was measured at the root of semicircular edge notches using acetate replicas. Crack growth rates are compared on a stress intensity factor basis, to those for large cracks to evaluate the extent of the small crack effect in each alloy. In addition, the various alloys are compared on a crack initiation and crack growth morphology basis. Author

#### A92-19760

#### SHORT FATIGUE CRACK GROWTH FROM BLUNT NOTCHES IN AN AERO-ENGINE ALLOY

I. W. HUSSEY (Rolls-Royce, PLC, Derby, England) and J. BYRNE (Portsmouth Polytechnic, England) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 2. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 1115-1120. refs Copyright

The growth of short corner defects from the bore extremities of blunt keyhole notches in CT specimens has been studied for a nickel-base superalloy. Variation in crack shape was determined by beach marking to establish an aspect ratio calibration with increasing crack length. Both surface and inferred bore results have been compared with an approximate analysis which determines the stress intensity factor for part-through cracks in regions of variable stress. The experimental results demonstrate that the theoretical predictions based on this analysis provide conservative estimates of the stress intensity in the absence of short crack effects and crack interactions. Author

#### A92-19767

#### CRACK INITIATION AND THE SHORT-TO-LONG CRACK GROWTH TRANSITION IN A NI-BASE SUPERALLOY

J. E. KING (Cambridge, University, England) and A. D. BOYD-LEE IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 2. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 1205-1210. Research supported by Rolls-Royce, PLC and British Gas, PLC. refs

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A study has been made of the initiation and early fatigue crack growth of 58 cracks in AP1 (Astroloy) with a necklace microstructure at 20 C under loading with a maximum stress equal to 0.8 of the yield stress and R = 0.1. Clear statistical trends observed in the microstructural conditions favoring initiation and the path taken by these cracks through the surface grains of the specimen are presented. Author

#### A92-19796

#### HIGH TEMPERATURE LOW CYCLE FATIGUE OF SINGLE CRYSTAL NICKEL BASE SUPERALLOYS

M. MARCHIONNI, E. PICCO, D. RANUCCI (CNR, Istituto per la Tecnologia dei Materiali Metallici non Tradizionali, Cinisello Balsamo, Italy), and V. CATENA (Fiat Aviazione S.p.A., Turin, Italy) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 3. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 1735-1740. refs

#### Copyright

The low-cycle fatigue behavior of three different single crystal nickel base superalloys (one with high density and two with low density) is analyzed in the temperature range 600-1000 C. The fatigue life of single crystal alloys is sensibly higher than that of other cast of directionally solidified nickel base alloys due to the presence of a low plastic strain component in the hysteresis loop. The fatigue results are discussed, taking into account the anisotropy of the alloys and their density. Author

#### A92-19799

## THERMO-MECHANICAL FATIGUE CRACK GROWTH IN AIRCRAFT ENGINE MATERIALS

T. NICHOLAS (USAF, Materials Laboratory, Wright-Patterson AFB, OH) and S. MALL (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 3. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 1905-1910. refs

#### Copyright

Crack growth under combined thermal and mechanical fatigue (TMF) is compared in Inconel 718 and a titanium aluminide intermetallic, Ti-24-11. Crack growth in Inconel 718 is dominated by a combination of fatigue and environmentally assisted crack growth processes. In the titanium aluminide, crack tip blunting due to creep is also present. Linear summation modeling is seen to work well for the Inconel 718, but retardation due to blunting has to be considered in the aluminide. Author

#### A92-19817

### PREDICTION OF FATIGUE CRACK GROWTH IN A TI-6AL-4V FAN DISK FORGING UNDER SPECTRUM LOADING

R. GALATOLO (Pisa, Universita, Italy) IN: Fatigue 90; Proceedings

of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2215-2220. Research supported by CNR. refs Copyright

Constant amplitude and spectrum loading fatigue crack growth data for the titanium alloy Ti-6AI-4V STA engine disks were used to evaluate the predictive accuracies of an advanced crack closure model (CORPUS). Predictions were very good except for the initial period of crack growth. The behavior at low crack growth rates is of course very important, because a large amount of the total life may be spent in that phase. This is therefore a serious problem and possible reasons for it are discussed. Author

#### A92-19820

#### METHODOLOGY FOR THE ASSESSMENT OF MATERIAL QUALITY EFFECTS ON AIRFRAME FATIGUE DURABILITY

P. E. MAGNUSEN, A. J. HINKLE, R. J. BUCCI, R. L. ROLF, and D. A. LUKSAK (Alcoa Laboratories, Alcoa Center, PA) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2239-2244. refs Copyright

A methodology is developed for quantifying the effects of reduced microporosity and constituent particles in aerospace aluminum alloys on the fatigue performance of these alloys. For microporosity studies, four lots of a commercially produced 144-mm-thick 7050-T7451 plate were used, with two of the lots produced using an old standard process and two others by using new processing methods described by Owen et al. (1989). For variations in constituents, two high-strength Al-Zn-Cu-Mg, 7XXX series alloys with different levels of Fe and Si were used. Smooth axial fatigue tests were performed using 7.6-mm-diam round specimens. Results show that, by reducing both the number and the severity of metallurgical inhomogeneities can result in dramatic fatigue improvement. For example, the fatigue strength at 100,000 cycles determined from the data is 112 Mpa for the old quality material and 131 for the material produced using new processing methods. More dramatic increases in fatigue strength are seen at the fatigue limit of the material when designing for infinite life.

1.S.

**A92-19828\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### PROOF TEST AND FATIGUE CRACK GROWTH MODELING ON 2024-T3 ALUMINUM ALLOY

J. C. NEWMAN, JR., C. C. POE, JR. (NASA, Langley Research Center, Hampton, VA), and D. S. DAWICKE (Analytical Services and Materials, Inc., Hampton, VA) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2407-2416. refs

Copyright

Pressure proof testing of aircraft fuselage structures has been suggested as a means of screening critical crack sizes and of extending their useful life. The objective of this paper is to study the proof-test concept and to model the crack-growth process on a ductile material. Simulated proof and operational fatigue life tests have been conducted on cracked panels made of 2024-T3 aluminum alloy sheet material. A fatigue crack-closure model was modified to simulate the proof test and operational fatigue cycling. Using crack-growth rate and resistance-curve data, the model was able to predict crack growth during and after the proof load. These tests and analyses indicate that the proof test increases fatigue life; but the beneficial life, after a 1.33 or 1.5 proof, was less than a few hundred cycles.

#### A92-20130

CURRENT STABILIZING OF FASTENED COMPOSITE JOINTS TO IMPROVE NON-SPARKING LIGHTNING CURRENT PERFORMANCE

D. L. HEIDLEBAUGH and J. M. CARTER (Boeing Co., Seattle, WA) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 9 p. refs

CFRP panels and slabs joined by fasteners, as found in wet-wing' integral fuel tanks, have been found to possess sparking properties sufficiently stable and predictable to allow reliable lightning-current protection design. The passing of simulated lightning current across the fastener-joint interface has been found to modify or 'stabilize' the interface so that subsequent application of simulated lightning-current waveforms will require significantly higher peak currents than identical joints which have not been stabilized. Test results show that effective stabilizing currents of the order of tens of amps are independent of waveform. O.C.

#### A92-20349

#### PROTECTIVE COATINGS OF THERMAL BARRIER TYPE [REVETEMENTS PROTECTEURS DE TYPE BARRIERE THERMIQUE]

S. ALPERINE (ONERA, Direction Scientifique des Materiaux, Chatillon, France) Revue Scientifique et Technique de la Defense (ISSN 0994-1541), 2nd Quarter, 1991, p. 111-114. In French. refs

Copyright

Thermal barrier coatings (TBCs) are a new generation of protective coatings for the high-temperature components of turbine or diesel engines. Several ONERA studies on such coatings are summarized here, with particular emphasis placed on the enhancement of the resistance of TBCs to thermomechanical fatigue in an oxidizing environment. Three complementary themes are considered: (1) the effect of the composition and microstructure of the coatings on their intrinsic thermomechanical resistance; (2) investigation of the physical structure of the coatings (pores, cracks) in relation to their toughness; and (3) the role played by the ceramic-bondcoat interface and its evolution at high temperature. I M

N92-14411# Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).

#### FATIGUE OF REPAIRED COMPOSITE STRUCTURES

GERHARZ, G. DANZER, and MAIER J. A. (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany, F.R.) In its Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 1 p 1991 Avail: NTIS HC/MF A04

Investigations into the strength of repaired stringer stiffened panels of Rigidite 5245C/T800 composite laminate are summarized. The panels were fatigue loaded with modified Falstaff for wing upper surface up to three lives (18,000 flights). Surviving panels were loaded in compression up to failure (residual compressive strength test). Workshop and field repair methods were applied. The workshop repair methods consisted of flush laminate patch repairs applied to punctured skin and stringer and the field repair methods consisted of blind rivet installation in the delaminated area of nonvisible damage. The workshop repair methods used . an adhesive in order to bond the patches to the reworked area of damage. The patches consisted of wet laid-up carbon fiber fabric laminate or of a laminate of fabric prepreg. The results of static and fatigue tests were dominated by the quality of the repair and the hot/wet sensitivity of the adhesive. Delamination, caused by 30 Joule low velocity impact on the skin opposite the stringer foot run out, propagated during the fatigue loading (modified Falstaff for upper wing surface). A field repair method of installing blind rivets in the delaminated area successfully delayed the delamination growth. ESA

N92-14413# Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).

#### ENVIRONMENTAL FATIGUE TESTS WITH COMPOSITE MATERIALS

M. BERG, D. ROTT, and H. HUTH In its Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 1 p 1991

Avail: NTIS HC/MF A04

Since the certification of composite airframe structures requires consideration of the effects of in service environmental conditions on fatigue and residual strength, two environmental test rigs for eight specimens were developed. Different graphite/epoxy materials and specimens were investigated in a variety of environmental fatigue tests using for example Falstaff and Airbus component loading sequences with superimposed thermal cycles. Some published results can be found in the references. FSA

N92-15191\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH. TRIBOLOGY NEEDS FOR FUTURE SPACE AND **AERONAUTICAL SYSTEMS** ROBERT L. FUSARO Dec. 1991 40 p

(NASA-TM-104525; E-6399; NAS 1.15:104525) Avail: NTIS HC/MF A03 CSCL 11/3

Future aeronautical and space missions will push tribology technology beyond its current capability. The objective is to discuss the current state of the art of tribology as it is applied to advanced aircraft and spacecraft. Areas of discussion include materials lubrication mechanisms, factors affecting lubrication, current and future tribological problem areas, potential new lubrication techniques, and perceived technology requirements that need to be met in order to solve these tribology problems. 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.

### A92-17288

#### NONDESTRUCTIVE TESTING DEVELOPMENTS IN THE AIRCRAFT INDUSTRY

DONALD J. HAGEMAIER (Douglas Aircraft Co., Long Beach, CA) Materials Evaluation (ISSN 0025-5327), vol. 49, Dec. 1991, p. 1470-1472, 1474-1476, 1478. refs Copyright

Recent developements in NDT methods designed for uses in the fabrication and maintenance inspections of aircraft materials and structures are reviewed. Among the fabrication inspection methods, special attention is given to the magnetic particle testing (MT) systems using 3D magnetization, the quantitative quality indicators for MT, the electronic shearography methods, and the eddy current liftoff dynamics for the composite cure monitoring. The maintenance inspection methods considered include low-frequency eddy current testing methods, testing with a mobile automated ultrasonic scanner, and the diffracto-sight method.

1.S.

#### A92-17289

#### REAL-TIME MICROFOCUS RADIOGRAPHY FOR ELECTRONIC FAILURE ANALYSIS

MICHAEL MARCHESE (USAF, Wright Laboratory, Wright-Patterson AFB, OH) and KAREN A. GLODOWSKI (DOD, Defense Electronics Supply Center, Dayton, OH) Materials 0025-5327), vol. 49, Dec. 1991, p. 1481-1485. Materials Evaluation (ISSN

This paper is formatted as a case history of several failure-analysis projects where real-time microfocus radiography was employed as an inspection tool. These projects investigated various devices such as printed wiring boards, switches, connectors, and filters. Author

#### A92-17290

ENHANCED VISUAL TECHNIQUE FOR RAPID INSPECTION OF AIRCRAFT STRUCTURES

JERZY P. KOMOROWSKI, DAVID L. SIMPSON, and RONALD W. GOULD (National Research Council of Canada, Institute for Aerospace Research, Ottawa) Materials Evaluation (ISSN 0025-5327), vol. 49, Dec. 1991, p. 1486-1490. refs

A new surface inspection technique termed diffracto-sight (D Sight) is described together with the details of an inspection procedure for the detection of large aircraft surface defects. Results obtained by applying the D Sight to the detection of small surface defects are presented. It is shown that D Sight is capable of detecting cold-worked holes, corrosion areas, and fatigue cracks associated with high stress-intensity factors, as long as the surface anomaly is greater than about 10 microns. To date, it has been demonstrated that D Sight is capable of detecting surface waviness in metallic and composite materials, impact damage and edge delamination in composites, and cold-worked holes, cracks, and corrosion in metallics.

#### A92-17292

RAPID ULTRASONIC SCANNING OF AIRCRAFT STRUCTURES M. K. REIGHARD, T. W. VAN OORDT, and N. L. WOOD (McDonnell Aircraft Co., Saint Louis, MO) Materials Evaluation (ISSN 0025-5327), vol. 49, Dec. 1991, p. 1506, 1508, 1510 (3 ff.). refs Copyright

An automated ultrasonic inspection system, called the Mobile Automated Ultrasonic System (MAUS), developed for the detection of defects in advanced aircraft composites, is described. The MAUS consists of a scanner, for positioning probes on the inspection surface, and an electronic package, for acquiring and imaging data on a video screen. The MAUS, originally developed for the 'time-of-flight' inspection, is suited for rapid assessment of a wide variety of aircraft structures and materials, including composite laminates, complex co-cured composites, and bonded structures. I.S.

#### A92-17293

## ASNT AND AEROSPACE - WHAT ABOUT THE NEXT 50 YEARS?

THOMAS D. COOPER (USAF, Wright Laboratory, Wright-Patterson AFB, OH) Materials Evaluation (ISSN 0025-5327), vol. 49, Dec. 1991, p. 1526-1529, 1531-1535. refs

Copyright

The 50-year history (since its inception in 1941) of the development of NDT inspection methods and of devices and systems for inspecting aircraft surfaces is described with special attention given to the technologies involved in these methods and devices and to the role of NDE in the damage-tolerance approach to designing new structures. Consideration is also given to recent improvements in the NDT methods developed for use in aerospace and to the projections of NDT developments for the next 50 years.

#### A92-17348

### HYDRAULIC PUMPS - THE KEY TO POWER GENERATION

JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 11. Dec. 1991, p. 9-13.

Copyright

A review is presented of the development of aircraft hydraulic pumps and their continuing growth due to the increasing demands dictated by the power requirements for higher aerodynamic loading and the integration of propulsion system devices (thrust vectoring) into the flight control system. Consideration is given to the various types of hydraulic pumps and the recent work directed at developing microprocessor-controlled pumps for use in variable-pressure hydraulic systems. R.E.P.

#### A92-17414

#### ULTRASONIC MOTOR UTILIZING ELASTIC FIN ROTOR

TATSUYA UCHIKI, KENTARO NAKAMURA, MINORU KUROSAWA, SADAYUKI UEHA (Tokyo Institute of Technology, Yokohama, Japan), and TORU NAKAZAWA (ALPS Electric Co., Ltd., Nagaoka, Japan) (Ferroelectric materials and their applications; Proceedings of the 8th Meeting, Kyoto, Japan, May 29-31, 1991. A92-17401 05-76) Japanese Journal of Applied

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Physics, Part 1 (ISSN 0021-4922), vol. 30, Sept. 1991, p. 2289-2291. refs

Copyright

The design principles of a 5-mm-diam ultrasonic micromotor utilizing an elastic fin rotor are discussed, and the characteristics of the experimental rotor model of the motor are described. The experimental rotation speed of the rotor model was found to be nearly equal to that of the theoretical.

#### A92-17562

## ENHANCEMENT OF MODAL SWEPT SINE DATA BY CONTROL OF EXCITING FORCES

G. C. FOSS (Boeing Defense and Space Group, Seattle, WA) Experimental Techniques (ISSN 0732-8818), vol. 15, Nov.-Dec. 1991, p. 22-26.

Copyright

A shaker control system is described which improves the quality of frequency response data obtained from nonlinear test articles during sine sweep excitation. The system showed good results on a prototype space truss and a missile fin. Currently it is used only with averaged sine FFT-type analysis. O.G.

#### A92-17627#

#### A REVIEW OF DIGITAL FLIGHT CONTROL SYSTEM UPSETS CAUSED BY ELECTROMAGNETIC INTERFERENCE

BRUCE T. CLOUGH (USAF, Flight Dynamics Directorate, Wright-Patterson AFB, OH) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 414-420.

(AIAA PAPER 91-3765) Examinations of the MIL-STD-461C data base, operational

experience, and specific tests show that upsets of digital flight-control systems are caused by low-frequency amplitude modulated signals corrupting the sensor inputs. Studies show that the current digital (and analog) flight-control systems are susceptible to electromagnetic radiation, that is, continuous wave, AM signal of 0 to 3 Hz modulation content, and has carrier frequencies of between 1 and 250 MHz. When the systems are placed in an airframe the frequency region constricts to 3 to 30 MHz, reflecting the influence of airframe/wire coupling. Field levels vary according to the electromagnetic interference susceptibility specifications the system was built to. Most current systems respond to average field levels of 200 V/m over some part of the carrier-frequency range. Steps to reduce the upset potential of analog portions are required during operation. Then, harder analog sensors and sensor/flight computer interfaces are required.

Author

#### A92-17823# CONJUGATE CONDUCTION/CONVECTION/NUCLEATE-BOILING HEAT TRANSFER WITH A HIGH-SPEED BOUNDARY LAYER

FREDERICK L. SHOPE (Calspan Corp., Arnold AFB, TN) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 12 p. refs

(AIAA PAPER 91-5033)

A space-marching boundary-layer program has been extensively modified to model conjugate conduction/convection heat transfer for the case of coflowing high-speed gas and liquid coolant. Solid body conduction is modeled as one-dimensional, constant property heat transfer. The coolant is modeled empirically as a bulk fluid with combined forced convection and nucleate boiling. The flow solver was modified to solve the group of conjugate boundary equations simultaneously and implicitly with the existing momentum and energy equations for the gas. The code has been applied to analysis of a backside water-cooled nozzle for a high-enthalpy, supersonic wind tunnel. A92-17843\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### ANALYSIS OF COOLING SYSTEMS FOR HYPERSONIC AIRCRAFT

DENNIS H. PETLEY (NASA, Langley Research Center, Hampton, VA), STUART C. JONES, and WILLIAM M. DZIEDZIC (Lockheed Engineering and Sciences Co., Hampton, VA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 13 p. refs (AIAA PAPER 91-5063) Copyright

A computer program has been written to analyze cooling systems of hypersonic aircraft. This computer program called NASP/SINDA is written into the SINDA'85 command structure and uses the SINDA'85 finite difference subroutines. Both internal fluid flow and heat transfer must be analyzed, because increased heating causes a decrease in the flow of the coolant. Also local hot spots will cause a redistribution of the coolant in the system. Both steady state and transient analyses have been performed. Details of empirical correlations are presented. Results for two cooling system applications are given. Author

#### A92-17950

#### **PVD COATINGS FOR AIRCRAFT TURBINE BLADES**

HELMUT LAEMMERMANN (Leybold AG, Hanau, Federal Republic of Germany) and GERHARD KIENEL (Karlsruhe, Technische Universitaet, Federal Republic of Germany) Advanced Materials and Processes (ISSN 0882-7958), vol. 140, Dec. 1991, p. 18-23. Copyright

In commercial operations, turbine blade-coating may be conducted via electron-beam vacuum evaporation, which is a PVD technique, and low-pressure plasma-spraying, which is a thermal-spray method possessing an equipment-cost advantage over PVD. Attention is presently given to the processing stages involved in vacuum evaporation, typical coating compositions, and vacuum-evaporation method variations. Low pressure plasma spraying is the only thermal-spray method capable of yielding the high coating purity and strong coating-substrate bond needed for turbine blade applications. O.C.

#### A92-18005

#### **ROLLING IN THE TOLERANCE**

Aerospace Composites and Materials (ISSN 0954-5832), vol. 3, Nov.-Dec. 1991, p. 30-33.

Copyright

Precision cold-rolling is recognized as a cost-effective method of producing net and near-net shapes with exotic and expensive alloys, such as those utilized in aerospace applications. This technique enables metal surfaces to be finished as finely as 10 to 16 rms, often eliminating the requirement for more final finishing operations. R.E.P.

A92-18362\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### ALGEBRAIC TURBULENCE MODELING FOR UNSTRUCTURED AND ADAPTIVE MESHES

DIMITRI J. MAVRIPLIS (NASA, Langley Research Center, AIAA Journal (ISSN 0001-1452), vol. 29, Dec. Hampton, VA) 1991, p. 2086-2093. Previously cited in issue 16, p. 2558, Accession no. A90-38781. refs Copyright

#### A92-18369

#### COMPRESSIBILITY EFFECTS IN THIN CHANNELS WITH INJECTION

A. LINAN, F. A. WILLIAMS (California, University, La Jolla), and G. BALAKRISHNAN AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2149-2154. Research supported by CICYT. refs (Contract AF-AFOSR-89-0310) Copyright

A theoretical analysis of the inviscid flow between a porous plate and a parallel impermeable plate is performed for small values of the ratio of the plate separation distance to the lateral extent of the plates, for both planar and axisymmetric geometries.

The problem of computing the flowfield is reduced to the solution of a single integral equation, which is accomplished numerically. The ratio of specific heats gamma is a parameter of the solution, and parametric results are presented from gamma = 1.0 to 1.67. The flow exhibits choking at a critical value of the lateral extent of the plate, in the vicinity of which the Mach number approaches unity. The results are needed in providing external boundary-layer conditions for studying the flame structure in the viscous region between two counterflowing streams when compressibility is important. Author

#### A92-18373\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. NUMERICAL STUDY ON USING SULFUR HEXAFLUORIDE AS

## A WIND TUNNEL TEST GAS

W. K. ANDERSON (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2179, 2180. Abridged. Previously cited in issue 16, p. 2544, Accession no. A90-37958. refs Copyright

#### A92-18377

#### EXPERIMENTAL AND THEORETICAL ANALYSIS OF COMPOSITE I-BEAMS WITH ELASTIC COUPLINGS

RAMESH CHANDRA and INDERJIT CHOPRA (Maryland, University, College Park) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2197-2206. refs (Contract DAAL03-88-C-022)

Copyright

#### A92-18830

#### SOME RESULTS ON METAL AND COMPOSITE PATCH REINFORCEMENT OF ALUMINUM HONEYCOMB PANEL

C. L. ONG and S. B. SHEN (Chung-Shan Institute of Science and Technology, Taichung, Republic of China) Theoretical and Applied Fracture Mechanics (ISSN 0167-8442), vol. 16, Nov. 1991, p. 145-153. refs

Copyright

Composite patches used to reinforce aircraft structures is on the increase as their advantages over that of rivet fastened metal patches are identified in application. This work further illustrates the superiority of bonding the cracked portion of an aluminum honeycomb panel with carbon or boron fiber-reinforced composite patches. Three different aluminum thicknesses were investigated: 2.5 mm, 4.1 mm, and 6.4 mm. The fatigue life increased three times over that of riveting metal patches to the same honeycomb. Moreover, repair can be administered to thicker structural components. Satisfactory results are obtained by honeycomb panels of 4.1 mm and 6.4 mm thick when patched, respectively, by adhesive bonding at room and higher temperature. Influence of the curing temperature on bonded strength is also discussed. Author

#### A92-19091

#### SIMULATION OF RADAR CLUTTER AND JET ENGINE MODULATION USING DIGITAL QUADRATURE MODULATOR

KENNETH R. HARRISON and RICHARD F. OLSON (Simulation Technologies, Inc., Huntsville, AL) IN: 1990 Annual Summer Computer Simulation Conference, 22nd, Calgary, Canada, July 16-18, 1990, Proceedings. San Diego, CA, Society for Computer Simulation, 1990, p. 907-911. refs Copyright

The use of a new Digital Quadrature Modulator (DQM) in radar signal synthesis is described. DQM performance measurements are compared with those from Linear Quadrature Modulators (LQMs) and found to be superior for a variety of signal synthesis trials. It is concluded that the introduction of the DQM-based signal generation into the RFSS will result in a marked reduction in setup and calibration time for the facility. Several changes are proposed to improve the DQM performance and allow it to operate on a wider range of input signals. C.D.

#### A92-19202

## AN ALTERNATIVE METHOD FOR ACQUIRING AVIONIC BUS DATA IN A CLASS I PCM TELEMETRY SYSTEM

THOMAS SALLEY and STEVEN E. THORSSELL (Metraplex Corp., Frederick, MD) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 1-5. refs

Copyright

IRIG 106-86 Chapter 8 describes the standard for acquisition of MIL-STD-1553 traffic flow. All incoming words (command, status, or data) are transmitted and fill words are used to maintain continuous data output. If all incoming words are not needed, or if other data such as sampled analog data from transducers are also to be transmitted, then a different approach is warranted. Selected data from the avionics bus can be placed into predefined PCM words, eliminating the transmission of useless data, and optimizing the bandwidth available to a Class I telemetry system. The engineering considerations and constraints for avionics bus data acquisition and analysis will be explored in this paper. Author

#### A92-19231

#### A STATE-OF-THE-ART DATA ACQUISITION SYSTEM

RICHARD D. TALMADGE (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) and MANSOUR RADMAND (Aydin Corp., Vector Div., Newtown, PA) IN: ITC/USA/'90; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 29-Nov. 2, 1990. Research Triangle Park, NC, Instrument Society of America, 1990, p. 351-360. refs

Copyright

Recent developments in manufacturing technology have afforded a new capability in miniaturized instrumentation systems. The advent of ASIC (Application Specific Integrated Circuit) technology has provided the tools to implement very sophisticated signal conditioning circuits in micro-miniature instrumentation. This paper discusses the development of the Automatic Gain Ranging Amplifier (AGRA) and its implementation in the Aydin Vector MMSC-800 instrumentation package. Also discussed is the miniaturization of a 1553 Bus monitor, IRIG-B Time Code reader/accumulator and the development of a helical scan miniature tape recording system capable of recording 2+ hours of 3.4 Mbps data. The paper concludes by giving applications for and benefits of using this new state-of-the-art instrumentation.

#### Author

#### A92-19463

#### REPRESENTATION OF GEOMETRIC STIFFENING IN MULTIBODY SYSTEM SIMULATION

OSKAR WALLRAPP and RICHARD SCHWERTASSEK (DLR, Institut fuer Dynamik der Flugsysteme, Oberpfaffenhofen, Federal Republic of Germany) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 32, Dec. 1991, p. 1833-1850. refs

Copyright

Geometric, rotational or dynamic stiffening is a well and long known phenomenon in the analysis of flexible bodies. In multibody dynamics the effect has attracted attention only recently. The objective of this paper is to contribute to the understanding of the modeling of geometric stiffening in multibody system simulation. Today's methods for modeling the effect assume that the (applied) stresses in a flexible system body are zero in its reference configuration, in which it performs large overall motions. The corresponding inertial loads are shown to be balanced by constraint stresses. This can be seen easily when formulating the system equations of motion for non-zero reference stresses. As a result one obtains an efficient alternative to compute the geometric stiffening terms. The method increases the generality of flexible body models for multibody system simulation.

#### A92-19618

#### LDV MEASUREMENTS AND INVESTIGATION OF FLOW FIELD THROUGH RADIAL TURBINE GUIDE VANES

HASAN EROGLU and WIDEN TABAKOFF (Cincinnati, University, OH) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 113, Dec. 1991, p. 660-667. refs (Contract DAAL03-87-G-0017; DAAL03-90-G-0129) Copyright

The results of LDV measurements and investigation of the detailed flow field in a radial inflow turbine nozzle are presented. The flow velocities were measured at upstream, inside and downstream of the nozzle blades for two different mass flow rates, using a three-component LDV system. Results are presented as contour plots of mean velocities, flow angles, and turbulence intensities. The flow field inside the nozzle blade passages was found to be influenced by the upstream scroll geometry. The flow turbulence increased in the downstream flow direction. The LDV mean flow results on the blade-to-blade midspan plane which is parallel to the end walls were also compared with an inviscid, 'panel method' solution.

#### A92-19677

## FATIGUE AND DAMAGE TOLERANCE VERIFICATION OF AIRCRAFT STRUCTURES

ANDERS F. BLOM (Aeronautical Research Institute of Sweden, Bromma) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 1. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 13-22. refs Copyright

The position is argued that to provide and maintain aircraft structural integrity comprehensive treatment be given to such interrelated issues as maintenance, testing, stress analysis, and load budgets. An overview is given of procedures related to damage-tolerance verification and fatigue analysis including initial flaw-size assumptions. The analytical concepts set forth emphasize the identification of fatigue-critical areas, the calculation of stress-intensity factors, and experimental truncation tests. Load spectra, interactions, and monitoring techniques are mentioned, and a protocol for structural testing is outlined. Durability of aircraft structures is found to be related to proper inspection and repair, whereas structural integrity relies primarily on data regarding flight profiles, the resulting load spectra, stress distributions, and material properties. C.C.S.

#### A92-19812

#### FRACTURE ANALYSIS AND CRACK PROPAGATION IN PRESSURIZED FUSELAGE STRUCTURES - EXPERIMENTAL AND NUMERICAL INVESTIGATIONS

E. BRUGNOLI, A. LA BARBERA, and M. MARCHETTI (Roma I, Universita, Rome, Italy) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2091-2096. Research supported by MPI. refs (Contract CNR-88,00370,11)

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The paper deals with fatigue-crack propagation and fracture analysis of pressurized fuselage structures. Cracks are initiated in the longitudinal direction, and during the propagation crack lengths are measured at both the crack tips. Finite-element analysis is developed in order to evaluate the elastic fields (stress, strain, and energy distributions), and both the overall and local responses are investigated. The effects of panel thickness and type of stiffening frame on crack propagation are singled out. Author

#### A92-19818

#### FATIGUE TESTING OF A GAS TURBINE FAN DISC

TARUN GOSWAMI (Wollongong, University, Australia) IN: Fatigue 90; Proceedings of the 4th International Conference on Fatigue and Fatigue Thresholds, Honolulu, HI, July 15-20, 1990. Vol. 4. Birmingham, England, Materials and Component Engineering Publications, Ltd., 1990, p. 2221-2226.

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Results are presented on a mission analysis of a gas turbine fan disc made of Ti6AL4V, assuming the predominance of

mechanical stresses. Results of disk tests on a cyclic spinning rig show that, for a fan disc of Ti6LA4V operating at room temperature, the number of equivalent cycles for a mission in the case of an engine in service is 75. The amplitude of rig rpm is 11,000, at the design limit. I.S.

#### A92-19977

### DARPA HIGH RESOLUTION DISPLAY TECHNOLOGIES

MARKO SLUSARCZUK (DARPA, Arlington, VA) IN: Airborne reconnaissance XIV; Proceedings of the Meeting, San Diego, CA, July 10-12, 1990. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 19-29.

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Much of the information of interest to pilots in flight is display-limited, and is undergoing substantial expansion due to improved sensor output and signal processing; attention is accordingly given to digitally-based instrument display imaging in the present evaluation of high-resolution cockpit display technologies. Also noted are the advantages of digitally transmitted sensor data in cases where the airborne reconnaissance user may be able to analyze telemetered airborne data in real time and respond with requests to the pilot for more detailed information of specific battlefield sites. O.C.

#### A92-19986

## RECONFIGURABLE MOBILE SYSTEM - GROUND, SEA AND AIR APPLICATIONS

GARY L. LAMONICA and JAMES W. STURGES (Loral Defense Systems, Litchfield Park, AZ) IN: Airborne reconnaissance XIV; Proceedings of the Meeting, San Diego, CA, July 10-12, 1990. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 128-137.

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The Reconfigurable Mobile System (RMS) is a highly mobile data-processing unit for military users requiring real-time access to data gathered by airborne (and other) reconnaissance data. RMS combines high-performance computation and image processing workstations with resources for command/control/communications in a single, lightweight shelter. RMS is composed of off-the-shelf components, and is easily reconfigurable to land-vehicle or shipboard versions. Mission planning, which involves an airborne sensor platform's sensor coverage, considered aircraft/sensor capabilities in conjunction with weather, terrain, and threat scenarios. RMS's man-machine interface concept facilitates user familiarization and features iron-based function selection and windowing. O.C.

#### A92-19988

#### AEROBUREAU - STRATEGIC TELEVISION AIRMOBILE REPORTS VIA SATELLITE

CHUCK DE CARO IN: Airborne reconnaissance XIV; Proceedings of the Meeting, San Diego, CA, July 10-12, 1990. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 173-198.

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'Aerobureau' is an airborne newsroom capable of furnishing news-gathering, communications, logistics, remote sensing, and satellite-uplink TV transmission functions for live coverage of major events. The Aerobureau organization plans to market its services to U.S. and foreign news networks, cable services, and local TV stations. Aerobureau will be unique in its ability to operate over politically unstable and logistically remote and isolated locales.

O.C.

**A92-20206\*** National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

#### PNĚUMATÍC DISTORTION COMPENSATION FOR AIRCRAFT SURFACE PRESSURE SENSING DEVICES

STEPHEN A. WHITMORE (NASA, Flight Research Center, Edwards, CA) and CORNELIUS T. LEONDES (Washington, University, Seattle) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 828-836. refs Copyright

In this paper a technique of compensating for pneumatic distortion in aircraft surface pressure sensing devices is developed. The compensation allows conventional pressure sensing technology to obtain improved unsteady pressure measurements. Pressure distortion caused by frictional attenuation and pneumatic resonance within the sensing system makes obtaining unsteady pressure measurements by conventional sensors difficult. Typically, most of the distortion occurs within the pneumatic tubing used to transmit pressure impulses from the surface of the aircraft to the measurement transducer. This paper develops a second-order distortion model that accurately describes the behavior of the primary wave harmonic of the pneumatic tubing. The model is expressed in state-variable form and is coupled with standard results from minimum-variance estimation theory to develop an algorithm to compensate for the effects of pneumatic distortion. Both postflight and real-time algorithms are developed and evaluated using simulated and flight data. Covariance selection and filter-tuning examples are presented. Results presented verify that, given appropriate covariance magnitudes, the algorithms accurately reconstruct surface pressure values from remotely sensed pressure measurements. Author

#### A92-20213

#### EXPERIMENTAL INVESTIGATION OF PERIODICALLY EXCITED ROTATING COMPOSITE ROTOR BLADES

O. RAND (Technion - Israel Institute of Technology, Haifa) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 876-884. refs

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Experimental procedure for investigating the structural dynamics characteristics of thin-walled composite helicopter rotor blades undergoing periodical excitation during rotation is proposed and demonstrated. The testing setup, which is based on measurements in a vacuum chamber, provides the isolation of the structural dynamics behavior by eliminating the aerodynamic loads and introducing deliberate periodic concentrated loads at the blade's tip. The study presented in this paper includes the testing of thin-walled composite box beams in the nonrotating static case and in the case of periodic loading during rotation at various angular speeds along with comparisons with theoretical predictions. The investigation of the measured composite-related couplings and rotational effects showed some significant nonlinear characteristics. Author

**A92-20215\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

## HEAT TRANSFER MEASUREMENTS FROM A SMOOTH NACA 0012 AIRFOIL

PHILIP E. POINSATTE, G. J. VAN FOSSEN, JAMES E. NEWTON (NASA, Lewis Research Center, Cleveland, OH), and KENNETH J. DE WITT (Toledo, University, OH) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 892-898. refs (Contract NAG3-72)

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Local convective heat transfer coefficients were measured from a smooth NACA 0012 airfoil having a chord length of 0.533 m. Flight data were taken for the smooth airfoil at Reynolds numbers based on chord in the range 1.24 to 2.50 million and at various angles of attack up to 4 deg. During these flight tests, the freestream velocity turbulence intensity was found to be very low. Wind tunnel data were acquired in the Reynolds number range 1.20 to 4.52 million and at angles of attack from -4 to +8 deg. The turbulence intensity in the IRT was 0.5-0.7 percent with the cloud-generating sprays off. A direct comparison between the results obtained in flight and in the IRT showed that the higher level of turbulence intensity in the IRT had little effect on the heat transfer for the lower Reynolds numbers but caused a moderate increase in heat transfer at the higher Reynolds numbers. Turning on the cloud-generating spray nozzle atomizing air in the IRT did not alter the heat transfer. The present data were compared with leading-edge cylinder and flat plate heat transfer correlations that are often used to estimate airfoil heat transfer in computer codes. Author

#### A92-20216 FLUTTER ANALYSIS OF ANISOTROPIC PANELS WITH PATCHED CRACKS

KUO-JIUN LIN, PONG-JEU LU, and JIANN-QUO TARN (National Cheng Kung University, Tainan, Republic of China) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 899-907. refs (Contract NSCRC-77-0210-D006-14)

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A finite element approach is developed to analyze the panel flutter problems of thin plate-like composite panels with patched cracks. The panel studies is a compound structure that comprises three layers including a thin cracked panel, an adhesive, and a thin patch. A 48-degree-of-freedom (DOF) triangular crack patching element is derived for numerically analyzing the compound structure. The aerodynamic pressure acting on the panel is estimated using linearized piston theory with aerodynamic damping effect neglected. By a proper tailoring of the materials, very high flutter and/or divergence boundary could usually be obtained for the composite panels. The existence of a crack usually reduces the aeroelastic stability boundary; however, some exceptions were found for the composite panel within certain range of specific filament orientation. The deterioration in flutter/divergence performance due to a crack can, in general, be cured by means of patching, and anisotropic patching is more effective as compared to the isotropic patching provided that the tailoring of the structural parameters is done correctly. Author

**A92-20217\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

## ROUGHNESS EFFECTS ON HEAT TRANSFER FROM A NACA 0012 AIRFOIL

PHILIP E. POINSATTE, G. J. VAN FOSSEN (NASA, Lewis Research Center, Cleveland, OH), and KENNETH J. DE WITT (Toledo, University, OH) Journal of Aircraft (ISSN 0021-8669), vol. 28, Dec. 1991, p. 908-911. Previously cited in issue 08, p. 1150, Accession no. A90-22180. refs (Contract NAG3-72)

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#### A92-20324

### TWO-DIMENSIONAL EFFECTS IN A TRIANGULAR CONVECTING FIN

A. AZIZ and H. NGUYEN (Gonzaga University, Spokane, WA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 6, Jan.-Mar. 1992, p. 165-167. refs Copyright

A FEM solution is presented for the two-dimensional triangular fin, together with heat-transfer data for a wide range of Biot number and length-to-base thickness ratio; the information may accordingly be used for purposes of performance prediction as well as design. In the case of design tasks, it must be recalled that the assumption

## of the analysis.

#### A92-20356 LIMITATIONS TO THE LARGE STRAIN THEORY

Y. M. CHENG (Hong Kong Polytechnic, Hong Kong) and Y. TSUI (University of Hong Kong, Hong Kong) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 33, Jan. 15, 1992, p. 101-114. refs Copyright

of a constant heat-transfer coefficient constitutes a major limitation

In the formulation of a large strain problem, the Euler-Cauchy-Stokes decomposition and the Eulerian objective stress and strain rates used for the formulation of the problem are actually applicable only for some special cases and are not suitable for general large strain and rotation rates. In this paper, the limitations and applicabilities of the conventional large strain formulation under various deformation cases will be studied.

Author

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#### A92-20741 DETECTION OF FLOW STATE IN AN UNSTEADY SEPARATING FLOW

M. A. RAMIZ and MUKUND ACHARYA (Illinois Institute of Technology, Chicago) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 117-123. Previously cited in issue 11, p. 1651, Accession no. A89-30527. refs (Contract F49620-86-C-0133)

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#### A92-20746

#### NONLINEAR STALL FLUTTER AND DIVERGENCE ANALYSIS OF CANTILEVERED GRAPHITE/EPOXY WINGS

PETER DUNN and JOHN DUGUNDJI (MIT, Cambridge, MA) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 153-162. Previously cited in issue 11, p. 1700, Accession no. A90-29373. refs

(Contract F49620-86-C-0066) Copyright

#### A92-20756

#### VIBRATION CHARACTERISTICS OF PRETWISTED AEROFOIL CROSS-SECTION BLADE PACKETS UNDER ROTATING CONDITIONS

M. SABUNCU (Ninth September University, Bornova, Turkey) and J. THOMAS (Surrey, University, Guildford, England) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 241-250. refs Copyright

Turbine blades are usually pretwisted and have asymmetric cross sections. Furthermore, turbine blades are formed into packets by joining them at critical locations with shrouds or lacing. Such a procedure alters the vibration characteristics of the blade. In this paper, the free vibration characteristics of rotating, shrouded, pretwisted aerofoil cross-section blade packets are investigated using a finite element model. One end of the pretwisted blade is assumed to be fixed at the periphery of a disk rotating about its center, whereas the other end of the blade is connected by a curved shroud. Expressions for kinetic and strain energies of a pretwisted blade packet subjected to centrifugal force are derived. Shear deformation and rotary inertia effects are neglected in the analysis. The effects pretwist, stagger angle, rotational speed, shroud length, shroud thickness, shroud width, and the distance of shear center from the centroid on the vibration characteristics of blade packets are investigated. Comparisons made between theoretical and experimental results show very good agreement.

Author

### A92-20764

## SIMPLE METHOD OF SUPERSONIC FLOW VISUALIZATION USING SMOKE

L. S. MILLER and E. IRANI (Wichita State University, KS) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 278, 279. refs Copyright

A modified smoke wire visualization method for application in high-speed and supersonic flows has been developed which produces a large number of fine smoke filaments that do not dissipate. This new technique is easily implemented in an open-inlet induction-type supersonic wind tunnel. Shock waves and expansion regions are clearly identified by the smoke filament behavior.

O.C.

### A92-20771

#### HOLOGRAPHIC-INTERFEROMETRY METHODS EMPLOYED FOR VIBRATION-STRENGTH TESTING OF AVIATION-ENGINE WORKPIECES

D. S. ELENEVSKII, N. I. KRAINIUKOV, IU. N. SHAPOSHNIKOV, and A. G. KHRAMOV (AN SSSR, Tsentral'noe Konstruktorskoe Biuro Unikal'nogo Priborostroeniia, Samara, USSR) Optics and Lasers in Engineering (ISSN 0143-8166), vol. 15, no. 5, 1991, p. 357-367. refs

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The vibroshifting fields generated by turbine blades and aerospace engines are calculated numerically with a mathematical system incorporating holographic-interferometry data. The vibroshift field is computed directly from the interferogram pattern, whereas the deformation and strain of the object are obtained experimentally

### 12 ENGINEERING

on the basis of the resulting data. The experimental installation is shown diagrammatically, and algorithms are presented which permit the analysis of brightness distributions of interferogram-pattern points, fringe centers, and the geometrical parameters of the image. Interferogram processing conducted on a PC with 512 x 512-pixel capacity is conducted for a compressor blade by means of the time-averaging and with the proposed local approximation by a second-order surface. The vibroshift vector field and corresponding projection demonstrate the results of detection of dark fringes and filtered skeletons facilitated by the method. C.C.S.

N92-13950\*# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aerodynamik und Gasdynamik.

## SUPERCRITICAL BLADE DESIGN ON STREAM SURFACES OF REVOLUTION WITH AN INVERSE METHOD

E. SCHMIDT and H.-D. GREIN *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 293-305 1991

Avail: NTIS HC/MF A99 CSCL 20D

A method to solve the inverse problem of supercritical blade-to-blade flow on stream surfaces of revolution with variable radius and variable stream surface thickness in a relative system is described. Some aspects of shockless design and of leading edge resolution in the numerical procedure are depicted. Some supercritical compressor cascades were designed and their complete flow field results were compared with computations of two different analysis methods. Author

#### N92-13962\*# Khmelnitsky Technological Inst. (USSR). IDENTIFICATION OF DYNAMIC CHARACTERISTICS OF FLEXIBLE ROTORS AS DYNAMIC INVERSE PROBLEM

W. P. ROISMAN and L. D. VAJINGORTIN *In* Pennsylvania State Univ., Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 457-468 1991

#### Avail: NTIS HC/MF A99 CSCL 20D

The problem of dynamic and balancing of flexible rotors were considered, which were set and solved as the problem of the identification of flexible rotor systems, which is the same as the inverse problem of the oscillation theory dealing with the task of the identifying the outside influences and system parameters on the basis of the known laws of motion. This approach to the problem allows the disclosure the picture of disbalances throughout the rotor-under-test (which traditional methods of flexible rotor balancing, based on natural oscillations, could not provide), and identify dynamic characteristics of the system, which correspond to a selected mathematical model. Eventually, various methods of balancing were developed depending on the special features of the machines as to their design, technology, and operation specifications. Also, theoretical and practical methods are given for the flexible rotor balancing at far from critical rotation frequencies, which does not necessarily require the knowledge forms of oscillation, dissipation, and elasticity and inertia characteristics, and to use testing masses. Author

N92-13985# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

#### NONSTATIONARY GASDYNAMICS

J. J. GOTTLIEB, C. P. T. GROTH, R. J. HAWBOLDT, D. F. HAWKEN, G. D. LOCK, C. H. WONG, Y. S. CHAN, J. MAILLETTE, G. L. PETRINI, J. S. PICKET et al. *In its* Activities of the University of Toronto Institute for Aerospace Studies p 93-95 1989 Avail: NTIS HC/MF A06

A review is provided of nonstationary gas dynamic investigations carried out at the University of Toronto Institute for Aerospace Studies. Numerical studies aimed at predicting the operation and performance of two stage light-gas guns and selecting optimum gas operating conditions are ongoing. Preliminary internal ballistics work on modelling the motions of propellant gases and projectiles in an experimental gun with a high pressure combustion section and a low pressure launch tube has been completed. The study of propellant combustion in a closed vessel to obtain propellant burning rates and combustion gas properties for use in modelling of gas guns is now underway. The nonequilibrium structure of a shock front in a dusty gas is being studied in a dusty shock tube facility to determine particle drag and heat transfer coefficients. Studies undertaken to provide data for the design of a large air-blast and thermal simulation facility include: investigation of the reflection eliminator, the venting from the test section of combustion products from thermal radiation sources, and the prediction of unsteady flow. A high pressure reservoir with an exit nozzle containing a slot has been constructed to obtain experimental data on discharge coefficients of orifices and slots in high-low pressure guns and on blast simulators.

CISTI

#### N92-14210\*# Rome Air Development Center, Griffiss AFB, NY. ARCHITECTURE FOR SURVIVABLE SYSTEM PROCESSING (ASSP)

RICHARD J. WOOD /n NASA. Lewis Research Center, Space Communications Technology Conference: Onboard Processing and Switching p 69-74 Nov. 1991

Avail: NTIS HC/MF A13 CSCL 17/2

The Architecture for Survivable System Processing (ASSP) Program is a multi-phase effort to implement Department of Defense (DOD) and commercially developed high-tech hardware, software, and architectures for reliable space avionics and ground based systems. System configuration options provide processing capabilities to address Time Dependent Processing (TDP), Object Dependent Processing (ODP), and Mission Dependent Processing (MDP) requirements through Open System Architecture (OSA) alternatives that allow for the enhancement, incorporation, and capitalization of a broad range of development assets. High technology developments in hardware, software, and networking models, address technology challenges of long processor life times, fault tolerance, reliability, throughput, memories, radiation hardening, size, weight, power (SWAP) and security. Hardware and software design, development, and implementation focus on the interconnectivity/interoperability of an open system architecture and is being developed to apply new technology into practical OSA components. To insure for widely acceptable architecture capable of interfacing with various commercial and military components, this program provides for regular interactions with standardization working groups (e.g.) the International Standards Organization (ISO), American National Standards Institute (ANSI), Society of Automotive Engineers (SAE), and Institute of Electrical and Electronic Engineers (IEEE). Selection of a viable open architecture is based on the widely accepted standards that implement the ISO/OSI Reference Model. Author

N92-14217\*# TRW Space Technology Labs., Redondo Beach, CA. Space and Technology Group.

GETTING EXPERT SYSTEMS OFF THE GROUND: LESSONS LEARNED FROM INTEGRATING MODEL-BASED

## DIAGNOSTICS WITH PROTOTYPE FLIGHT HARDWARE

AMY STEPHAN and CAROL A. ERIKSON /n NASA. Lewis Research Center, Space Communications Technology Conference: Onboard Processing and Switching p 135-141 Nov. 1991 Avail: NTIS HC/MF A13 CSCL 17/2

As an initial attempt to introduce expert system technology into an onboard environment, a model based diagnostic system using the TRW MARPLE software tool was integrated with prototype flight hardware and its corresponding control software. Because this experiment was designed primarily to test the effectiveness of the model based reasoning technique used, the expert system ran on a separate hardware platform, and interactions between the control software and the model based diagnostics were limited. While this project met its objective of showing that model based reasoning can effectively isolate failures in flight hardware, it also identified the need for an integrated development path for expert system and control software for onboard applications. In developing expert systems that are ready for flight, artificial intelligence techniques must be evaluated to determine whether they offer a real advantage onboard, identify which diagnostic functions should be performed by the expert systems and which are better left to the procedural software, and work closely with both the hardware and the software developers from the beginning of a project to produce a well designed and thoroughly integrated application. Author

N92-14262\*# Ohio State Univ., Columbus. ElectroScience Lab. SATCOM ANTENNA SITING STUDY ON P-3C AIRCRAFT, VOLUME 1 Final Report

D. A. BENSMAN and R. J. MARHEFKA Sep. 1991 198 p (Contract NAG2-542)

(NASA-CR-189514; NAS 1.26:189514; FR-721711-4-VOL-1) Avail: NTIS HC/MF A09 CSCL 20/14

The NEC-BSC (Basic Scattering Code) was used to study the performance of a SATCOM antenna on a P-3C aircraft. After plate cylinder fields are added to version 3.1 of the NEC-BSC, it is shown that the NEC-BSC can be used to accurately predict the performance of a SATCOM antenna system on a P-3C aircraft. The study illustrates that the NEC-BSC gives good results when compared with scale model measurements provided by Boeing and Lockheed. Author

N92-14263\*# Ohio State Univ., Columbus. ElectroScience Lab. SATCOM ANTENNA SITING STUDY ON P-3C AIRCRAFT, VOLUME 2 Final Report

D. A. BENSMAN and R. J. MARHEFKA Sep. 1991 193 p (Contract NAG2-542)

(NASA-CR-189515; NAS 1.26:189515; FR-721711-4-VOL-2) Avail: NTIS HC/MF A09 CSCL 20/14

This volume contains an antenna location study for the P-3C aircraft. From this location study, a determination can be made of the complete antenna system required to achieve the desired pattern and polarization coverage. The antenna used is the same Batwing airborne UHF satellite communications antenna use in volume 1. The aircraft model used in the majority of the locations studied is the simple cylindrical aircraft model defined in volume 1. Author

#### N92-14270# Federal Aviation Administration, Atlantic City, NJ. DATA MULTIPLEXING NETWORK (DMN) PHASE 3 EQUIPMENT OPERATIONAL TEST AND EVALUATION (OT AND E)/INTEGRATION TEST REPORT WAYNE F. BELL Dec. 1991 123 p.

WAYNE E. BELL Dec. 1991 123 p (DOT/FAA/CT-TN91/50) Avail: NTIS HC/MF A06

This test report contains the results of the Operational Test and Evaluation (OT&E)/Integration testing of the Data Multiplexing Network (DMN) Phase 3 B Commercial Off-The-Shelf (COTS) Equipment. The OT&E/Integration testing was accomplished by conducting unit level tests at the Federal Aviation Administration (FAA) Technical Center, and integration tests at the key test sites of Albuquerque, New Mexico; Minneapolis, Minnesota; and Denver, Colorado, Air Route Traffic Control Centers (ARTCC's). The FAA-E-2786 Verification Requirement Matrix (VRTM) and NAS-SS-1000, Volumes 1 and 4, were verified during OT&E/Integration. Also, the test results determined the operational effectiveness and suitability of the Motorola Codex COTS equipment in the National Airspace System (NAS) environment. Based on the test results, it is concluded that the Motorola Codex COTS equipment performed its function of providing data exchange between NAS facilities and is considered qualified for operational development. Author

#### N92-14309# David Taylor Research Center, Bethesda, MD. NAVIER-STOKES ANALYSIS OF TURBULENT BOUNDARY LAYER AND WAKE FOR TWO-DIMENSIONAL LIFTING BODIES

PHUC NGUYEN and J. GORSKI *In* NAS-NRC, Eighteenth Symposium on Naval Hydrodynamics p 633-644 1991 Avail: NTIS HC/MF A99

Navier-Stokes calculations were performed on two 2-D lifting foils which have been tested in a wind tunnel. In the experiment, the angles of attack for the two foils were set up to yield approximately the same lift at a Reynolds number of 2.25x10(exp 6) (based on chord). One foil has a thicker trailing edge than the other, and has mild flow separation on the last 4 percent chord of the suction side. The flow solver, called the David Taylor Navier-Stokes (DTNS) code, is formulated with artificial compressibility and upwind differencing. The Launder-Spalding kappa-epsilon turbulence model is used. Predictions of the turbulent flow quantities of the boundary layer and wake are compared with the experimental data for both foils. These predictions, including flow separation location, agree reasonably well with the data. After these validation predictions, the Navier-Stokes analysis method and a design technique based on conformal mapping are combined to develop new 2-D foil sections. Since the turbulent kinetic energy is the dynamic pressure, and the Reynolds shear stresses are related to the turbulence production, these quantities are used to develop new 2-D sections with desirable turbulent boundary layer characteristics. The characteristics of one new section are presented as results of the new foil design process. Author

**N92-14310\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

## A NĂVIER-STOKES SOLUTION OF HULL-RING WING-THRUSTER INTERACTION

C.-I. YANG (David Taylor Research Center, Bethesda, MD.), P. HARTWICH, and P. SUNDARAM *In* NAS-NRC, Eighteenth Symposium on Naval Hydrodynamics p 687-696 1991 Avail: NTIS HC/MF A99 CSCL 20/4

Navier-Stokes simulations of high Reynolds number flow around an axisymmetric body supported in a water tunnel were made. The numerical method is based on a finite-differencing high resolution second-order accurate implicit upwind scheme. Four different configurations were investigated, these are: (1) barebody; (2) body with an operating propeller; (3) body with a ring wing; and (4) body with a ring wing and an operating propeller. Pressure and velocity components near the stern region were obtained computationally and are shown to compare favorably with the experimental data. The method correctly predicts the existence and extent of stern flow separation for the barebody and the absence of flow separation for the three other configurations with ring wing and/or propeller.

**N92-14313\*#** Nevada Univ., Reno. Engineering Research and Development Center.

NUMERICAL INVESTIGATIONS IN THREE-DIMENSIONAL

INTERNAL FLOWS Semiannual Status Report, 1 Jul. - 31 Dec. 1991

WILLIAM C. ROSE 1991 27 p

(Contract NCC2-507)

(NASA-CR-189467; NAS 1.26:189467) Avail: NTIS HC/MF A03 CSCL 20/4

The general objectives of NASA's Generic Hypersonics Research Program (GHP) are to develop a technology background required for aeronautical research in the hypersonic Mach number flow range. These research efforts are to complement the National Aerospace Plane (NASP) Program and are geared toward the development of experimental and computational fluid dynamics (CFD) techniques. One of the prominent goals of inlet design for high speed applications is to produce an inlet that delivers uniform flow at its exit in the shortest possible distance. In previous studies, the technologies for determining contours for both the ramp and cowl were demonstrated that allowed a nearly shock free exiting flow field to be obtained. This technology was developed further during the present reporting period and applied to a preliminary design investigation of a biconic hypersonic research vehicle with a nearly 2-D inlet attached near the aft end of the vehicle. The results of a parametric investigation of this proposed inlet for freestream Mach numbers between 10 and 15 are described.

Author

**N92-14344\***# Texas A&M Univ., College Station. Dept. of Mechanical Engineering.

NONLINEAR ROTORDYNAMICS ANALYSIS Final Report SHERIF T. NOAH Feb. 1991 96 p

### 12 ENGINEERING

#### (Contract NAS8-37465)

(NASA-CR-184263; NAS 1.26:184263) Avail: NTIS HC/MF A05 CSCL 13/9

Effective analysis tools were developed for predicting the nonlinear rotordynamic behavior of the Space Shuttle Main Engine (SSME) turbopumps under steady and transient operating conditions. Using these methods, preliminary parametric studies were conducted on both generic and actual HPOTP (high pressure oxygen turbopump) models. In particular, a novel modified harmonic balance/alternating Fourier transform (HB/AFT) method was developed and used to conduct a preliminary study of the effects of fluid, bearing and seal forces on the unbalanced response of a multi-disk rotor in the presence of bearing clearances. The method makes it possible to determine periodic, sub-, super-synchronous and chaotic responses of a rotor system. The method also yields information about the stability of the obtained response, thus allowing bifurcation analyses. This provides a more effective capability for predicting the response under transient conditions by searching in proximity of resonance peaks. Preliminary results were also obtained for the nonlinear transient response of an actual HPOTP model using an efficient, newly developed numerical method based on convolution integration. Currently, the HB/AFT is being extended for determining the aperiodic response of nonlinear systems. Initial results show the method to be promisina. Author

N92-14345# Defence Research Establishment Pacific, Victoria (British Columbia). Research and Development Branch. FILTER DEBRIS ANALYSIS: A CONCRETE APPROACH TO WEAR DIAGNOSIS

H. P. DOMINIQUE and A. J. MCKENZIE (RE TECH Ltd., Victoria, British Columbia ) Nov. 1988 29 p Original contains color illustrations

(DREP-TM-88-20; CTN-91-60271) Avail: NTIS HC/MF A03

The diagnostic merits of microscopic inspection and chemical analysis of metallic debris recovered from lubricating oil filters in a variety of oil-wetted machinery are discussed. The filter cleaning method and how it affects the amount of debris recovered is considered. The significance of representative debris levels and some criteria for establishing these levels are discussed. Abnormat accumulations and the corresponding mechanical debris malfunctions are presented to illustrate how filter debris analysis can be used to diagnose increased component wear in a variety of machinery. Merits for application of this technique for the diagnosis of machinery condition are considered. The report concludes that this method of assessing wear is particularly suited for equipment fitted with fine lubricating oil filters such as diesel, turbo-prop, and gas turbine engines and is recommended as a complement to other methods currently used for machinery Author (CISTI) condition monitoring.

**N92-14346\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### ROTORDYNAMIC INSTABILITY PROBLEMS IN

#### **HIGH-PERFORMANCE TURBOMACHINERY, 1990**

Washington Oct. 1991 458 p Workshop held in College Station, TX, 21-23 May 1990; sponsored by Texas A and M Univ. and NASA. Lewis Research Center

(NASA-CP-3122; E-5628; NAS 1.55:3122) Avail: NTIS HC/MF A20 CSCL 13/9

The present workshop continues to report field experience and experimental results, and it expands the use of computational and control techniques with the integration of damper, bearing, and eccentric seal operation results. The intent of the workshop was to provide a continuing impetus for an understanding and resolution of these problems.

**N92-14348\*#** Kyushu Electric Power Co., Inc., Fukuoka (Japan). Thermal Power Dept.

FIELD TELEMETRY OF BLADE-ROTOR COUPLED TORSIONAL VIBRATION AT MATUURA POWER STATION NUMBER 1 UNIT

KUNIYOSHI ISII, HIDEAKI MURAKAMI, YASUHIKO OTAWARA,

and AKIRA OKABE (Hitachi Ltd., Japan) /n NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 15-20 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

The quasi-modal reduction technique and finite element model (FEM) were used to construct an analytical model for the blade-rotor coupled torsional vibration of a steam turbine generator of the Matuura Power Station. A single rotor test was executed in order to evaluate umbrella vibration characteristics. Based on the single rotor test results and the quasi-modal procedure, the total rotor system was analyzed to predict coupled torsional frequencies. Finally, field measurement of the vibration of the last stage buckets was made, which confirmed that the double synchronous resonance was 124.2 Hz, meaning that the machine can be safely operated. The measured eigen values are very close to the predicted value. The single rotor test and this analytical procedure thus proved to be a valid technique to estimate coupled torsional vibration.

Author

**N92-14349\***# Southampton Univ. (England). Dept. of Mechanical Engineering.

### THE EFFECTS OF MANUFACTURING TOLERANCES ON THE

**VIBRATION OF AERO-ENGINE ROTOR-DAMPER ASSEMBLIES** J. E. H. SYKES and R. HOLMES *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 21-47 Oct. 1991 Sponsored in part by The Science and Engineering Research Council, England, and Rolls Royce plc

Avail: NTIS HC/MF A20 CSCL 13/9

A range of rotor assemblies incorporating one and two squeeze film dampers with various static misalignments is investigated. Waterfall diagrams are constructed which demonstrate the effects of such misalignment and damper support flexibility on the nature and severity of subsynchronous resonance and jump phenomena. Vibration signatures of similar rotor-bearing assemblies are shown to contrast strongly due to different accumulations of tolerances during manufacture, fitting, and operation. Author

**N92-14350\***# Northwestern Polytechnical Univ., Xian (China). Vibration Research Council.

#### THE STABILITY OF THE STEADY STATE AND BISTABLE RESPONSE OF A FLEXIBLE ROTOR SUPPORTED ON SQUEEZE FILM DAMPERS

GUANG MENG *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 49-62 Oct. 1991 Original language document was announced in IAA as A91-22355 Sponsored in part by Aviation Scientific Foundation of China

Avail: NTIS HC/MF A20 CSCL 13/9

The stability of the steady state response, the bistable response, and the jumping characteristics are analyzed for the case when a system accelerates or decelerates through the bistable region of a flexible rotor-centralized squeeze film damper system. It was found that the system steady state responses have two unstable regions. The larger the unbalance parameter and the smaller the bearing parameter and the external damping ratio, the easier it is for the system to lose stability. The larger the mass ratio and the smaller the stiffness ratio, the lower the threshold rotating speed of instability. The instability of the system steady-state response determined here is due to the system nonsynchronous response in many cases. Author

#### N92-14351\*# University of South Florida, Tampa. STABILITY OF INTERSHAFT SQUEEZE FILM DAMPERS

A. EL-SHAFEI *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 63-77 Oct. 1991 Previously announced in IAA as A91-50240 Avail: NTIS HC/MF A20 CSCL 13/9

Intershaft squeeze film dampers were investigated for damping of dual rotor aircraft jet engines. It was thought that the intershaft damper would enhance the stability of the rotor-bearing system. Unfortunately, it was determined that the intershaft squeeze film damper was unstable above the engine's first critical speed. Here, a stability analysis of rotors incorporating intershaft squeeze film dampers is discussed. A rotor model consisting of two Jeffcott rotors with two intershaft squeeze film dampers was investigated. Examining the system characteristic equation for the conditions at which the roots indicate an ever-growing unstable motion results in the stability conditions. The cause of the instability is identified as the rotation of the oil in the damper clearance. Several proposed configurations of intershaft squeeze film dampers are discussed, and it is shown that the intershaft dampers are stable supercritically only with a configuration in which the oil film does not rotate.

Author

#### N92-14354\*# Stuttgart Univ. (Germany, F.R.). Inst. fuer Thermische Stroemungsmaschinen und Maschinenlaboratorium. EXPERIMENTAL INVESTIGATIONS OF EXCITING FORCES CAUSED BY FLOW IN LABYRINTH SEALS

G. THIELEKE and H. STETTER *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 109-134 Oct. 1991 Sponsored in part by Forschungsvereinigung Verbrennungskraftmaschinen e. V., Frankfurt/Main, Fed. Republic of Germany

Avail: NTIS HC/MF A20 CSCL 13/9

The interaction of the flow through the labyrinth seals with the shaft of the rotor can have an effect on the stability of turbomachines. Thus, the excited forces, so-called cross forces or nonconservative forces, arise, which act perpendicular to the rotor eccentricity. This effect is caused by an unsymmetrical pressure distribution within the labyrinth cavities. Experimental studies were carried out for different types of labyrinth geometries: two staggered labyrinths with teeth on the stator and grooved rotor as well as a full and a convergent stepped labyrinth. These labyrinths can be found on the tip shrouding of bladings in steam or gas turbines. The following parameters were varied in the test facility: geometry of the labyrinth seals (number of cavities, inlet region), shaft rotation, pressure difference on the seal, entry swirl and eccentricity of the rotor. The results are presented for stiffness coefficients of the labyrinth seals, leakage flow and circumferential flow in each cavity which was measured with special probes. Generally, the inlet swirl has the greatest influence on the coefficients of the seals. The experimental results were compared with theoretical results and were in good agreement. Author

N92-14356\*# Kaiserslautern Univ. (Germany, F.R.). Dept. of Mechanical Engineering. EVALUATION OF ROTORDYNAMIC COEFFICIENTS OF

#### EVALUATION OF ROTORDYNAMIC COEFFICIENTS OF LOOK-THROUGH LABYRINTHS BY MEANS OF A THREE VOLUME BULK FLOW MODEL

R. NORDMANN and P. WEISER *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 147-163 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

To describe the compressible, turbulent flow in a labyrinth seal, a three volume bulk flow model is presented. The conservation equations for mass, momentum, and energy are established in every control volume. A perturbation analysis is performed, yielding zeroth order equations for centric rotor position and first order equations describing the flow field for small rotor motions around the seal center. The equations are integrated numerically. From perturbation pressure, the forces on the shaft and the dynamic coefficients are calculated. Author

N92-14357\*# Texas A&M Univ., College Station. Turbomachinery Lab.

#### TEST RESULTS FOR ROTORDYNAMIC COEFFICIENTS OF THE SSME HPOTP TURBINE INTERSTAGE SEAL WITH TWO SWIRL BRAKES

DARA W. CHILDS, ERIAN BASKHARONE, and CHRISTOPHER RAMSEY In NASA. Lewis Research Center, Rotodynamic Instability Problems in High-Performance Turbomachinery, 1990 p 165-178 Oct. 1991 Previously announced in IAA as A91-29469

(Contract NAG3-181)

Avail: NTIS HC/MF A20 CSCL 13/9

Test results are presented for the HPOTP Turbine Interstage Seal with both the current and an alternate, aerodynamically designed, swirl brake. Tests were conducted at speeds out to 16,000 rpm, supply pressures up to 18.3 bars, and the following three inlet tangential velocity conditions: (1) no preswirl; (2) intermediate preswirl in the direction of rotation; and (3) high preswirl in the direction of rotation. The back pressure can be controlled independently and was varied to yield the following four pressure ratios: 0.4, 0.45, 0.56, and 0.67. The central and simplest conclusion to be obtained from the test series is that the alternate swirl brake consistently outperforms the current swirl brake in terms of stability performance. The alternate swirl brake's whirl frequency ratio was generally about one half or less than corresponding values for the current design. In many cases, the alternate design yielded negative whirl frequency ratio values in comparison to positive values for the current design. The alternate design can be directly substituted into the space currently occupied by the current design. There is no change in leakage performance. Author

**N92-14360\*#** Kaiserslautern Univ. (Germany, F.R.). Dept. of Mechanical Engineering.

#### DETERMINATION OF ROTORDYNAMIC COEFFICIENTS FOR LABYRINTH SEALS AND APPLICATION TO ROTORDYNAMIC DESIGN CALCULATIONS

P. WEISER and R. NORDMANN /n NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 203-221 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

In today's rotordynamic calculations, the input parameters for a finite element analysis (FEA) determine very much the reliability of eigenvalue and eigenmode predictions. While modeling of an elastic structure by means of beam elements etc. is relatively straightforward to perform and the input data for journal bearings are usually known exactly enough, the determination of stiffness and damping for labyrinth seals is still the subject of many investigations. Therefore, the rotordynamic influence of labyrinths is often not included in FEA for rotating machinery because of a lack of computer programs to calculate these parameters. This circumstance can give rise to severe vibration problems especially for high performance turbines or compressors, resulting in remarkable economic losses. The forces generated in labyrinths can be described for small motions around the seal center with a linearized force-motion relationship. Several years ago, we started with the development of computer codes for the determination of rotordynamic seal coefficients. Our different approaches to evaluate the dynamic fluid forces generated by turbulent, compressible seal flow are introduced. Author

#### N92-14361\*# Kobe Univ. (Japan). Faculty of Engineering. EXPERIMENT OF STATIC AND DYNAMIC CHARACTERISTICS OF SPIRAL GROOVED SEALS

T. IWATSUBO, B. C. SHENG, and M. ONO *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 223-233 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

The leakages and the dynamic characteristics of six types of spiral grooved seals are experimentally investigated. The effect of the helix angle of the seal is investigated mainly under the condition of the same nominal clearances, land and groove lengths, and groove depths. The dynamic characteristics are measured for various parameters such as preswirl velocity, pressure difference between inlet and outlet of the seal, whirling amplitude, whirling speed, and rotating speed of the rotor. The results are also compared with leakage increases with the increase of the helix angle, but as the rotating speed increases, the leakages of the larger helix angle seals quickly drop. The leakage of the smooth-stator (SS)/smooth-grooved rotor (SGR) seal drops faster than that of the spiral-grooved stator (SGS)/smooth-rotor (SR) seal. It is found that a circumferential flow can be produced by the flow along the helix angle direction, and this circumferential flow acts as a negative swirl. For the present helix angle range, there is an optimum helix angle with which the seal has a

comparatively positive effect on the rotor stability. Compared with the SGS/SR seals, the SS/SGR seal has a worse effect on the Author rotor stability.

#### N92-14362\*# Sulzer Bros. Ltd., Winterthur (Switzerland). ANNULAR SEALS OF HIGH ENERGY CENTRIFUGAL PUMPS: PRESENTATION OF FULL SCALE MEASUREMENT

S. FLORJANCIC, R. STUERCHLER, and T. MCCLOSKEY (Electric Power Research Inst., Palo Alto, CA.) In NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 235-267 Oct. 1991

(Contract RP-1884-10)

Avail: NTIS HC/MF A20 CSCL 13/9

Prediction of rotordynamic behavior for high energy concentration centrifugal pumps is a challenging task which still imposes considerable difficulties. While the mechanical modeling of the rotor is solved most satisfactorily by finite element techniques, accurate boundary conditions for arbitrary operating conditions are known for journal bearings only. Little information is available on the reactive forces of annular seals, such as neck ring and interstage seals and balance pistons, and on the impeller interaction forces. The present focus is to establish reliable boundary conditions at annular seals. For this purpose, a full scale test machine was set up and smooth and serrated seal configurations measured. Dimensionless coefficients are presented and compared with a state of the art theory. Author

N92-14363\*# Technische Univ., Munich (Germany, F.R.). Inst. of Mechanics.

#### HYDRAULIC ACTUATOR SYSTEM FOR ROTOR CONTROL

HEINZ ULBRICH and JOSEF ALTHAUS In NASA, Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbornachinery, 1990 p 269-284 O Avail: NTIS HC/MF A20 CSCL 13/9 Oct. 1991

In the last ten years, several different types of actuators were developed and fabricated for active control of rotors. A special hydraulic actuator system capable of generating high forces to rotating shafts via conventional bearings is addressed. The actively controlled hydraulic force actuator features an electrohydraulic servo valve which can produce amplitudes and forces at high frequencies necessary for influencing rotor vibrations. The mathematical description will be given in detail. The experimental results verify the theoretical model. Simulations already indicate the usefulness of this compact device for application to a real rotor system. Author

N92-14364\*# General Electric Co., Cincinnati, OH. Aircraft Engines.

#### A SIMPLIFIED METHOD FOR PREDICTING THE STABILITY OF AERODYNAMICALLY EXCITED TURBOMACHINERY

In NASA. Lewis Research Center, ALBERT F. STORACE Problems in High-Performance Rotordynamic Instability Turbomachinery, 1990 p 285-299 Oct. 1991

Avail: NTIS HC/MF A20 CSCL 13/9

A method is presented for the quick and accurate prediction of the stability of aerodynamically excited turbomachinery using real eigenvalue/eigenvector data obtained from a rotordynamics model. An expression is presented which uses the modal data and the transmitted torque to provide a numerical value of the relative stability of the system. This approach provides a powerful design tool to quickly ascertain the effects of squeeze-film damper bearings, bearing location, and support changes on system stability. Author

#### N92-14366\*# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.

#### DYNAMIC CHARACTERISTICS AND STABILITY ANALYSIS OF SPACE SHUTTLE MAIN ENGINE OXYGEN PUMP

EDGAR J. GUNTER and LYLE BRANAGAN In NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 317-344 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

The dynamic characteristics of the Space Shuttle high pressure

oxygen pump are presented. Experimental data is presented to show the vibration spectrum and response under actual engine operation and also in spin pit testing for balancing. The oxygen pump appears to be operating near a second critical speed and is sensitive to self excited aerodynamic cross coupling forces in the turbine and pump. An analysis is presented to show the improvement in pump stability by the application of turbulent flow seals, preburner seals, and pump shaft cross sectional modifications. Author

N92-14367\*# Bently Rotor Dynamics Research Corp., Minden, NV

#### **ROTOR-TO-STATOR PARTIAL RUBBING AND ITS EFFECTS ON ROTOR DYNAMIC RESPONSE**

AGNES MUSZYNSKA, WESLEY D. FRANKLIN, and ROBERT D. HAYASHIDA In NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 345-362 Oct. 1991

(Contract NAS8-36719)

Avail: NTIS HC/MF A20 CSCL 13/9

Results from experimental and analytical studies on rotor to stationary element partial rubbings at several locations and their effects on rotor dynamic responses are presented. The mathematical model of a rubbing rotor is given. The computer program provides numerical results which agree with experimentally obtained rotor responses. Author

Bently Rotor Dynamics Research Corp., Minden, N92-14370\*# NV

#### COMMENTS ON FREQUENCY SWEPT ROTATING INPUT PERTURBATION TECHNIQUES AND IDENTIFICATION OF THE FLUID FORCE MODELS IN ROTOR/BEARING/SEAL SYSTEMS AND FLUID HANDLING MACHINES

AGNES MUSZYNSKA and DONALD E. BENTLY In NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 391-410 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

Perturbation techniques used for identification of rotating system dynamic characteristics are described. A comparison between two periodic frequency-swept perturbation methods applied in identification of fluid forces of rotating machines is presented. The description of the fluid force model identified by inputting circular periodic frequency-swept force is given. This model is based on the existence and strength of the circumferential flow, most often generated by the shaft rotation. The application of the fluid force model in rotor dynamic analysis is presented. It is shown that the rotor stability is an entire rotating system property. Some areas for further research are discussed. Author

N92-14371\*# Newcastle Polytechnic, Newcastle-upon-Tyne (England).

#### THE APPLICATION OF A CYLINDRICAL-SPHERICAL FLOATING RING BEARING AS A DEVICE TO CONTROL STABILITY OF TURBOGENERATORS

P. S. LEUNG, I. A. CRAIGHEAD, and T. S. WILKINSON (NEI Parsons Ltd., Newcastle-upon-Tyne, England ) /n NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 411-426 Oct. 1991 Avail: NTIS HC/MF A20 CSCL 13/9

The development of a new device to control stability of turbogenerators is described. The device comprises a floating ring installed between the journal and bearing housing of a fluid film bearing. The journal and the inner surface of the ring are cylindrical while the outer surface of the ring and bearing surface are spherical providing axial location of the ring and self-alignment of the bearing. The employment of this device would lead to a consistent machine performance. System stability may be controlled by changing a number of bearing and floating ring parameters. This device also offers an additional advantage of having a very low frictional characteristic. A feasibility study was carried out to investigate the suitability of the new device to turbogenerator applications. Both theoretical analysis and experimental observations were carried

out. Initial results suggest that the new floating ring device is a competitive alternative to other conventional arrangements.

Author

**N92-14373\*#** Texas A&M Univ., College Station. Dept. of Mechanical Engineering.

### EFFECT OF EČCENTŘICITY ON THE STATIC AND DYNAMIC PERFORMANCE OF A TURBULENT HYBRID BEARING

LUIS A. SANANDRES *In* NASA. Lewis Research Center, Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 443-459 Oct. 1991 Sponsored in part by Rockwell International Corp., and State of Texas Advanced Technology Program

Avail: NTIS HC/MF A20 CSCL 13/9

The effect of journal eccentricity on the static and dynamic performance of a water lubricated, 5-recess hybrid bearing is presented in detail. The hydrostatic bearing has been designed to operate at a high speed and with a large level of external pressurization. The operating conditions determine the flow in the bearing to be highly turbulent and strongly dominated by fluid inertia effects. The analysis covers the spectrum of journal center displacements directed towards the middle of a recess and towards the mid-land portion between two consecutive recesses. Predicted dynamic force coefficients are uniform for small to moderate eccentricities. For large journal center displacements, fluid cavitation and recess position determine large changes in the bearing dynamic performance. The effect of fluid inertia force coefficients on the threshold speed of instability and whirl ratio of a single mass flexible rotor is discussed.

**N92-14374\*#** Aerojet-General Corp., Sacramento, CA. Propulsion Div.

## CERAMIC REGENERATOR PROGRAM Final Report, Aug. 1988 - Jun. 1991

JERROLD E. FRANKLIN Nov. 1991 180 p Original contains color illustrations

(Contract NAS3-25416)

(NASA-CR-189053; NAS 1.26:189053; KFF-FR; RPT/F0094.93A) Avail: NTIS HC/MF A09; 5 functional color pages CSCL 21/5

The feasibility of fabricating an Air Turbo Ramjet (ATR) regenerator containing intricate hydraulic passages from a ceramic material in order to allow operation with high temperature combustion gas and to reduce weight as compared with metallic materials was demonstrated. Platelet technology, ceramic tape casting, and multilayer ceramic packaging techniques were used in this fabrication of subscale silicon nitride components. Proof-of-concept demonstrations were performed to simulate a methane cooled regenerator for an ATR engine. The regenerator vane was designed to operate at realistic service conditions, i.e., 600 psi in a 3500 R (3040 F), 500 fps combustion gas environment. A total of six regenerators were fabricated and tested. The regenerators were shown to be able to withstand internal. pressurization to 1575 psi. They were subjected to testing in 500 fps, 3560 R (3100 F) air/propane combustion products and were operated satisfactorily for an excess of 100 hr and 40 thermal cycles which exceeded 2460 R (2000 F). Author

**N92-14382#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).

### APPLICATION OF MSC/DYNA TO SHOCK AND IMPACT PROBLEMS IN AIRCRAFT INDUSTRY

KLAUS WOLF, IOANNIS NITSOPOULOS, HARALD SUSKI, and DETLEF LIEBE (MacNeal-Schwendler G.m.b.H., Munich, Germany, F.R.) 19 Mar. 1991 19 p Presented at the 18th MSC European Users' Conference, Prien am Chiemsee, Fed. Republic of Germany, 19-21 Jun. 1991

(MBB-UD-0593-91-PUB; OTN-021385; ETN-91-90195) Avail: NTIS HC/MF A03

Applications to important problems in aircraft industry are presented. In the first one the so called Hammershock and the flight loads are forcing the intake of a jet engine plane. The flight loads as the static part are treated with MSC/NASTRAN for efficiency, the hammershock as the highly transient with MSC/DYNA. How to combine these totally different calculations is described. The second problem is about an impact of a steel sphere on a fabric laminated plate. Using the failure criterion of SIMO-Chang, it can be shown, that, after the sphere has bounced off, the plate is partly destroyed caused by failed plies and remaining deformations. Considering the assumptions made the results of MSC/DYNA are in good agreement with the experiment. ESA

### N92-14386# Wright Lab., Wright-Patterson AFB, OH. PROCEEDINGS OF DAMPING 1991, VOLUME 3 Final Report,

Feb. 1989 - Feb. 1991 Aug. 1991 517 p Conference held in San Diego, CA, 13-15 Feb. 1991

(Contract AF PROJ. 2401)

(AD-A241313; WL-TR-91-3078-VOL-3) Avail: NTIS HC/MF A22 CSCL 20/11

Individual papers are presented, and the topics covered include the following: viscoelastic material testing and characterization, passive damping concepts, passive damping analysis and design techniques, optimization, damped control/structure interaction, viscous dampers, friction damping, other vibration suppression techniques, damping identification and dynamic testing, applications to aircraft, space structures, marine structures, commercial products, defense applications, and payoffs of vibration suppression. GRA

**N92-14391\*#** Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.

AIRFOIL VIBRATION DAMPERS PROGRAM Final Report ROBERT M. COOK 11 Nov. 1991 242 p

(Contract NAS8-36720)

(NASA-CR-188929; NAS 1.26:188929; RI/RD-91-230; REPT-91RC13695) Avail: NTIS HC/MF A11 CSCL 20/11

The Airfoil Vibration Damper program has consisted of an analysis phase and a testing phase. During the analysis phase, a state-of-the-art computer code was developed, which can be used to guide designers in the placement and sizing of friction dampers. The use of this computer code was demonstrated by performing representative analyses on turbine blades from the High Pressure Oxidizer Turbopump (HPOTP) and High Pressure Fuel Turbopump (HPFTP) of the Space Shuttle Main Engine (SSME). The testing phase of the program consisted of performing friction damping tests on two different cantilever beams. Data from these tests provided an empirical check on the accuracy of the computer code developed in the analysis phase. Results of the analysis and testing showed that the computer code can accurately predict the performance of friction dampers. In addition, a valuable set of friction damping data was generated, which can be used to aid in the design of friction dampers, as well as provide benchmark test cases for future code developers. Author

**N92-14397**# Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).

REVIEW OF INVESTIGATIONS ON AERONAUTICAL FATIGUE IN THE FEDERAL REPUBLIC OF GERMANY Review Period, Jun. 1989 - May 1991

O. BUXBAUM and A. SCHOEPFEL 1991 65 p Presented at 22d International Committee on Aeronautical Fatigue, Tokyo, Japan, 1991

(ETN-92-90317) Avail: NTIS HC/MF A04

Results of investigations in the field of fatigue gained by industry and research organizations are summarized. Most of the subjects are fatigue test results from specimens and components under constant amplitude; program and random loading. Other reports concern investigations about the cyclic stress strain behavior as well as crack propagation, fracture mechanics, and residual strength. A considerable amount of reports on investigations of composite materials, especially of graphite/epoxies and their properties under environmental influence, are included. **N92-14405#** Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

#### LOW CYCLE FATIGUE OF CAST NICKEL BASE TURBINE ROTORS

J. W. BERGMANN and C. M. SONSINO (Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt, Germany, F.R.) *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 2 p 1991 Avail: NTIS HC/MF A04

A research program on rotor materials of turbochargers and gas turbines and on appropriate life prediction methods is considered. Crack initiation and short crack propagation behavior in smooth and notched specimens, simulating real hot spot areas, is experimentally determined under constant and variable amplitude loading. Crack propagation is investigated both on smooth specimens under strain control using the marker load technique and on compact tension specimens. Fatigue life prediction models for crack initiation (safe life approach) and short crack propagation (damage tolerance approach) will be checked on the basis of test results from notched specimens. Materials under investigation are IN 713 C and MAR-M-247 LC in a fine grain and hipped condition. Testing temperatures are 400, 600, and 760 C.

**N92-14414**# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

#### COMPARISON BETWEEN HOT/WET TEST AND RT/DRY TEST ON THE SEASTAR HORIZONTAL STABILIZER AND FIN

C. PETERS *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 2 p 1991

Avail: NTIS HC/MF A04

A fatigue qualification test carried out with the horizontal stabilizer and fin of the amphibian Seastar is described. The fatigue test was carried out successfully without damage and no damage propagation was identified according to the damage types effected in the damage tolerance concept. The certification requirements were more than fulfilled because the residual strength test after three lives was also carried out successfully. By the comparison of the hot/wet test and the RT/dry test it was established that the environmental conditions led to a strength reduction of approximately 12 percent. Assuming that the temperature cycles do not reduce the strength in the fatigue test, the strength reduction occurred due to the influence of humidity.

N92-14424# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

#### PROBABILISTIC LIFING APPROACH FOR AERO ENGINE DISKS MADE OF POWDER NICKEL BASE ALLOYS CONTAINING CERAMIC DEFECTS

J. W. BERGMANN, R. HEIDENREICH, H. JAECKELS, A. BRUECKNER-FOIT, U. QUADFASEL, H: FISCHMEISTER, G. KOENIG, and E. AFFELT (Motoren- und Turbinen-Union Muenchen G.m.b.H., Germany, F.R.) *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 1 p 1991

Avail: NTIS HC/MF A04

In a joint research program a probabilistic approach for fatigue lifing of engine disks was developed to a preliminary state. This approach is mainly based on the distribution of the size and occurrence of ceramic particles in a nickel base powder alloy disk and the scatter and type of distribution of crack propagation data. Crack propagation data was established by smooth specimen tests under constant and variable (TURBISTAN) strain controlled loading. The material under investigation was Udimet 700 as hipped in the technically pure version and in three additional versions with 20, 50 and 100 micron Al2O3 particles, which were introduced intentionally into the clean powder in a well defined fraction. The temperatures were 400C and 600C. Microstructural effects on crack propagation were recorded and will be included in the lifing approach. The probabilistic and a deterministic approach will be applied to a model disk and results will be compared. Final reports are expected in 1991. FSA

N92-14425# Deutsche Airbus G.m.b.H., Hamburg (Germany, F.R.).

#### AIRBUS INDUSTRIE A330/A340: FULL SCALE FATIGUE TEST OF CENTER FUSELAGE AND WING

T. NIELSEN *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 3 p. 1991

Avail: NTIS HC/MF A04

Principles of the EF2 (French acronym for trial fatigue 2) test of a center fuselage and wing are given. The goal of the test is to verify that the A330/A340 structure reaches or exceeds its design goals. The A330/A340 structures are almost identical, but differ with respect to the number of engines and will be subjected to different mission profiles. One combined test specimen was defined. The test will be divided into two phases beginning with combined loads of the A340 short and medium range versions up to 40,000 flights, followed by A330 short range loading up to the test end, resulting in a total of 80,000 flights. The test specimen is illustrated and its control and loading described. Methods to verify the damage tolerance behavior of the A330/A340 primary structure and to investigate the fatigue and damage tolerance behavior of aluminum lithium material which makes up part of the EF2 fuselage structure are summarized. ESA

N92-14428# Deutsche Airbus G.m.b.H., Hamburg (Germany, F.R.).

## METHODOLOGY FOR ASSESSMENT OF SKIN REPAIRS ON AIRBUS AIRCRAFT

B. BRANDECKER and U. SCHMAELZLE *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 2 p 1991 Avail: NTIS HC/MF A04

The assessment of existing repairs on in-service aircraft, i.e., the determination of necessary inspection threshold and intervals, and/or time of modification or replacement for each repair, is discussed. Static aspects as well as fatigue and damage tolerance aspects are considered. A new methodology which includes guidance material allowing operators to assess the repairs without both complex calculation and support from the manufacturer is reviewed. For example, wing repairs cannot be generalized. The methodology is limited to the fuselage and vertical tail and comprises the following subjects: skin and longitudinal lap joint repairs; circumferential joint repairs; door skin repairs; repairs of door surrounding frames; repairs around door cut outs; repairs of vertical tail skin. As an example, the basic features of the method used for assessing skin and lap joint repairs are described. ESA

N92-14431# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).

## A CONCEPT FOR THE REVISIONS OF STRUCTURAL INSPECTION SCHEDULES

H.-J. MEYER and L. SCHWARMANN *In* Fraunhofer Inst. fuer Betriebsfestigkeit, Review of Investigations on Aeronautical Fatigue in the Federal Republic of Germany 31 p 1991 Avail: NTIS HC/MF A04

Revisions of established inspection schedules should not only be released in case of an in service finding, but also institutionally updated following an Airframe Condition Monitoring Procedure (ACMP). In order to improve methods and inspection procedures, it is aimed to perform an inspection just when a crack reaches its detectable length or, more realistically, to schedule inspections closer to damage. Since aircraft utilization and loading environment differ individually, a closer to damage inspection schedule must account for these differences. The basic general inspection program has to be attuned to the actual service experience for each individual aircraft. It is anticipated that reliable tools for individual aircaft tracking will soon be available and a Flexible Response Inspection Schedule (FRIS) can be established. ACMP, a software system comprising all data processing necessary to transfer collected airline sevice data into a structural inspection adjustment program, is considered. Update sequences will ensure continuing lifelong structural reassessment. Monitoring a fleet with ACMP will for the first time provide relations between aircraft utilization, including environment, and occurrence of damage. During the life of the aircraft, the Schedule for Structural Inspection (SSI) of the Maintenance Review Board (MRB) is expected to change completely from the originally supposed SSI to in service findings. Although the main objective of ACMP is to adjust inspection threshold and intervals, ACMP results can on the other hand be used to change aircraft operation in order to extend intervals or to postpone thresholds or even repair and replacement actions. ESA

#### **N92-15004#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Div. de Thermophysique. **ABLATION AND TEMPERATURE SENSORS FOR FLIGHT MEASUREMENTS IN REENTRY BODY HEAT SHIELDS**

J. J. CASSAING, D. L. BALAGEAS, A. A. DEOM, and J. C. LESTEL *In* ESA, Aerothermodynamics for Space Vehicles p 241-246 Jul. 1991 Sponsored in part by CEA and Aerospatiale

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Since 1977, Onera has ground and flight tested different techniques for heat shield recession: acoustic and combined temperature/ablation optical measurements. This last technique uses a gage that views the radiation optically from a cavity embedded within the heat shield. Flight measurements, both of temperature and of passage of the ablation front are compared with data generated by a predictive numerical code. The ablation and the heat diffusion into the instrumented ablator can be simulated numerically to evaluate accurately the errors due to the presence of the gage. The ablation measurement alone of the reentry body nose is made by an acoustic gage. The temperature measurement alone of the heatshield inner wall will be soon carried out by an optical sensor.

**N92-15027**# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.). Aerodynamics Dept.

#### COMPUTATIONAL AEROTHERMODYNAMIC METHODS FOR INDUSTRIAL APPLICATIONS TO RE-ENTRY AND HYPERSONIC CRUISE PROBLEMS

H. RIEGER, H. STOCK, and B. WAGNER In ESA, Aerothermodynamics for Space Vehicles p 421-437 Jul. 1991 Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

A survey of computational fluid dynamics capabilities and related methodologies which may be useful to support the design of vehicles flying at high supersonic speeds in cruise conditions or passing the hypersonic flight regime during reentry from low Earth orbit, is given. A main objective in hypersonic design is the search for the best compromise between a feasible flight control system and an aerodynamic shape exposed to thermal loads which can be tolerated by the thermal protection system. For the prediction of aerokinetic thermal loads, depending on the flow situation, several alternatives exist which can give reliable answers. Emphasis is placed on Euler and Navier-Stokes methods as well as on more limiting prediction tools like parabolized Navier-Stokes and boundary layer methods. Application of these flow simulation methods to simple as well as to complex configurations of current interest are presented. Activities in the area of transition for hypersonic flows are discussed. FSA

**N92-15029#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

#### NUMERICAL SIMULATION OF THERMOCHEMICAL NON-EQUILIBRIUM VISCOUS FLOWS AROUND REENTRY BODIES

F. COQUEL, V. JOLY, C. MARMIGNON, and C. FLAMENT (Ohio State Univ., Columbus.) *In* ESA, Aerothermodynamics for Space Vehicles p 447-452 Jul. 1991 Previously announced in IAA as A91-45648 Sponsored by Direction des Recherches, Etudes et Techniques

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

A fully coupled implicit finite volume method is applied to the

prediction of axisymmetric and plane equilibrium viscous flows around reentry bodies. The governing equations are discretized using a second order upwind scheme of Harten type for the inviscid fluxes and a space centered scheme for the viscous fluxes. The effects of different physical assumptions and models are investigated. Chemical and thermochemical nonequilibrium calculations around a hyperboloid are compared. The numerical simulation of the chemical nonequilibrium flow around a double ellipse is presented. Comparisons are made respectively between two chemical models and between two transport phenomenon models. ESA

**N92-15030#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### EQUILIBRIUM SOLUTION OF THE EULER AND NAVIER-STOKES EQUATIONS AROUND A DOUBLE ELLIPSOIDAL SHAPE WITH MONO- AND MULTI-BLOCKS INCLUDING REAL GAS EFFECTS, PART 1

H. WONG and J. HAEUSER In its Aerothermodynamics for Space Vehicles p 453-458 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Chemical and thermal equilibrium solutions of the Euler and Navier-Stokes equations around a double ellipsoidal shape at Mach 25 with an angle of attack of 30 degrees are presented. Atmospheric air is assumed to be the continuum medium and is modeled as a real gas. The solutions are obtained by using a finite volume method and the algorithm employs a cell centered fully implicit upwind scheme. Three dimensional mono and multiblock structured grids are employed in order to study the influence of grid topology on the physical solution. Moreover, the grid qualities such as orthogonality, grid point clustering, smoothness, and grid size are also discussed. In particular, the effect of grid adaptation with respect to the physical solution was examined. The aerodynamic coefficients, property contours, and shock standoff distance are presented and compared in each case. ESA

N92-15033# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

#### PARALLELIZATION OF A DIRECT SIMULATION MONTE CARLO (DSMC) CODE FOR FLUID DYNAMICS

GIULIO PRISCO In its Aerothermodynamics for Space Vehicles p 477-482 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Direct Simulation Monte Carlo (DSMC) codes are an essential tool for the computation of aerothermodynamical effects on hypersonic space vehicles. They permit computer simulation of flows to be extended in the rarefied regime, where macroscopic fluid equations do not hold. Being more CPU (Central Processing Unit) intensive than other computational approaches, DSMC codes are an ideal application for parallel machines. The work done in order to modify a DSMC code for parallel/vector execution is described. Short, but, self contained introductions to rarefied gas dynamics, Monte Carlo techniques, and parallel/vector processing are also given. ESA

# N92-15083\*# Mechanical Technology, Inc., Latham, NY. INDUSTRIAL CODE DEVELOPMENT

WILBUR SHAPIRO In NASA. Lewis Research Center, Seals Flow Code Development p 15-26 Mar. 1991 Avail: NTIS HC/MF A08 CSCL 11/1

The industrial codes will consist of modules of 2-D and simplified 2-D or 1-D codes, intended for expeditious parametric studies, analysis, and design of a wide variety of seals. Integration into a unified system is accomplished by the industrial Knowledge Based System (KBS), which will also provide user friendly interaction, contact sensitive and hypertext help, design guidance, and an expandable database. The types of analysis to be included with the industrial codes are interfacial performance (leakage, load, stiffness, friction losses, etc.), thermoelastic distortions, and dynamic response to rotor excursions. The first three codes to be completed and which are presently being incorporated into the KBS are the incompressible cylindrical code, ICYL, and the compressible cylindrical code, GCYL. Author

#### N92-15084\*# CFD Research Corp., Huntsville, AL. DEVELOPMENT OF A CFD CODE FOR ANALYSIS OF FLUID DYNAMIC FORCES IN SEALS

MAHESH M. ATHAVALE, ANDRZEJ J. PRZEKWAS, and ASHOK K. SINGHAL In NASA. Lewis Research Center, Seals Flow Code Mar. 1991 Development p 27-39

Avail: NTIS HC/MF A08 CSCL 20/4

The aim is to develop a 3-D computational fluid dynamics (CFD) code for the analysis of fluid flow in cylindrical seals and evaluation of the dynamic forces on the seals. This code is expected to serve as a scientific tool for detailed flow analysis as well as a check for the accuracy of the 2D industrial codes. The features necessary in the CFD code are outlined. The initial focus was to develop or modify and implement new techniques and physical models. These include collocated grid formulation, rotating coordinate frames and moving grid formulation. Other advanced numerical techniques include higher order spatial and temporal differencing and an efficient linear equation solver. These techniques were implemented in a 2D flow solver for initial testing. Several benchmark test cases were computed using the 2D code, and the results of these were compared to analytical solutions or experimental data to check the accuracy. Tests presented here include planar wedge flow, flow due to an enclosed rotor, and flow in a 2D seal with a whirling rotor. Comparisons between numerical and experimental results for an annular seal and a 7-cavity labyrinth seal are also included. Author

## N92-15089\*# Army Propulsion Lab., Cleveland, OH.

ARMY RESEARCH CONCERNS IN ENGINE SEALING

ROBERT C. BILL In NASA. Lewis Research Center, Seals Flow Code Development p 75-82 Mar. 1991

Avail: NTIS HC/MF A08 CSCL 11/1

The Army Propulsion Directorate is primarily concerned with small engine technology, where sealing performance is most critical. Tip leakage and secondary flow losses have a much greater performance impact on small engine aero-components than on large engines. A brief survey and critique of presently employed sealing concepts is presented. Some recent new research thrusts that show promise for substantial improvement are discussed. An especially promising approach for small engine applications is brush seals. Brush seal concepts are being considered for outer air seal and secondary airflow system seal locations. Author

N92-15092\*# Air Force Systems Command, Wright-Patterson AFB, OH. Lubrication Branch.

PROGRAMS AT WRIGHT-PATTERSON AIR FORCE BASE

RON DAYTON In NASA. Lewis Research Center, Seals Flow Code Development p 103-106 Mar. 1991

Avail: NTIS HC/MF A08 CSCL 11/1

The Lubrication Branch has two active programs that are developing gas turbine engine mainshaft air/oil seals. Both of these programs, one of which is with General Electric Aircraft Engines and the other with Pratt & Whitney Aircraft, are addressing counter-rotating intershaft applications which involve very high rubbing velocities. The objectives and requirements of these efforts are briefly addressed. Author

#### N92-15093\*# Detroit Diesel Allison, MI. SEAL DEVELOPMENT ACTIVITIES AT ALLISON TURBINE **DIVISION Abstract Only**

JOHN MUNSON In NASA. Lewis Research Center, Seals Flow Code Development p 107 Mar. 1991 Avail: NTIS HC/MF A08 CSCL 11/1

Brush seals are being evaluated for potential near and far term gas turbine engine applications. Development is in the form of rig component testing and engine testing. Allison has tested an engine with 20 individual brush seal positions. These seals were

located throughout the engine. The emphasis of the current work is on obtaining long term performance data for brush seals. Very little of this data is available. Allison is presently developing film riding face seal technology to support future gas turbine engine applications. A face seal with an approximate 7 inch diameter was successfully tested to 1000 F, 100 psid, and 650 ft/sec. Seal leakage remained below 1 scfm throughout the duration of the test. A model for the compressible gas film was developed which separates the model for the compressible gas film was developed which separates the primary seal rings during operation. This model is based on the traditional Reynold's approach which is customarily applied to lubrication type problems. Because of the difficulty of experimentally verifying the program predictions, a commercial Navier-Stokes code was used in parallel. By comparing predictions for similar cases, it is expected that the limitations of the Reynold's model can be assessed as it applies to this particular seal.

Author

N92-15094\*# General Electric Co., Cincinnati, OH. AREAS OF SEAL R/D AT GE

A. NELSON POPE In NASA. Lewis Research Center, Seals Flow Code Development p 109-112 Mar. 1991

Avail: NTIS HC/MF A08 CSCL 11/1

About four years ago, work was completed on a 36 inch diameter gas to gas carbon ring seal used to buffer low pressure turbine air at the rim of the forward outer flowpath on the GE36 unducted fan (UDF) engine. At about the same time, we were developing a long life counter-rotating intershaft air-oil seal of approximately 7.6 inch diameter for operation at 800 fps, 800 F, and 50 psid. Although we were successful in meeting most program goals with a split ring seal of the axial bushing type, the seal with the greatest payoff in life and air leakage rates, bearing many features in common with the GE36 seal, could not be successfully tested because of the structural weakness of the primary seal ring carbon material. This was a split ring seal using a hybrid combination of orifice compensated hydrostatic and shrouded hydrodynamic gas bearings. We are presently working to develop this design in conjunction with high strength materials being developed by Pure Carbon Co. In the area of engine secondary gas flow path-sealing for performance improvement, we are currently working with carbon and all metal face seals. A 15 inch diameter all metal 'aspirating' face seal, using self-acting hydrostatic bearings, was successfully tested to 700 fps, 100 psid, and 1000 F, demonstrating long life at flow reduction of 86 percent compared to a 'best' labyrinth. This seal will be developed through 1400 F, 900 fps, and 350 psid. The seal 'aspirates' closed at about idle speed pressure during engine start and reopens at engine shutdown. A hydraulic thrust balance seal, currently using orifice compensated hydrostatics, is under development. Other aspects of these projects are briefly covered. Author

N92-15095\*# Edgerton, Germeshausen and Grier, Inc., Wellesley, MA. Fluid Components Technology Group

#### SEAL RELATED DEVELOPMENT ACTIVITIES AT EG/G

HAROLD F. GREINER In NASA. Lewis Research Center, Seals Flow Code Development p 113-122 Mar. 1991 Avail: NTIS HC/MF A08 CSCL 11/1

Seal related development activities including modeling, analysis, and performance testing are described for several current seal related projects. Among the current seal related projects are the following: high pressure gas sealing systems for turbomachinery; brush seals for gas path sealing in gas turbines; and tribological material evaluation for wear surfaces in sealing systems. Author

N92-15203\* National Aeronautics and Space Administration. Pasadena Office, CA.

### MULTICOMPONENT GAS SORPTION JOULE-THOMSON **REFRIGERATION** Patent

JACK A. JONES, inventor (to NASA), S. WALTER PETRICK, inventor (to NASA), and STEVEN BARD, inventor (to NASA) (Jet Propulsion Lab., California Inst. of Tech., Pasadena.) 12 Nov. 1991 7 p Filed 28 Jun. 1990 Supersedes N90-26176 (28 - 20, p 2844)

(NASA-CASE-NPO-17569-1-CU; US-PATENT-5,063,747; US-PATENT-APPL-SN-545236; US-PATENT-CLASS-62-461; US-PATENT-CLASS-624-3.2; US-PATENT-CLASS-624-51.2; US-PATENT-CLASS-624-467; US-PATENT-CLASS-624-500; INT-PATENT-CLASS-F17C-11/00) Avail: US Patent and Trademark Office CSCL 13/9

The present invention relates to a cryogenic Joule-Thomson refrigeration capable of pumping multicomponent gases with a single stage sorption compressor system. Alternative methods of pumping a multicomponent gas with a single stage compressor are disclosed. In a first embodiment, the sorbent geometry is such that a void is defined near the output of the sorption compressor. When the sorbent is cooled, the sorbent primarily adsorbs the higher boiling point gas such that the lower boiling point gas passes through the sorbent to occupy the void. When the sorbent is heated, the higher boiling point gas is desorbed at high temperature and pressure and thereafter propels the lower boiling point gas out of the sorption compressor. A mixing chamber is provided to remix the constituent gases prior to expansion of the gas through Joule-Thomson valve. Other methods of pumping a multicomponent gas are disclosed. For example, where the sorbent is porous and the low boiling point gas does not adsorb very well, the pores of the sorbent will act as a void space for the lower boiling point gas. Alternatively, a mixed sorbent may be used where a first sorbent component physically adsorbs the high boiling point gas and where the second sorbent component chemically absorbs the low boiling point gas.

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

N92-15272# Technology Development Corp., Madrid (Spain). ELECTRONICALLY STEERABLE ANTENNA FOR AIRCRAFT J. BARBERO, M. L. HERNANZ, M. HERNANZ, C. MARTIN, J. VASSALLO, and B. HEDGE *In* ESA, Second European Conference on Satellite Communications ECSC-2 p 425-427 Oct. 1991 Copyright Avail: NTIS HC/MF A22; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

The design of an electronically steerable medium gain antenna for aircraft able to provide voice communication via satellite is presented. The antenna consists of 5 radiating facets and the coverages achieved, including the effect of the aircraft fuselage, are based on the experimental results obtained with the actual components of the beam forming network (switches, phase shifters, power dividers) and the radiating facets including the matching network. One hundred percent of the mandatory coverage (colatitude 0 to 85 degrees) is achieved with a gain greater than 10 dBi and 12 dBi are achieved in 60 percent of it. Concerning the goal coverage (colatitude 0 to 105 degrees) a gain greater than 7 dBi is achieved in 84 percent of it. The dimensions of the radome required for this antenna are: length 1780 mm, width 255 mm, height 197 mm. FSA

N92-15367# Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.

#### FERRUNDI COMPANY SUPPLIES 4500 MODEL HEAD UP DISPLAY DEVICES TO INDIA'S MIG-21 AIRCRAFT

25 Jul. 1991 6 p Transl. into ENGLISH from Guoji Hangkong (China), no. 7, 1985 p 52-53

(AD-A241044; FTD-ID(RS)T-0172-91) Avail: NTIS HC/MF A02 CSCL 09/5

The 4500 Model head up display device is a type which is produced by the Ferrundi Company. It is a light weight head up display device and weapon aiming system which is capable of being supplied for retrofit use. the display device is a conventional non-holographic system which is capable of supplying a 25 degree circumference field of vision and uses direct or alternating current power sources. The system also possesses auto-supervision and control as well as automatic measurement and testing functions. GRA

N92-15385# Solar Turbines, Inc. San Diego, CA. HIGH-TEMPERATURE COMBUSTOR AND SEAL FOR A WATER PISTON PROPULSOR Final Report, Jun. 1985 - Mar. 1991

M. A. GALICA and R. T. LECREN Mar. 1991 61 p (Contract N00167-85-C-0042; NR PROJ. C31-50)

(AD-A242493; SR90-R-5253-76; DTRC/SD-CR-16/91) Avail: NTIS HC/MF A04 CSCL 21/2

The detailed design and testing of a high temperature combustor and seal for a water piston propulsor is reported. The system is comprised of a high pressure combustor together with a carbon graphite rotor-contacting face seal. Analyses are presented to support the design of an air cooled combustor liner. The seal is pneumatically loaded against the rotor face using a variable pressure. Superalloy materials are selected for most components with a vitreous enamel corrosion resistant coating applied to the high-temperature combustor liner. The combustor was subjected to a series of rig tests to define its performance prior to integrating it with the rotor system. A simulated rotor test was also conducted to study the seal plate bellows pressure relationship required to attain a satisfactory seal. After the solar combustion and seal system was integrated with the rotor system, three series of water channel tests were conducted to determine the overall system performance. The combustor performed satisfactorily although the imposed operating conditions, i.e., pressure and air flow, were significantly different from the original design specifications, requiring the combustor to operate at higher combustor loadings. The tested propulsion efficiency of the WPP was lower than predicted. An attempt to improve performance by matching the shape of the combustor outlet to the rotor passage inlet yielded minimal improvements. GRA

#### N92-15392# Sandia National Labs., Albuquerque, NM. NUMERICAL SIMULATION OF VAWT STOCHASTIC AERODYNAMIC LOADS PRODUCED BY ATMOSPHERIC TURBULENCE: VAWT-SAL CODE

G. F. HOMICZ Sep. 1991 73 p (Contract DE-AC04-76DP-00789)

(DE92-000597; SAND-91-1124) Avail: NTIS HC/MF A04

Blade fatigue life is an important element in determining the economic viability of the Vertical-Axis Wind Turbine (VAWT). A principal source of blade fatigue is thought to be the stochastic (i.e., random) aerodynamic loads created by atmospheric turbulence. This report describes the theoretical background of the VAWT Stochastic Aerodynamic Loads (VAWT-SAL) computer code, whose purpose is to numerically simulate these random loads, given the rotor geometry, operating conditions, and assumed turbulence properties. A Double-Multiple-Stream Tube (DMST) analysis is employed to model the rotor's aerodynamic response. The analysis includes the effects of Reynolds number variations, different airfoil sections and chord lengths along the blade span, and an empirical model for dynamic stall effects. The mean ambient wind is assumed to have a shear profile which is described by either a power law or a logarithmic variation with height above ground. Superimposed on this is a full 3-D field of turbulence: i.e., in addition to random fluctuations in time, the turbulence is allowed to vary randomly in planes perpendicular to the mean wind. The influence of flow retardation on the convection of turbulence through the turbine is also modeled. Calculations are presented for the VAWT 34-m Test Bed currently in operation at Bushland, Texas. Predicted time histories of the loads, as well as their Fourier spectra, are presented and discussed. Particular emphasis is placed on the differences between so-called 'steady-state' (mean wind only) predictions, and those produced with turbulence present. Somewhat surprisingly, turbulence is found to be capable of either increasing or decreasing the average output power, depending on the turbine's tip-speed ratio. A heuristic explanation for such behavior is postulated, and a simple formula is derived for predicting the magnitude of this effect without the need for a full stochastic simulation. DOF

N92-15402\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ANALYSIS OF AIRCRAFT ENGINE BLADE SUBJECT TO ICE IMPACT

E. S. REDDY, G. H. ABUMERI (Sverdrup Technology, Inc., Brook Park, OH.), CHRISTOS C. CHAMIS, and P. L. N. MURTHY 1991

24 p Presented at the Ninth Conference on Fibrous Composites in Structural Design, Lake Tahoe, NV, 4-7 Nov. 1991; cosponsored by DOD, NASA, and FAA

(NASA-TM-105336; E-6703; NAS 1.15:105336) Avail: NTIS HC/MF A03 CSCL 20/11

The ice impact on the engine blade made of layered composite is simulated. The ice piece is modeled as an equivalent spherical object and has the velocity opposite to that of the aircraft with direction parallel to the engine axis. Near the impact region and along the leading edge, the blade is assumed to be fully stressed and undergoes large deflection. A specified portion of the blade around the impact region is modeled. The effect of ice size and velocity on the average leading edge strain are investigated for a modified SR-2 model unswept composite propfan blade. Parametric studies are performed to study the response due to ice impact at various locations along the span. Also, the effects of engine speed on the strain and impact displacements are discussed. It is found that for a given engine speed, a critical ice speed exists that corresponds to the maximum strain and this critical speed increases with increase in the engine speed. Author

N92-15406\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH. STRUCTURAL DYNAMICS BRANCH RESEARCH AND ACCOMPLISHMENTS FOR FY 1990

Nov. 1991 43 p

(NASA-TM-103747; E-5993; NAS 1.15:103747) Avail: NTIS HC/MF A03 CSCL 20/11

Presented here is a collection of FY 1990 research highlights from the Structural Dynamics Branch at the NASA Lewis Research Center. Highlights are from the branch's major work areas: aeroelasticity, vibration control, dynamic systems, and computational structural methods. A listing is given of FY 1990 branch publications. Author

### 13

### GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

#### A92-18902

#### MESOSCALE DYNAMICS OF COLD FRONTS - STRUCTURES DESCRIBED BY DROPSOUNDINGS IN FRONTS 87

ALAN J. THORPE and SID A. CLOUGH (Reading, University, England) Royal Meteorological Society, Quarterly Journal (ISSN 0035-9009), vol. 117, pt. B, July 1991, p. 903-941. refs

Data from dropsoundings in Fronts 87 research aircraft are analyzed. Several new aspects of cold-front dynamics are identified from these data. The aircraft flew a pattern with four or five runs oriented approximately at right angles to the front, but with each run displaced in the along-front direction by about 100 km. The dropsondes gave soundings to a height of approximately 7 km with a cross frontal spacing of 20 km at best and 60 km on average. A minimal and objective analysis of the data is presented, but the high resolution of the dropsonde observations permits the evaluation of differentiated quantities, such as potential vorticity, with some confidence. Issues addressed include the degree of thermal-wind balance, the structure of conserved variables such as equivalent potential temperature and absolute momentum, the cross-frontal circulation, and the role of diabatic processes such as the evaporation of snow, and the potential vorticity structure on the mesoscale and its interpretation. C.A.B.

A92-20128\* Electro Magnetic Applications, Inc., Lakewood, CO. NONLINEAR TRIGGERED LIGHTNING MODELS FOR USE IN FINITE DIFFERENCE CALCULATIONS

TERENCE RUDOLPH, RODNEY A. PERALA, and POH H. NG

(Electro Magnetic Applications, Inc., Lakewood, CO) International Conference on Lightning and Static Electricity, University of Bath, England, Sept. 26-28, 1989. 9 p. refs (Contract NAS1-16984; NAS1-17748)

Two nonlinear triggered lightning models have been developed for use in finite difference calculations. Both are based on three species of air chemistry physics and couple nonlinearly calculated air conductivity to Maxwell's equations. The first model is suitable for use in three-dimensional modeling and has been applied to the analysis of triggered lightning on the NASA F106B Thunderstorm Research Aircraft. The model calculates number densities of positive ions, negative ions, and electrons as a function of time and space through continuity equations, including convective derivative terms. The set of equations is closed by using experimentally determined mobilities, and the mobilities are also used to determine the air conductivity. Results from the model's application to the F106B are shown. The second model is two-dimensional and incorporates an enhanced air chemistry formulation. Momentum conservation equations replace the mobility assumption of the first model. Energy conservation equations for neutrals, heavy ions, and electrons are also used. Energy transfer into molecular vibrational modes is accounted for. The purpose for the enhanced model is to include the effects of temperature into the air breakdown, a necessary step if the model is to simulate more than the very earliest stages of breakdown. Therefore, the model also incorporates a temperature-dependent electron avalanche rate. Results from the model's application to breakdown around a conducting ellipsoid placed in an electric field are shown. Author

### 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.

#### A92-17582#

#### MODEL BASED REASONING IN THE AEROSPACE DOMAIN

W. E. BOND (McDonnell Douglas Research Laboratories, Saint Louis, MO), JON STICKLEN, and M. PEGAH (Michigan State University, East Lansing) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 40-47. Research supported by McDonnell Douglas Independent Research and Development Program. refs

(AIĂA PAPER 91-3709) Copyright

Model based reasoning has been investigated for its use in both simulation and diagnostic tasks. This paper outlines how an appropriate model-based representation can also document and assist the engineering design process for small to medium-sized designs. A specific representation and reasoning methodology (Functional Modeling/Functional Reasoning) is outlined and applied to the task of modeling the fuel system of the U.S. Navy/McDonnell Douglas F/A-18 fighter aircraft.

#### A92-17585\*# ORA Corp., Ithaca, NY. FORMAL SPECIFICATION AND VERIFICATION OF ADA SOFTWARE

GEOFFREY R. HIRD (Ora Corp., Ithaca, NY) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 62-68. refs (Contract NAS1-18972)

(AIAA PAPER 91-3713) Copyright

The use of formal methods in software development achieves levels of quality assurance unobtainable by other means. The Larch

approach to specification is described, and the specification of avionics software designed to implement the logic of a flight control system is given as an example. Penelope is described which is an Ada-verification environment. The Penelope user inputs mathematical definitions, Larch-style specifications and Ada code and performs machine-assisted proofs that the code obeys its specifications. As an example, the verification of a binary search function is considered. Emphasis is given to techniques assisting the reuse of a verification effort on modified code. Author

#### A92-17594\*# Mitre Corp., Houston, TX. CASE FOR REAL-TIME SYSTEMS DEVELOPMENT - QUO VADIS?

DONA M. ERB (Mitre Corp., Houston, TX) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 144-152. refs (Contract NAS9-18057)

(AIAA PAPER 91-3726) Copyright

The paper focuses on the distinctive issues of computer-aided software engineering (CASE) products for the development of CASE , technologies real-time systems. and associated standardization efforts are evolving from sets of conflicting interests. The majority of case products are intended for use in the development of management information systems. CASE products to support the development of large, complex real-time systems must provide additional capabilities. Generic concerns include the quality of the implementation of the required method for the phase of the system's development and whether the vendor is stable and committed to evolving the products in parallel with nonproprietary standards. The CASE market is undergoing considerable consolidation. The paper describes the major forces, cooperating entities, and remaining uncertainties that need to be weighed in near-term CASE procurements to limit risk of loss of investment in project time, trianing, and money. Author

#### A92-17605#

## KNOWLEDGE MAINTENANCE IN AN EVOLVING SYSTEM USING A DEEP STRUCTURE REPRESENTATION

NORMAN D. GEDDES (Applied Systems Intelligence, Inc., Gainesville, GA) and RICHARD ARMSTRONG (ISC Corp., Marietta, GA) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 234-242. Research supported by DARPA, USAF, and Lockheed Corp. refs

(AIAA PAPER 91-3941) Copyright

This work develops an alternate view of the role of a deep structure knowledge representation as a knowledge archiving language that can be freely translated to or from application-specific representations that are efficient for execution. A prototype of such a system has been developed as a means for maintaining, archiving, and translating the immense nonstatic tactical air combat knowledge bases created for the DARPA/USAF/Lockheed Pilot's Associate program. Significant gains in knowledge consistency and maintainability are expected to be possible as a result of this approach. Author

#### A92-17608# ADVANCED AVIONICS SYSTEM DEVELOPMENT ENVIRONMENT

MILES B. PELLAZAR (Northrop Corp., Aircraft Div., Hawthorne, CA) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 261-269. Research supported by Northrop Corp. refs (AIAA PAPER 91-3944) Copyright

While avionics systems continue to increase in complexity and sophistication, tools to facilitate the development of avionics software continue to lag behind. Rapidly escalating costs associated with developing, deploying, and managing large-scale avionics software systems continue to plague avionics engineering organizations. There is a crucial need for advanced mechanisms

### 15 MATHEMATICAL AND COMPUTER SCIENCES

that will improve software productivity and significantly reduce software development costs. This paper presents an overview of Northrop's Advanced Avionics System Development Environment (AASDE) project initiated to address these pressing software issues. The paper begins with a discussion on the proposed AASDE framework and its major subsystems. Next, a detailed description of new avionics software tools being developed under this project is presented. The paper concludes with the current state of the project and its future direction. Author

#### A92-17626#

### RADAR TROUBLESHOOTING ASSISTANT EXPERT SYSTEM

DANIEL R. DORRANCE and KENNETH M. GROHMAN (McDonnell Douglas Avionics Laboratories, Saint Louis, MO) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 411-413. refs (AIAA PAPER 91-3764) Copyright

The application of AI to expert systems is discussed in terms of a product for solving radar problems caused by the final stages of the F-15E manufacturing cycle. The system employs a knowledge-based approach with production rules and can use backward chaining and limited forward chaining. The assistant expert system supports manufacturing personnel by recommending replacement of specific radar LRUs or by suggesting troubleshooting techniques. C.C.S.

A92-17629\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### APPLICATIONS OF AN AUTOMATED PROGRAMMING SYSTEM

CARRIE K. WALKER (NASA, Langley Research Center, Hampton, VA), JOHN J. TURKOVICH, and THOMAS K. MASOTTO (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 427-439. refs (AIAA PAPER 91:3767) Convright

(AIAA PAPER 91-3767) Copyright A Computer-Aided Software Engineering (CASE) system has been developed at the Charles Stark Draper Laboratory (CSDL) under the direction of the NASA Langley Research Center. The Automated Programming Subsystem is the core of the CSDL CASE system. The Automated Programming Subsystem allows an engineer to describe software specifications as hierarchical engineering block diagrams, a natural design technique for the specification of real-time software. The objective of the Automated Programming Subsystem is to capture completely and consistently both logical and schematic information as diagrams are developed, and then to automatically transform this information into source code (Ada or C) and documentation. The Automated Programming Subsystem of CSDL CASE has been used on many applications, from small to moderate size. Six of these applications are described in this paper.

**A92-17637\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

OPTICAL COMPUTING AT NASA AMES RESEARCH CENTER MAX B. REID, MARIA G. BUALAT, JOHN D. DOWNIE, DAVID GALANT, CHARLES K. GARY, BUTLER P. HINE, PAUL W. MA, ANNA H. PRYOR, and LILLY SPIRKOVSKA (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 503-515. refs (AIAA PAPER 91-3779) Copyright

Optical computing research at NASA Ames Research Center seeks to utilize the capability of analog optical processing, involving free-space propagation between components, to produce natural implementations of algorithms requiring large degrees of parallel computation. Potential applications being investigated include robotic vision, planetary lander guidance, aircraft engine exhaust analysis, analysis of remote sensing satellite multispectral images, control of space structures, and autonomous aircraft inspection. Author

### A92-17645#

### FAULT TREE INTERPRETER

TERRY DICKERSON (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 580-585.

#### (AIAA PAPER 91-3789) Copyright

The Fault Tree Interpreter (FTI) is an expert system shell for developing rule-based expert systems to control automatic test equipment (ATE). The FTI, which is implemented in Ada. brings expert system technology to any computing system which has an Ada compiler. Using the FTI, test station programmers can easily develop a rule group (i.e., test program) to test a unit under test (UUT) and determine if it is good or bad. Optimized for use in the automatic test station environment, the FTI interfaces with test station and executive software. Conventional test methodology halts UUT testing at the first fault. However, a rule-based system can diagnose multiple independent UUT failures. Included with the FTI is a rule group development system which is independent of ATE hardware. The FTI has been ported to multiple computer platforms and can easily be ported to additional platforms. To date the FTI has been delivered on two ATE systems and is performing very well. Author

#### A92-17654#

### FAILURE ENVIRONMENT ANALYSIS TOOL (FEAT) DEVELOPMENT STATUS

ROBERT W. STEVENSON, JAMES G. MILLER, and MICHAEL E. AUSTIN (Lockheed Engineering and Sciences Co., Houston, TX) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991; Technical Papers. Vol. 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 676-682. refs

#### (AIAA PAPER 91-3803) Copyright

This paper describes a computer software application which operates on digraph models of systems to determine and display failure effects. The software was developed by NASA to help integrate effects across large systems, to support mission controllers in making time critical decisions in response to indications of failures in flight systems, and to provide a portion of a planned engineering workstation based upon advanced graph and network theory. Author

#### A92-17664#

#### DESIGNING THROUGH TEST

BARRY T. MCKINNEY (USAF, Rome Laboratory, Griffiss AFB, NY) and F. M. SPEED, JR. (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH) IN: AIAA Computing in Aerospace Conference, 8th, Baltimore, MD, Oct. 21-24, 1991, Technical Papers. Vol. 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 763-767. refs (AIAA PAPER 91-3822)

Engineers at the Air Force's Rome Laboratory and Aeronautical

Systems Division, in an effort to extend the design process through the entire procurement cycle, have begun software development that automates the design and analysis of accelerated reliability tests. Test designs and resulting analysis will comply with standard validation requirements and economic considerations. The software will progressively develop component unique, experimentally designed, reliability quantification procedures, as well as perform a complete data reduction and final estimation of the component's inherent operational reliability. Author

A92-17813\*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA. MULTIDISCIPLINARY MODELING AND SIMULATION OF A

## GENERIC HYPERSONIC VEHICLE

K. K. GUPTA, K. L. PETERSEN (NASA, Flight Research Center, Edwards, CA), and C. L. LAWSON (Eloret Institute, Claremont,

CA) AIAA, International Aerospace Planes Conference, 3rd, Orlando, FL, Dec. 3-5, 1991. 13 p. refs

(AIAA PAPER 91-5015) Copyright

The modeling and simulation of hypersonic vehicles which involve the interaction of a number of major technical disciplines including aerodynamics, structures, heat transfer, propulsion, and control engineering are described. Finite element numerical formulations of individual disciplines including their appropriate integration for multidisciplinary simulation are presented. An efficient unstructured grid generation strategy, evolved by modifying an existing code, is developed. R.E.P.

### A92-18464

## AN ALTERNATIVE DERIVATION OF THE MODIFIED GAIN FUNCTION OF SONG AND SPEYER

PEGGY J. GALKOWSKI and MOHAMMED A. ISLAM (IBM Corp., Federal Sector Div., Owego, NY) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. 36, Nov. 1991, p. 1323-1326. Copyright

A simpler derivation of the modified gain function for the bearings-only measurement problem as defined by Song et al. (1985) is presented. The form which results shows the relationship between the modified gain and the standard gain. The relationship between the modified gain and the standard gain of an extended Kalman filter is shown. It is confirmed that the modified gain extended Kalman filter performs better than the standard extended Kalman filter.

## A92-18616

## OPTIMAL CONTROL PROBLEMS WITH MAXIMUM FUNCTIONAL

PING LU (Iowa State University of Science and Technology, Ames) and NGUYEN X. VINH (Michigan, University, Ann Arbor) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, Nov.-Dec. 1991, p. 1215-1223. refs

Copyright

This paper considers the optimal control problem with a performance index that includes a maximum functional. Necessary conditions are derived that are more general than those of previous work, some of which is shown to be reducible and, therefore, included in the results found here. An illustrative example demonstrates that necessary conditions are satisfied by a unique solution of the problem. The problem of threat avoidance for aircraft is formulated as the optimal control problem considered here. Numerical results for a subsonic diider are presented. Author

#### A92-19084

#### VERIFICATION OF FLIGHT SOFTWARE BY EMBEDDING SOFTWARE SIMULATION IN SIMULATION OF EXTERNAL ENVIRONMENT

NORMAN H. FISCHER and DOUGLAS PERRY (Battelle, Columbus, OH) IN: 1990 Annual Summer Computer Simulation Conference, 22nd, Calgary, Canada, July 16-18, 1990, Proceedings. San Diego, CA, Society for Computer Simulation, 1990, p. 463-468. Copyright

Flight software can be tested by embedding it in a detailed simulation of the spacecraft, sensors, and external stimulants. This paper shows the application of this approach to three Delta SDIO missions. Sample results regarding attitude determination, navigation, and attitude control are reported. C.D.

#### A92-19094

## A PROCESSOR-IN-THE-LOOP SIMULATION USING AN XANALOG COMPUTER

LOUISA J. CYNAMON (Raytheon Co., Bedford, MA) IN: 1990 Annual Summer Computer Simulation Conference, 22nd, Calgary, Canada, July 16-18, 1990, Proceedings. San Diego, CA, Society for Computer Simulation, 1990, p. 931-937. Copyright

A real-time closed-loop 6-DOF processor-in-the-loop (PIL) simulation facility has been developed using a Xanalog computer. This computer provides a high speed, desk-top environment for a simulation that runs at less than 1.67 ms. This facility is used to

debug and validate digital autopilot software. The Xanalog provides an alternative to the more expensive real-time computers on the market. This paper presents a discussion of the models used in the simulation, their implementation, and provides a critique of the Xanalog as a real-time simulation processor. Author

#### A92-19386

## CLEANROOM - AN ALTERNATIVE SOFTWARE DEVELOPMENT PROCESS

HARLAN D. MILLS (Software Engineering Technology, Inc., Vero Beach, FL) IN: Aerospace software engineering - A collection of concepts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1991, p. 187-200. refs Copyright

The Cleanroom software engineering process develops software of certified reliability under statistical quality control in a pipeline of increments, with no program debugging before independent statistical usage testing of the increments. It requires rigorous methods of software specification, design, and testing, with which disciplined software engineering teams are capable of producing low- or zero-defect software of arbitrary size and complexity. Such engineering discipline is not only capable of producing highly reliable software, but also the certification of the reliability of the software as specified. The IBM COBOL Structuring Facility, a complex product of some 80 K lines of source code, was developed in the Cleanroom discipline, with no debugging before usage testing and certification of its reliability. A version of the HH60 (helicopter) flight control program of over 30 KLOC was also developed in Cleanroom. Author

#### A92-19405 AEROSPACE SOFTWARE ENGINEERING IN THE UNITED KINGDOM

NICHOLAS JENNINGS (British Aerospace, PLC, Sowerby Research Centre, Bristol, England) IN: Aerospace software engineering -A collection of concepts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1991, p. 545-559. refs Copyright

Certain aspects of software engineering that are of importance to the UK aerospace industry are discussed in the light of the currently considered new UK draft defense standard aimed at increasing the standards for safety-critical software. Particular emphasis is placed on formal methods and their application to aerospace software engineering. The discussion covers requirements analysis, static analysis tools, low-level languages, tools for dynamic testing, code design and implementation, and integrated project support environments. V.L.

#### A92-19406

#### **AEROSPACE SOFTWARE IN SWEDEN**

INGEMAR CARLSSON (Defence Materiel Administration, Stockholm, Sweden) IN: Aerospace software engineering - A collection of concepts. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1991, p. 561-580. refs Copyright

Recent developments and current trends in aerospace software systems and processes in Sweden are reviewed. In particular, attention is given to to the use of a high-order language system, Pascal D80, in the JAS 39 multirole combat aircraft, the use of the Ada language, computers in space applications, and an industrial approach to the object-oriented development of large-scale systems. The discussion also covers Base/OPEN, a tool development and tool integration framework; the CAX framework concept; and future processing paradigms. V.L.

#### A92-19605\* Pennsylvania State Univ., University Park. A STOCHASTIC REGULATOR FOR INTEGRATED COMMUNICATION AND CONTROL SYSTEMS. I -FORMULATION OF CONTROL LAW. II - NUMERICAL ANALYSIS AND SIMULATION

LUEN-WOEI LIOU and ASOK RAY (Pennsylvania State University, University Park) ASME, Transactions, Journal of Dynamic Systems, Measurement, and Control (ISSN 0022-0434), vol. 113,

### 15 MATHEMATICAL AND COMPUTER SCIENCES

#### Dec. 1991, p. 604-619. refs

(Contract N00014-90-J-1513; NAG3-323; NSF DMC-87-07648) Copyright

A state feedback control law for integrated communication and control systems (ICCS) is formulated by using the dynamic programming and optimality principle on a finite-time horizon. The control law is derived on the basis of a stochastic model of the plant which is augmented in state space to allow for the effects of randomly varying delays in the feedback loop. A numerical procedure for synthesizing the control parameters is then presented, and the performance of the control law is evaluated by simulating the flight dynamics model of an advanced aircraft. Finally, recommendations for future work are made. V.L.

A92-19609\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

# SOME ASPECTS OF UNCERTAINTY IN COMPUTATIONAL FLUID DYNAMICS RESULTS

U. B. MEHTA (NASA, Ames Research Center, Moffett Field, CA) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 113, Dec. 1991, p. 538-543. refs Copyright

Uncertainties are inherent in computational fluid dynamics (CFD). These uncertainties need to be systematically addressed and managed. Sources of these uncertainty analysis are discussed. Some recommendations are made for quantification of CFD uncertainties. A practical method of uncertainty analysis is based on sensitivity analysis. When CFD is used to design fluid dynamic systems, sensitivity-uncertainty analysis is essential. Author

#### A92-19619\* Old Dominion Univ., Norfolk, VA. AERODYNAMIC SENSITIVITY ANALYSIS METHODS FOR THE COMPRESSIBLE EULER EQUATIONS

OKTAY BAYSAL and MOHAMED E. ELESHAKY (Old Dominion University, Norfolk, VA) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 113, Dec. 1991, p. 681-688. refs

(Contract NAG1-1188) Copyright

This study presents a mathematical formulation developed for aerodynamic sensitivity coefficients based on a discretized form of the compressible 2D Euler equations. A brief motivating introduction to the aerodynamic sensitivity analysis and the reasons behind an integrated flow/sensitivity analysis for design algorithms presented. The finite difference approach and the are quasi-analytical approach are used to determine the aerodynamic sensitivity coefficients. A new flow prediction concept, which is an outcome of the direct method in the guasi-analytical approach, is developed and illustrated with an example. Surface pressure coefficient distributions of a nozzle-afterbody configuration obtained from the predicted flowfield solution are compared successfully with their corresponding values obtained from a flowfield analysis code and the experimental data. P.D.

### A92-20150

#### SOVIET CFD - AN INTERNATIONAL PERSPECTIVE

V. A. SOSUNOV and M. IA. IVANOV (Tsentral'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR) Aerospace America (ISSN 0740-722X), vol. 30, Jan. 1992, p. 48-51.

Copyright

An overview is presented of Soviet CFD development and the organizations that have had experience using moderately powerful computers to solve practical problems encountered in aerospace design methods. Highly accurate monotonic difference methods that follow the local flow structure, have been developed and now form the basis for constructing effective algorithms and codes that solve practical external and internal aerodynamics problems. Consideration is given to a potential area for international CFD cooperation that would involve solving problems connected with the design of scramjets for the aerospace plane. R.E.P.

### 15 MATHEMATICAL AND COMPUTER SCIENCES

N92-14598\*# Computer Sciences Corp., Hampton, VA. ANALYSIS OF OBJECTS IN BINARY IMAGES M.S. Thesis -Old Dominion Univ.

DESIREE M. LEONARD Washington NASA Dec. 1991 76 p

(Contract NAS1-19038)

(NASA-CR-4420; NAS 1.26:4420) Avail: NTIS HC/MF A05 CSCL 12/1

Digital image processing techniques are typically used to produce improved digital images through the application of successive enhancement techniques to a given image or to generate quantitative data about the objects within that image. In support of and to assist researchers in a wide range of disciplines, e.g., interferometry, heavy rain effects on aerodynamics, and structure recognition research, it is often desirable to count objects in an image and compute their geometric properties. Therefore, an image analysis application package, focusing on a subset of image analysis techniques used for object recognition in binary images, was developed. This report describes the techniques and algorithms utilized in three main phases of the application and are categorized as: image segmentation, object recognition, and quantitative analysis. Appendices provide supplemental formulas for the algorithms employed as well as examples and results from the various image segmentation techniques and the object recognition algorithm implemented. Author

N92-14673# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

#### ARTIFICIAL NEURAL NETWORK APPROACHES IN GUIDANCE AND CONTROL

Sep. 1991 183 p Lecture series held in Monterey, CA, 8-9 Oct. 1991, in Kjeller, Norway, 14-15 Oct. 1991, and in Neubiberg, Fed. Republic of Germany, 17-18 Oct. 1991

(AGARD-LS-179; ISBN-92-835-0635-9) Copyright Avail: NTIS HC/MF A09; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Ever increasing operational and technical requirements have led to highly integrated flight, guidance and control, and weapons delivery systems. The effective implementation of these functions makes the fusion and interpretation of sensor data and the multifunctional use of sensor information inevitable. Neural networks, consisting of parallel microcomputing elements, hold great promise for guidance, navigation, and control applications because of their ability to learn and acquire knowledge. The objective of this lecture series, sponsored by the Guidance and Control Panel of AGARD, was to present both the fundamentals of neural networks and a number of guidance, navigation, and control (GNC) applications. Some specific topics addressed include neural network architectures and design methodologies, target detection and recognition, vision systems, robots, and multisensor data fusion.

**N92-14674**# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.). Intelligent Systems Div.

#### INTRODUCTION TO NEURAL COMPUTING AND CATEGORIES OF NEURAL NETWORK APPLICATIONS TO GUIDANCE, NAVIGATION AND CONTROL

UWE K. KROGMANN *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 24 p Sep. 1991

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The creation of artificial neural networks (ANN) is directed towards the realization of capabilities and characteristics such as self-organization, learning, and associative memory. This is achieved by the particular structure of neural networks where a large number of simple processor elements are interconnected with uni-directional signal channels to single- or multi-layer networks. All processing elements are working in parallel as compared to one central, extremely efficient computer for sequential arithmetic and/or symbolic information processing. Artificial neural networks are not programmed but trained and learn like their biological paradigm, the brain. This is done by changing the intensity of the connections between processor elements and by generating or eliminating structural connections. A brief introduction to the architecture and functional characteristics of neural networks is presented. In addition, the general structure of guidance and control problems is described and the application of ANNs to guidance and control tasks is examined. Example applications relate to the fault tolerant measurement of the proprio-specific motion of an air vehicle and neural target classification. M.G.

N92-14677# Hecht-Nielsen Neurocomputer Corp., Inc., San Diego, CA.

## PROCESSING COMPLEXITY OF TWO APPROACHES TO OBJECT DETECTION AND RECOGNITION

TODD GUTSCHOW and ROBERT HECHT-NIELSEN *In* AGARD, Artificial Neural Network Approaches in Guidance and Control 12 p Sep. 1991 Prepared in cooperation with California Univ., San Diego, La Jolla

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The computational complexity of a processing function is a driving factor in the implementation of that function in an operational system. Artificial neural networks offer the potential for significant improvements in the computational complexity of a number of guidance and control functions. To illustrate such an improvement, a comparison is considered between two different approaches to object detection and recognition: a traditional approach using a wide field of view and constant spatial resolution throughout the image sensing and processing chain; and a foveal approach using a roving eyeball circularly symmetric sampling grid with a radially variant resolution in the processing chain. The rationale and characteristics of these two approaches are described and compared. Quantitative evaluations of the processing loads and data transfer rates are then carried out for both approaches. These processing requirements are then compared and the operational implications of this comparison are discussed. While the efficacy of the foveal approach is not explicitly discussed, references are provided to relevant research results in this regard. Author

**N92-15658\*#** Institute for Computer Applications in Science and Engineering, Hampton, VA.

#### APPROXIMATION METHODS FOR CONTROL OF ACOUSTIC/STRUCTURE MODELS WITH PIEZOCERAMIC ACTUATORS Final Report

H. T. BANKS, W. FANG (California Univ., Los Angeles.), R. J. SILCOX, and R. C. SMITH Dec. 1991 31 p Submitted for publication

(Contract NAS1-18605; NAS1-18107; NAG1-1116;

AF-AFOSR-0091-90)

(NASA-CR-189578; NAS 1.26:189578; ICASE-91-88) Avail: NTIS HC/MF A03 CSCL 12/1

The active control of acoustic pressure in a 2-D cavity with a flexible boundary (a beam) is considered. Specifically, this control is implemented via piezoceramic patches on the beam which produces pure bending moments. The incorporation of the feedback control in this manner leads to a system with an unbounded input term. Approximation methods in this manner leads to a system with an unbounded input term. Approximation methods in the speceration of linear quadratic regulator (LQR) state space control formulation are discussed and numerical results demonstrating the effectiveness of this approach in computing feedback controls for noise reduction are presented.

**N92-15870\*#** City Univ. of New York, Bronx. Dept. of Engineering Technologies.

#### DEVELOPMENT OF A CALIBRATED SOFTWARE RELIABILITY MODEL FOR FLIGHT AND SUPPORTING GROUND SOFTWARE FOR AVIONIC SYSTEMS

STELLA LAWRENCE /n Alabama Univ., Research Reports: 1991 NASA/ASEE Summer Faculty Fellowship Program 4 p Oct. 1991

(Contract NGT-01-008-021)

Avail: NTIS HC/MF A12 CSCL 09/2
The object of this project was to develop and calibrate quantitative models for predicting the quality of software. Reliable flight and supporting ground software is a highly important factor in the successful operation of the space shuttle program. The models used in the present study consisted of SMERFS (Statistical Modeling and Estimation of Reliability Functions for Software). There are ten models in SMERFS. For a first run, the results obtained in modeling the cumulative number of failures versus execution time showed fairly good results for our data. Plots of cumulative software failures versus calendar weeks were made and the model results were compared with the historical data on the same graph. If the model agrees with actual historical behavior for a set of data then there is confidence in future predictions for this data. Considering the quality of the data, the models have given some significant results, even at this early stage. With better care in data collection, data analysis, recording of the fixing of failures and CPU execution times, the models should prove extremely helpful in making predictions regarding the future pattern of failures, including an estimate of the number of errors remaining in the software and the additional testing time required for the software quality to reach acceptable levels. It appears that there is no one 'best' model for all cases. It is for this reason that the aim of this project was to test several models. One of the recommendations resulting from this study is that great care must be taken in the collection of data. When using a model, the data should satisfy the model assumptions. 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.

# A92-18388

# RESONANCE PREDICTION FOR SLOTTED CIRCULAR WIND TUNNEL USING FINITE ELEMENT

IN LEE and KI-YOUNG BAIK (Korea Advanced Institute of Science and Technology, Taejon, Republic of Korea) AIAA Journal (ISSN 0001-1452), vol. 29, Dec. 1991, p. 2266-2269. refs Copyright

A resonance analysis is presented for a circular cross-section with slots; while it is in principle difficult to analytically predict the resonant frequencies of a slotted wind tunnel, FEM is shown to be a useful approach. An eight-node FEM analysis shows that, for the same open ratio, both horizontal and vertical vibration-mode frequencies for three slots are higher than those for one slot.

0.C.

# A92-18683\* Florida State Univ., Tallahassee. BROADBAND SHOCK-ASSOCIATED NOISE FROM SUPERSONIC JETS IN FLIGHT

C. K. W. TAM (Florida State University, Tallahassee) Journal of Sound and Vibration (ISSN 0022-460X), vol. 151, Nov. 22, 1991, p. 131-147. refs (Contract NAG1-421)

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The stochastic model theory of broadband shock-associated noise from supersonic jets, developed earlier (Tam, 1987, 1990), is extended to jets in flight. Forward flight affects broadband shock-associated noise generation through noise source modification. It also affects the intensity and characteristics of the noise radiated in a given direction through the mean flow convection effect. Noise source modification arises when the external flow associated with forward flight alters the mean velocity profile and shock cell structure of the jet. The mean flow convection effect arises because the radiated sound waves now have to propagate through a moving medium to reach the observation point. The present theory suggests that both the noise source modification effect and the mean flow convection effect would produce narrower broadband shock-associated noise spectral peaks with lower peak frequencies. The theory is further extended to the case of a supersonic jet embedded in an open wind tunnel bounded by a vortex sheet. Detailed comparisons between the calculated results and the measurements of Norum and Shearin (1984, 1986) are reported here. Very good agreements are found over a broad range of jet Mach numbers and wind tunnel Mach numbers. Author

# Aut

# A92-19982

# NUMERICAL CALCULATION OF MODULATION TRANSFER FUNCTIONS FOR LOW FREQUENCY MECHANICAL VIBRATIONS

M. FISHER, O. HADAR, and N. S. KOPEIKA (Negev, University, Beersheba, Israel) IN: Airborne reconnaissance XIV; Proceedings of the Meeting, San Diego, CA, July 10-12, 1990. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 72-83. Research supported by Paul Ivanier Center for Robotics and Production Management. refs

Copyright

Numerical calculations of modulation transfer functions (MTFs) for low-frequency mechanical vibrations are presented. The problem is significant in practical reconnaissance where primary vibrations are at frequencies too low to be described by the usual closed form Bessel function MTF. The low vibration frequency situation involves random process blur radii and MTFs which can only be handled statistically since no closed form solution is possible. This is illustrated here. Comparisons are made to a closed form approximate MTF solution suggested previously. Agreement is generally good, especially for relatively large and linear blur radius situations.

**A92-20301\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

# RATE PARAMETERS FOR COUPLED

# VIBRATION-DISSOCIATION IN A GENERALIZED SSH APPROXIMATION

SURENDRA P. SHARMA, WINIFRED M. HUO, and CHUL PARK (NASA, Ames Research Center, Moffett Field, CA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 6, Jan.-Mar. 1992, p. 9-21. Previously cited in issue 19, p. 3193, Accession no. A88-47075. refs Copyright

**A92-20729\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

# REMOVAL OF SPURIOUS REFLECTIONS FROM COMPUTATIONAL FLUID DYNAMIC SOLUTIONS WITH THE COMPLEX CEPSTRUM

KRISTINE R. MEADOWS and JAY C. HARDIN (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 30, Jan. 1992, p. 29-34. Previously cited in issue 02, p. 229, Accession no. A91-12463. refs Copyright

**N92-14779\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

# AEROACOUSTICS OF FLIGHT VEHICLES: THEORY AND PRACTICE. VOLUME 2: NOISE CONTROL

HARVEY H. HUBBARD, ed. Washington Aug. 1991 443 p Sponsored in cooperation with the Army Aviation Systems Command

(Contract F33615-84-C-3202)

(NASA-RP-1258-VOL-2; L-16926-VOL-2; NAS 1.61:1258-VOL-2; WRDC-TR-90-3052-VOL-2) Avail: NTIS HC/MF A19 CSCL 20/1

Flight vehicles and the underlying concepts of noise generation, noise propagation, noise prediction, and noise control are studied. This volume includes those chapters that relate to flight vehicle noise control and operations: human response to aircraft noise; atmospheric propagation; theoretical models for duct acoustic propagation and radiation; design and performance of duct acoustic treatment; jet noise suppression; interior noise; flyover noise measurement and prediction; and quiet aircraft design and operational characteristics.

N92-14780\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

HUMAN RESPONSE TO AIRCRAFT NOISE

CLEMANS A. POWELL and JAMES M. FIELDS (General Accounting Office, Washington, DC.) In its Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control p 1-52 Aug. 1991

Avail: NTIS HC/MF A19 CSCL 20/1

The human auditory system and the perception of sound are discussed. The major concentration is on the annoyance response and methods for relating the physical characteristics of sound to those psychosociological attributes associated with human response. Results selected from the extensive laboratory and field research conducted on human response to aircraft noise over the past several decades are presented along with discussions of the methodology commonly used in conducting that research. Finally, some of the more common criteria, regulations, and recommended practices for the control or limitation of aircraft noise are examined in light of the research findings on human response. Author

# N92-14782\*# Missouri Univ., Rolla. THEORETICAL MODELS FOR DUCT ACOUSTIC **PROPAGATION AND RADIATION**

WALTER EVERSMAN In NASA. Langley Research Center, Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Aug. 1991 Noise Control p 101-163

Avail: NTIS HC/MF A19 CSCL 20/1

The development of computational methods in acoustics has led to the introduction of analysis and design procedures which model the turbofan inlet as a coupled system, simultaneously modeling propagation and radiation in the presence of realistic internal and external flows. Such models are generally large, require substantial computer speed and capacity, and can be expected to be used in the final design stages, with the simpler models being used in the early design iterations. Emphasis is given to practical modeling methods that have been applied to the acoustical design problem in turbofan engines. The mathematical model is established and the simplest case of propagation in a duct with hard walls is solved to introduce concepts and terminologies. An extensive overview is given of methods for the calculation of attenuation in uniform ducts with uniform flow and with shear flow. Subsequent sections deal with numerical techniques which provide an integrated representation of duct propagation and near- and far-field radiation for realistic geometries and flight conditions.

Author

# N92-14783\*# General Electric Co., Cincinnati, OH. **DESIGN AND PERFORMANCE OF DUCT ACOUSTIC** TREATMENT

R. E. MOTSINGER and R. E. KRAFT In NASA. Langley Research Center, Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control p 165-206 Aug. 1991 Avail: NTIS HC/MF A19 CSCL 20/1

The procedure for designing acoustic treatment panels used to line the walls of aircraft engine ducts and for estimating the resulting suppression of turbofan engine duct noise is discussed. This procedure is intended to be used for estimating noise suppression of existing designs or for designing new acoustic treatment panels and duct configurations to achieve desired suppression levels. Author

N92-14784\*# General Electric Co., Cincinnati, OH. JET NOISE SUPPRESSION

P. R. GLIEBE, J. F. BRAUSCH, R. K. MAJJIGI, and R. LEE NASA. Langley Research Center, Aeroacoustics of Flight Vehicles: Theory and Practice, Volume 2: Noise Control p 207-269 Aua. 1991

Avail: NTIS HC/MF A19 CSCL 20/1

The objectives of this chapter are to review and summarize

the jet noise suppression technology, to provide a physical and theoretical model to explain the measured jet noise suppression characteristics of different concepts, and to provide a set of guidelines for evolving jet noise suppression designs. The underlying principle for all jet noise suppression devices is to enhance rapid mixing (i.e., diffusion) of the jet plume by geometric and aerothermodynamic means. In the case of supersonic jets, the shock-cell broadband noise reduction is effectively accomplished by the elimination or mitigation of the shock-cell structure. So far, the diffusion concepts have predominantly concentrated on jet momentum and energy (kinetic and thermal) diffusion, in that order, and have yielded better noise reduction than the simple conical nozzles. A critical technology issue that needs resolution is the effect of flight on the noise suppression potential of mechanical suppressor nozzles. A more thorough investigation of this mechanism is necessary for the successful development and design of an acceptable noise suppression device for future high-speed civil transports. M.G.

N92-14785\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. INTERIOR NOISE

JOHN S. MIXSON and JOHN F. WILBY (Atlantic Applied Research Corp., Los Angeles, CA.) In its Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control p 271-355 Aug. 1991

Avail: NTIS HC/MF A19 CSCL 20/1 The generation and control of flight vehicle interior noise is discussed. Emphasis is placed on the mechanisms of transmission through airborne and structure-borne paths and the control of cabin noise by path modification. Techniques for identifying the relative contributions of the various source-path combinations are also discussed along with methods for the prediction of aircraft interior noise such as those based on the general modal theory and statistical energy analysis. M.G.

N92-14786\*# Boeing Co., Seattle, WA. Noise Engineering Organization.

# FLYOVER-NOISE MEASUREMENT AND PREDICTION

NOEL A. PEART In NASA. Langley Research Center, Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control p 357-382 Aug. 1991 Avail: NTIS HC/MF A19 CSCL 20/1

Details are presented for the measurement and prediction of aircraft flyover noise to be used for certification, research and development, community noise surveys, airport monitors, and pass fail criteria. Test details presented are applicable to all types of aircraft, both large and small, and the use of Federal Aviation Regulations (FAR) Part 36 (ref. 1) is emphasized. Accuracy of noise measurements is important. Thus, a pass-fail criterion should be used for all noise measurements. Finally, factors which influence the sound propagation and noise prediction procedures, such as atmospheric and ground effects, are also presented. Author

# N92-14787\*# Boeing Co., Seattle, WA. QUIET AIRCRAFT DESIGN AND OPERATIONAL **CHARACTERISTICS**

CHARLES G. HODGE In NASA. Langley Research Center, Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control p 383-413 Aug. 1991

Avail: NTIS HC/MF A19 CSCL 20/1

The application of aircraft noise technology to the design and operation of aircraft is discussed. Areas of discussion include the setting of target airplane noise levels, operational considerations and their effect on noise, and the sequencing and timing of the design and development process. Primary emphasis is placed on commercial transport aircraft of the type operated by major airlines. Additionally, noise control engineering of other types of aircraft is briefly discussed. Author

N92-14788\*# AeroChem Research Labs., Inc., Princeton, NJ. DIRECT COMPUTATION OF TURBULENCE AND NOISE Final Report, 29 Mar. 1989 - 29 Jun. 1991

C. BERMAN, G. GORDON, G. KARNIADAKIS, P. BATCHO, E. JACKSON, and S. ORSZAG (Vector Technology, Inc., Princeton, NJ.) Sep. 1991 77  $\rho$ 

(Contract NAS1-18849)

(NASA-CR-187616; NAS 1.26:187616; TP-499) Avail: NTIS HC/MF A05 CSCL 20/1

Jet exhaust turbulence noise is computed using a time dependent solution of the three dimensional Navier-Stokes equations to supply the source terms for an acoustic computation based on the Phillips convected wave equation. An extrapolation procedure is then used to determine the far field noise spectrum in terms of the near field sound. This will lay the groundwork for studies of more complex flows typical of noise suppression nozzles. Author

**N92-14789\***# Florida Atlantic Univ., Boca Raton. Dept. of Ocean Engineering.

# THE APPLICATION OF EXPERIMENTAL DATA TO BLADE WAKE INTERACTION NOISE PREDICTION

STEWART A. L. GLEGG and WILLIAM J. DEVENPORT Oct. 1991 20 p Presented at the 6th International Symposium on Unsteady Aerodynamics, Aeroacoustics and Aeroelasticity of Turbomachines and Propellers, Notre Dame, IN, 15-19 Sep. 1991 (Contract NAG1-1119)

(NASA-CR-189461; NAS 1.26:189461) Avail: NTIS HC/MF A03 CSCL 20/1

Blade wake interaction noise (BWI) has been defined as the broadband noise generated by the ingestion of turbulent trailing tip vortices by helicopter rotors. This has been shown to be the dominant contributor to the subjectively important part of the acoustic spectrum for the approach stage of a helicopter flyover. A prediction method for BWI noise based on the calculated trailing vortex trajectories has been developed and estimates of the vortex turbulence have been made. These measurements were made on a trailing vortex from a split wing arrangement and did not give the spectrum of the velocity fluctuations. A recent experiment carried out to measure the turbulence associated with a trailing vortex and the application of the results to BWI noise prediction is described. Author

N92-14791# Institute for Water Resources, Fort Belvoir, VA. REDUCING ENVIRONMENTAL NOISE IMPACTS: A USAREUR NOISE MANAGEMENT PROGRAM HANDBOOK Final Report

TIMOTHY D. FEATHER and TED K. SHEKELL Jun. 1991 167 p Prepared in cooperation with Planning and Management Consultants Ltd., Carbondale, IL

(AD-A240797; IWR-91-R-5) Avail: NTIS HC/MF A08 CSCL 20/1

Noise pollution is a major environmental problem faced by the U.S. Army in Europe. Noise-related complaints from German citizens can escalate into intense political issues in German communities. This in turn hampers efficient operation of military training and often times threatens the Army's mission. In order to remedy these problems, USAREUR has developed a noise management program. A successful noise management program will limit the impact of unavoidable noise on the populace. This report, a component of the noise management program, is a reference document for noise management planning. It contains guidelines and rules-of-thumb for noise management. This document contains procedures which operation and training level personnel can understand and apply in their day to day noise management planning. Noise mitigation tips are given. Basic technical information that will aid in understanding noise mitigation is provided along with noise management through land use planning. Noise management for specific components of the military community, (airfields, base operations, training areas, and housing and recreation areas) are addressed. The nature of noise generated, means of noise abatement at the source, path, and receiver (both physical and organizational/public relations methods), and a case study example are described. GRA

**N92-14795\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

# COMPUTATION OF SUPERSONIC JET MIXING NOISE FOR AN AXISYMMETRIC CD NOZZLE USING K-EPSILON TURBULENCE MODEL

ABBAS KHAVARAN (Sverdrup Technology, Inc., Brook Park, OH.), EUGENE A. KREJSA, and CHAN M. KIM 1991 16 p Proposed for presentation at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA (NASA-TM-105338; E-6705; NAS 1.15:105338; AIAA-92-0500) Avail: NTIS HC/MF A03 CSCL 20/1

The turbulent mixing noise of a supersonic jet is calculated for a round convergent-divergent nozzle at the design pressure ratio. Aerodynamic computations are performed using the PARC code with a k-epsilon turbulence model. Lighthill's acoustic analogy combined with Ribner's assumption is adopted. The acoustics solution is based upon the methodology followed by GE in the MGB code. The source correlation function is expressed as a linear combination of second-order tensors. Assuming separable second-order correlations and incorporating Batchelor's isotropic turbulence model, the source term was calculated from the kinetic energy of turbulence. A Gaussian distribution for the time-delay of correlation was introduced. The computational fluid dynamics (CFD) solution was used to obtain the source strength as well as the characteristic time-delay of correlation. The effect of sound/flow interaction was incorporated using the high frequency asymptotic solution to Lilley's equation for axisymmetric geometries. Acoustic results include sound pressure level directivity and spectra at different polar angles. The aerodynamic and acoustic results demonstrate favorable agreement with experimental data.

Author

**N92-14797\***# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

# A SURVEY OF THE BROADBAND SHOCK ASSOCIATED NOISE PREDICTION METHODS

CHAN M. KIM, EUGENE A. KREJSA, and ABBAS KHAVARAN (Sverdrup Technology, Inc., Brook Park, OH.) 1992 26 p Proposed for presentation at the 30th Aerospace Sciences Meeting and Exhibit, Reno, NV, 6-9 Jan. 1992; sponsored by AIAA (Contract NAS3-25266)

(NASA-TM-105365; E-6743; NAS 1.15:105365; AIAA-92-0501) Avail: NTIS HC/MF A03 CSCL 20/1

Several different prediction methods to estimate the broadband shock associated noise of a supersonic jet are introduced and compared with experimental data at various test conditions. The nozzle geometries considered for comparison include a convergent and a convergent-divergent nozzle, both axisymmetric. Capabilities and limitations of prediction methods in incorporating the two nozzle geometries, flight effect, and temperature effect are discussed. Predicted noise field shows the best agreement for a convergent nozzle geometry under static conditions. Predicted results for nozzles in flight show larger discrepancies from data and more dependable flight data are required for further comparison. Qualitative effects of jet temperature, as observed in experiment, are reproduced in predicted results.

**N92-14798**# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.

# PROPELLER-DRIVEN-SMALL AIRPLANE NOISE CERTIFICATION

G. J. J. RUIJGROK and D. M. VANPAASSEN Dec. 1990 31 p (LR-650; ETN-92-90417) Avail: NTIS HC/MF A03

The existing international standards and recommended practices for light propeller driven airplane noise as published in annex 16 to the Convention on International Civil Aviation are reviewed. These airplanes are defined as having a maximum certificated takeoff mass below 9000 kg. The determination of atmospheric attenuation rate and the establishment of a confidence level are discussed. ESA

# N92-15013# Naples Univ. (Italy). LINEAR ACOUSTICS IN GAS MIXTURES WITH RATE PROCESSES

LUIGI G. NAPOLITANO In ESA, Aerothermodynamics for Space Vehicles p 317-324 Jul. 1991

Copyright Avail: NTIS HC/MF A24; ESA, EPD, ESTEC, Noordwijk, Netherlands, HC 90 Dutch guilders

Linear acoustics in an unbounded medium in which an arbitrary number of independent rate processes (chemical reactions and/or excitations on internal decrees of freedom) take place are dealt with. The medium is supposed to be in an initial quiescent and full equilibrium state and all diffusion processes are assumed to be negligible. (Linear acoustics without neglection of diffusion processes or in nonquiescent media and nonlinear acoustics with and without diffusion processes are not dealt with). The extremely simplified case dealt with is nonetheless very useful. It allows for the following: elucidation of the role played by a number of basic notions of thermodynamics such as equilibrium and stability; quantification of the 'response' of the media to small disturbances; and suggestion of diagnostic techniques which may be used to study the kinetics of rate processes and their couplings, and so forth. Equilibrium and nonequilibrium thermodynamics of composite systems as specialized to the subject case are considered. The field equations and their linearized form appropriate to the study of linear acoustics are addressed, as are the general features of linear acoustics, dispersion equation, and properties of the acoustic susceptibility. ESA

N92-15761# Oak Ridge National Lab., TN.

# SCOPING STUDIES FOR SMALL STEADY-STATE TOKAMAKS FOR DIVERTOR TESTING

J. D. GALAMBOS, Y. K. M. PENG, B. E. NELSON, S. P. HIRSHMAN, and P. J. FOGARTY 1991 6 p Presented at the 14th IEEE Symposium on Fusion Engineering, San Diego, CA, 30 Sep. - 3 Oct. 1991

(Contract DE-AC05-84OR-21400)

(DE92-000740; CONF-910968-10) Avail: NTIS HC/MF A02

A prime uncertainty in next-generation devices is the divertor performance. For the International Thermonuclear Experimental Reactor (ITER), the divertor limit often plays a more critical role in the operational scenario definition than do beta limit and energy confinement constraints. Hence, it is desirable to test the divertors in an environment as close as possible to that expected in next-step burning plasma experiments. Initial global scoping studies are done for small, steady-state, copper coil, beam-driven tokamaks that are dedicated to divertor testing. The usual ITER global physics models (beta limit, energy confinement, and analytic divertor heat load calculation) are incorporated, and for performance criteria we require that the divertor heat load and plasma collisionality in the edge region be similar to those expected in ITER. The smallest, lowest-cost devices satisfying these constraints tend to have major radius below 1 m, plasma current of 0.5 to 1 MA, and low aspect ratio and costs of a few tens of millions of dollars. Injection powers of about 4 to 5 MW are needed to sustain the plasma current, maintain plasma power balance, and provide the required divertor heat load DOF

# 17

# SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

**N92-14923#** Congress of the United States, Washington, DC. **NATIONAL AERONAUTICS AND SPACE ADMINISTRATION** *In its* Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1992 p 83-90 18 Jul. 1991

Avail: Document Room, House of Representatives, Washington, DC 20515 HC free

House committee recommendations for appropriations for the National Aeronautics and Space Administration for the fiscal year ending September 30, 1992 are presented. The budget recommendations provide an outline of budgetary information for research and development; construction of facilities; space flight, control and data communication; research and program management; the Office of Inspector General; and administrative provisions. J.P.S.

# N92-14925# Committee on Appropriations (U.S. Senate). NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*In its* Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, 1992 p 130-148 1991

Avail: Document Room, Senate, Washington, DC, 20510 HC free

Senate committee recommendations for appropriations for the National Aeronautics and Space Administration for the fiscal year ending September 30, 1992 are presented. The budget recommendations provide an outline of budgetary information for space transportation; space sciences; commercial, technology, and educational programs; air and space flight; communications; propulsion; international radio astronomy programs; construction of facilities; and research and program management. J.P.S.

# N92-14927# Committee on Appropriations (U.S. Senate). NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*In its* Departments of Veterans Affairs and Housing and Urban Development and Independent Agencies Appropriations for Fiscal Year 1992, Part 2 p 297-395 1991

Avail: Committee on Appropriations, Senate, Washington, DC, 20510 HC free

Following opening statements of members of the subcommittee of the Senate Committee on Appropriations, the National Aeronautics and Space Administration presents its fiscal year 1992 budget. Previous and planned programs are discussed. It is noted that the entire NASA budget equals only a little over 1 percent of the total Federal budget, and that 99 percent of NASA's \$15.8 billion is needed for ongoing programs. The subcommittee noted that Congress and the General Accounting Office use different standards in measuring science and space programs. Concern was expressed for the future impact of current science and space program underfunding. Questions submitted to NASA after the hearing, and their answers, are included in the record. Topics discussed include NASA's priorities, a strategic plan, budget reserves, the space station, shuttles, the advanced solid rocket motor, Mission to Planet Earth, a new launch vehicle, the Mars Observer, Landsat, education, communications, management, commerce, NASA field Center maintenance, and technology and information transfer. J.P.S.

N92-14933# Office of Technology Assessment, Washington, DC.

# NEW WAYS: TILTROTOR AIRCRAFT AND MAGNETICALLY LEVITATED VEHICLES

1992 118 p

(OTA-SET-507; ISBN-0-16-035630-X) Avail: NTIS HC/MF A06 The Office of Technology Assessment presents a study on tiltrotor aircraft and magnetically levitated (maglev) vehicular technology. The purpose of the study was to provide the House Committee on Appropriations with information that would aid their

Committee on Appropriations with information that would aid their decisionmaking on how much and what kind of additional investment they should make in these new technologies to help resolve transportation congestion. Federal policy issues are presented, as well as various options for operational implementation. J.P.S.

# N92-15937# Committee of Conference (U.S. Congress). NATIONAL AERONAUTICS AND SPACE ADMINISTRATION RESEARCH AND DEVELOPMENT

In its Making Appropriations for the Depts. of Veterans Affairs

and Housing and Urban Development, and for Sundry Independent Agencies, Commissions, Corps., and Other Offices for the Fiscal Year Ending 30 Sep. 1992, and for Other Purposes p 51-61 1991

Avail: Document Room, House of Representatives, Washington, DC 20515 HC free

The Conference Committee presents its report on recommended appropriations for the National Aeronautics and Space Administration (NASA) for the fiscal year ending September 30, 1992. Items addressed by the Conference Committee include agreed upon changes, amendments, funding by program, and decisions that the Committee made regarding differences. Both NASA's ongoing programs and new initiatives are included in the list of appropriations considered. J.P.S.

**N92-15938**# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Dienstelistungsbereich.

# THE ACOUSTIC FLASHLIGHT [DIE AKUSTISCHE TASCHENLAMPE]

STEPHAN BRUEHL 1990 6 p In GERMAN Original contains color illustrations

(MBB-Z-0359-90-PUB; REPT-3/1990; ETN-92-90610) Avail: NTIS HC/MF A02

It is shown that for traveling speeds over three hundred kilometers per hour, sound radiation is determined by aerodynamical effects, e.g., by local shedding of vortices and large area boundary layer noise. In order to obtain exact information on the position and strength of these aerodynamic sources of sound on vehicle surfaces, a measurement process aiming at localizing and analyzing quantitatively quick moving sources of sound welveloped. The measuring equipment is described, e.g., a directional microphone which is placed at about five meters off the roadway. Using light cabinets, the vehicle position can be exactly determined, with regard to the measuring station at any overhaul time.

# AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

April 1992



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flight

ABLATION Ablation sensors and temperature for measurements in reentry body heat shields p 227 N92-15004 ABLATIVE MATERIALS The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009 ACCELERATED LIFE TESTS Designing through test [AIAA PAPER 91-3822] p 232 A92-17664 ACCELEROMETERS Short time force measurement system p 208 N92-15001 ACOUSTIC ATTENUATION Theoretical models for duct acoustic propagation and idiation p 236 N92-14782 radiation ACOUSTIC DUCTS Theoretical models for duct acoustic propagation and radiation p 236 N92-14782 Design and performance of duct acoustic treatment p 236 N92-14783 ACOUSTIC MEASUREMENT A survey of the broadband shock associated noise prediction methods [NASA-TM-105365] p 237 N92-14797

Ablation	and	temperature	sensors	for	flight
measureme	nts in r	eentry body he	at shields		
			p 227	N92-	15004
The acou	stic flas	shlight			
[MBB-Z-035	59-90-P	UB)	p 239	N92-	15938
ACOUSTIC P	ROPAC	ATION			

Aeroacoustics of flight vehicles: Theory and practice. Volume 2: Noise control

p 235 N92-14779 [NASA-BP-1258-VOL-21 Theoretical models for duct acoustic propagation and p 236 N92 14782 radiation

## ACTIVE CONTROL

Helicopter air re:	sonance	modeling	and	suppression
using active control	l		p 204	A92-18625
Hydraulic actuato	r system	for rotor of	contro	ol 🛛
			~~ ~	. Non 44000

- p 224 N92-14363 Approximation methods for control of acoustic/structure
- models with piezoceramic actuators [NASA-CR-189578] p 234 N92-15658
- TUATORS Hydraulic actuator system for rotor control
- p 224 N92-14363 F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation
- [AD-A242637] p 206 N92-15073 Approximation methods for control of acoustic/structure models with piezoceramic actuators
- [NASA-CR-189578] p 234 N92-15658 ADA (PROGRAMMING LANGUAGE)
- Formal specification and verification of Ada software p 230 A92-17585 [AIAA PAPER 91-3713] Applications of an automated [AIAA PAPER 91-3767] programming system p 231 A92-17629
- ADAPTIVE CONTROL Project of an adaptive multiaxial autopilot with learning
- pilot control [ETN-92-90592] o 205 N92-15072
- ADAPTIVE FILTERS
- Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-18611
- AERIAL RECONNAISSANCE
- Reconfigurable Mobile System Ground, sea and air p 218 A92-19986 applications Aerobureau - Strategic television airmobile reports via atellite p 218 A92-19988
- AEROACOUSTICS Removal of spurious reflections from computational fluid dynamic solutions with the complex cepstrum
- p 235 A92-20729 Aeroacoustics of flight vehicles: Theory and practice. Volume 2: Noise control

NASA-RP-1258-VOL-21	p 235	N92-14779

- p 236 N92-14784 Jet noise suppression Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model
- [NASA-TM-105338] p 237 N92-14795 A survey of the broadband shock associated noise prediction methods
- p 237 N92-14797 [NASA-TM-105365] Linear acoustics in gas mixtures with rate processes
- p 238 N92-15013 AEROASSIST
- Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge
- p 183 N92-15020 **AERODYNAMIC BRAKES**
- Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge
- p 183 N92-15020 AERODYNAMIC CHARACTERISTICS
- Flight test of a half-scale unmanned air vehicle p 193 A92-20208 Incompressible steady aerodynamics using a standard p 174 A92-20218 finite element code Turbulent boundary-layer characteristics over a flat-plate/wedge configuration at Mach 6 p 176 A92-20761 Design of transonic compressor cascades using p 202 N92-13973 hodograph method fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes p 185 N92-15050 [NASA-TM-104186]
- AERODYNAMIC COEFFICIENTS Aerodynamic sensitivity analysis methods for the p 233 A92-19619 compressible Euler equations
  - A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986 Applicability of bridging methods to hypersonic rarefied

flow aerodynamics of reentry vehicles p 184 N92-15032

Transitional flows around re-entry bodies p 184 N92-15035 Computation of aerodynamic coefficients on Hermes-Ariane5 configuration p 184 N92-15040 **AERODYNAMIC CONFIGURATIONS** Three-dimensional solution-adaptive grid generation on composite configurations p 172 A92-18352 Numerical calculation of subsonic and supersonic aerodynamic loads around complex configuration vehicle p 175 A92-20488 Aerodynamic shape optimization of arbitrary hypersonic vehicles p 194 N92-13954 Aerothermodynamics for Space Vehicles [ESA-SP-318] p 180 N92-14973 Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results p 211 N92-14975 Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980 Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at p 181 N92-14987 super- and hypersonic speed Interference heating near fin/body junctions on prersonic vehicles p 182 N92-14996 hypersonic vehicles Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise p 227 N92-15027 problems Aerothermodynamics for United States advanced p 184 N92-15039 programs Computation of aerodynamic coefficients on Hermes-Ariane5 configuration p 184 N92-15040 Grid impact on 3D hypersonic flows p 184 N92-15041 Evolution and development of hypersonic configurations 1958-1990 [AD-A242768] p 197 N92-15069 AERODYNAMIC DRAG Drag balance for hypervelocity impulse facilities p 207 A92-18375 Flight test of a half-scale unmanned air vehicle p 193 A92-20208 Inviscid drag prediction for transport wings using a full-potential method p 174 A92-20212 Aerodynamic shape optimization of arbitrary hypersonic vehicles p 194 N92-13954 The effects of winglets on low aspect ratio wings at supersonic Mach numbers INASA-CR-44071 p 178 N92-13996 A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin wings [NASA-CR-4414] p 178 N92-13997 A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076 AERODYNAMIC FORCES Aerodynamic damping of blade vibrations turbomachines --- Russian book p 200 A92-18198

- Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations p 204 A92-18622 Dynamic characteristics and stability analysis of space p 224 N92-14366 shuttle main engine oxygen pump
- Short time force measurement system p 208 N92-15001

# AERODYNAMIC HEAT TRANSFER

- Engineering method for calculating surface pressures and heating rates on vehicles with embedded shocks [AIAA PAPER 91-5060] p 171 A92-17842 Interference heating near fin/body junctions on hypersonic vehicles p 182 N92-14996 Infrared measurements of aerodynamic heating in hypersonic wind tunnel ypersonic wind tunnel p 208 N92-15002 Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 AERODYNAMIC HEATING
- Effect of nose shape on three-dimensional stagnation region streamlines and heating rates [AIAA PAPER 91-5032] p 171 A92-17822

p 184 N92-15031

p 184 N92-15039

p 184 N92-15040

of the Saenger p 184 N92-15042

on

coefficients

# AERODYNAMIC INTERFERENCE

Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17843 Three-dimensional thermal structural analysis of a swept cowl leading edge subjected to skewed shock-shock p 174 A92-20306 interference heating Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020 AERODYNAMIC INTERFERENCE ody junctions on p 182 N92-14996 Interference heating near fin/body hypersonic vehicles

AERODYNAMIC LOADS A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058] p 171 A92-17841 Static aeroelastic analysis for generic configuration p 174 A92-20201 wing Numerical calculation of subsonic and supersonic

aerodynamic loads around complex configuration vehicle p 175 A92-20488 Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067 Numerical simulation of VAWT stochastic aerodynamic

loads produced by atmospheric turbulence: VAWT-SAL code p 229 N92-15392 (DE92-000597) AERODYNAMIC NOISE

Flyover-noise measurement and prediction p 236 N92-14786 Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model [NASA-TM-105338] p 237 N92-14795

The acoustic flashlight [MBB-Z-0359-90-PUB] AERODYNAMIC STABILITY p 239 N92-15938

A simplified method for predicting the stability of aerodynamically excited turbomachinery p 224 N92-14364

Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076

AERODYNAMIC STALLING

Nonlinear stall flutter and divergence analysis of cantilevered graphite/epoxy wings p 219 A92-20746 AERODYNAMICS

A perspective on aerospace CFD p 169 A92-20145 Review of aerodynamic design in the Netherlands p 193 N92-13929 A comparison of two closely-related approaches to

aerodynamic design optimization p 193 N92-13933 Recent progress in inverse methods in France p 201 N92-13938

Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances p 201 N92-13939

The research progress on Hodograph Method of aerodynamic design at Tsinghua University D 177 N92-13974

International aviation (selected articles) p 170 N92-13993 [AD-A241119]

JPRS report: Science and technology. USSR: Space p 211 N92-14101 [JPRS-USP-91-007] Experimental research of the aerodynamics of nozzles

and plumes at hypersonic speeds p 185 N92-15048 [NASA-CB-187316]

**AEROELASTIC RESEARCH WINGS** Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations p 204 A92-18622

Static aeroelastic analysis for generic configuration p 174 A92-20201 wina AEROELASTICITY

Aeroservoelastic stabilization techniques for hypersonic flight vehicles

[AIAA PAPER 91-5056] p 203 A92-17839 Cabin structural vibration and noise for transport p 192 A92-17876 aircraft Aerodynamic damping of blade vibrations inbomachines --- Russian book p 200 A92-18198 Experimental and theoretical analysis of composite turbomachines --- Russian book

p 216 A92-18377 I-beams with elastic couplings Parameter insensitive control utilizing eigenspace methods --- for flutter suppression in aeroelastic vehicles p 204 A92-18615

Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 Nonlinear stall flutter and divergence analysis of cantilevered graphite/epoxy wings p 219 A92-20746 Time domain flutter analysis of cascades using a

full-potential solver p 176 A92-20747 International aviation (selected articles) p 170 N92-13993 [AD-A241119]

The benchmark aeroelastic models program: Description and highlights of initial results p 185 N92-15049 [NASA-TM-104180]

**AERONAUTICAL ENGINEERING** Technology in the lives of an aircraft designer [AIAA PAPER 91-3069] p 192 A92-20000 International aviation (selected articles) p 170 N92-13993 [AD-A241119] Review of investigations on aeronautical fatigue in the Federal Republic of Germany [ETN-92-90317] p 225 N92-14397 AEROSPACE ENGINEERING JPRS report: Science and technology. USSR: Space [JPRS-USP-91-007] p 211 N92-14101 p 211 N92-14101 AEROSPACE PLANES

'Spaceplanes' R&D status of Japan [AIAA PAPER 91-5002] p 209 A92-17802

A geometric approach to regulator and tracker design for an aerospace plane [AIAA PAPER 91-5054] p 203 A92-17837 Hydrogen exhaust gas disposition by afterburning [AIAA PAPER 91-5075] p 200 A92-1 p 200 A92-17848

p 212 A92-18002 Hypersonic materials Rapid near-optimal aerospace plane trajectory generation and guidance [NASA-CR-189469]

p 205 N92-14066 History of EPOS air-launched spaceplane project p 211 N92-14103

Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results p 211 N92-14975

AEROSPACE SYSTEMS

Aerospace software engineering in the United p 233 A92-19405 Kingdom Aerospace software in Sweden p 233 A92-19406

AEROSPACE VEHICLES A perspective on aerospace CFD p 169 A92-20145 AEROTHERMOCHEMISTRY

Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and p 235 A92-20301 Herzfeld Aerothermodynamics for Space Vehicles

[ESA-SP-318] p 180 N92-14973 Hypersonic viscous shock layer in thermochemical nonequilibrium p 183 N92-15014 Influence of chemical modeling on the solution of

p 183 N92-15016 hypersonic shock layers Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies

p 227 N92-15029 AEROTHERMODYNAMICS

Thrust nozzle test facility at DLR Cologne p 206 A92-17818 [AIAA PAPER 91-5024] Application of the STAPAT II code to hypersonic vehicle aerothermodynamics

[AIAA PAPER 91-5035] p 209 A92-17824 Turbulent boundary-layer characteristics over a

flat-plate/wedge configuration at Mach 6 p 176 A92-20761

Aerothermodynamics for Space Vehicles [ESA-SP-318] p 180 N92-14973 Aerothermodynamic challenges for ESA programmes

p 180 N92-14974 Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results

p 211 N92-14975 Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles

p 211 N92-14977 Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests

p 211 N92-14980 Experimental study of hypersonic shock wave boundary

layer interactions by means of infrared technique p 182 N92-14994

Interference heating near fin/body junctions on personic vehicles p 182 N92-14996 hypersonic vehicles Hypersonic aerothermodynamic computations using a

point-implicit TVD method p 183 N92-15006 Linear acoustics in gas mixtures with rate processes p 238 N92-15013

Hypersonic viscous shock layer in thermochemical nonequilibrium p 183 N92-15014 FALKE and COBRA technology development in

aerodynamics and aerothermodynamics p 183 N92-15017

Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020

High enthalpy testing in the Aachen (Fed. Republic of p 206 N92-15021 Germany) shock tunnel TH 2 Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise p 227 N92 15027 problems Numerical simulation of thermochemical non-equilibrium

viscous flows around reentry bodies p 227 N92-15029

Computation of aerodynamic Hermes-Ariane5 configuration Aerothermodynamic challenges space-transportation system AFTERBURNING

programs

Hydrogen exhaust gas disposition by afterburning [AIAA PAPER 91-5075] p 200 A92-1 p 200 A92-17848 AIR BREATHING BOOSTERS Potential hypersonic vehicles applications

(DSMC) code for fluid dynamics

(AIAA PAPER 91-5086) p 169 A92-17854 AIR BREATHING ENGINES

Behaviour and modelling of the aerothermodynamics of

Parallelization of a Direct Simulation Monte Carlo

OSMC) code for fluid dynamics p 227 N92-15033 Aerothermodynamics for United States advanced

ballistic entry vehicles in the high altitude flow regimes

Supersonic inlet flow computation

p 171 A92-17502 Hypersonic airbreathing propulsion activities for Saenger [AIAA PAPER 91-5040]

p 200 A92-17828 Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles

[NASA-TM-102687] p 206 N92-15076 AIR COOLING

High-temperature combustor and seal for a water piston propulsor [AD-A242493]

p 229 N92-15385 AIR DEFENSE

Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048

AIR FLOW

An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861 SIMOUN and Scirocco wind tunnel nozzle viscous flow

p 208 N92-14999 study AIR INTAKES

Analysis of an advanced ducted propeller subsonic inlet

[NASA-TM-105393] p 179 N92-14002 AIR LAUNCHING

History of EPOS air-launched spaceplane project p 211 N92-14103

AIR TRAFFIC Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a

[ACD-340] p 191 N92-14034 AIR TRAFFIC CONTROL

Z-Basic algorithm for collision avoidance system

p 188 A92-18482 The application of neural networks to drone control

p 205 A92-19273 Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan,

December 3, 1990 [PB91-910405] p 187 N92-14006

Electronic systems in transportation [TP-9983] p 189 N92-14009

A strategy for exploiting the full potential of MLS based terminal procedures in Canada p 190 N92-14025 A Taxi And Ramp Management And Control system

p 207 N92-14027 (TARMAC) A unique approach to aircraft conflict resolution using artificial intelligence techniques p 190 N92-14029

Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034

Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report [DOT/FAA/CT-TN91/50]

n 221 N92-14270 Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis (SCT-9088-441

p 191 N92-15061 AIR TRANSPORTATION

Electronic systems in transportation p 189 N92-14009 [TP-9983] AIRBORNE EQUIPMENT

Radar troubleshooting assistant expert system [AIAA PAPER 91-3764] p 231 A9

p 231 A92-17626 A new 1553 all-bus instrumentation monitor

p 198 A92-19252 Aerobureau - Strategic television airmobile reports via p 218 A92-19988 satellite

ambient

On the accuracy of an aircraft-borne electric-field measuring system p 186 A AIRBORNE/SPACEBORNE COMPUTERS p 186 A92-20127 Verification of flight software by embedding software

simulation in simulation of external environment p 232 A92-19084

International aviation (selected articles) [AD-A241119] p 170 N92-13993

Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype flight hardware p 220 N92-14217

Formulation of a strategy for monitoring control integrity in critical digital control systems [NASA-TM-104158] p 206 N92-15075

AIRCRAFT ACCIDENT INVESTIGATION Fair weather convection and light aircraft accidents [IAF PAPER ST-91-004] p 186 A92-20651

[IAF PAPER ST-91-004] p 186 A92-20651 Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990

[PB91-910405] p 187 N92-14006 Aircraft accident/incident summary report: Midair collision involving Lycoming Air Services Piper Aerostar PA-60 and Sun Company Aviation Department Bell 412, Merion, Pennsylvania, April 4, 1991

[PB91-910407] p 187 N92-15055

Aging aircraft programme entails major effort and expense p 169 A92-20023 Analysis of changes in the pilot population and general aviation accidents p 187 A92-20722

Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990

[PB91-910405] p 187 N92-14006 Aircraft accident/incident summary report: Midair collision involving Lycoming Air Services Piper Aerostar PA-60 and Sun Company Aviation Department Bell 412, Merion, Pennsylvania, April 4, 1991

(PB91-910407) p 187 N92-15055 AIRCRAFT ANTENNAS

SATCOM antenna siting study on P-3C aircraft, volume

[NASA-CR-189514] p 221 N92-14262 SATCOM antenna siting study on P-3C aircraft, volume

[NASA-CR-189515] p 221 N92-14263 Electronically steerable antenna for aircraft

- p 229 N92-15272 AIRCRAFT APPROACH SPACING
- A Taxi And Ramp Management And Control system (TARMAC) p 207 N92-14027 Evaluation of triple simultaneous parallel ILS approaches
- spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034 AIRCRAFT CARRIERS
- Neural network and fuzzy logic technology for naval flight control

[AD-A242650] p 206 N92-15074 AIRCRAFT COMMUNICATION

Design and implementation of a total flight test system p 189 A92-19278 Rotorcraft low attitude IFR benefit/cost analysis:

- Operations analysis
- [SCT-90RR-44] p 191 N92-15061 AIRCRAFT COMPARTMENTS Interior noise p 236 N92-14785
- AIRCRAFT CONFIGURATIONS A configuration development strategy for the NASP
- [AIAA PAPER 91-5044] p 210 A92-17830 Engineering method for calculating surface pressures and heating rates on vehicles with embedded shocks
- [AIAA PAPER 91-5060] p 171 A92-17842 Aerodynamic aircraft design methods and their notable applications: Survey of the activity in Japan

p 193 N92-13930 On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931

Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948

p 194 N92 AIRCRAFT CONSTRUCTION MATERIALS

Current stabilizing of fastened composite joints to improve non-sparking lightning current performance p 213 A92-20130 The use of finite difference electromagnetic analysis in

the design and verification of modern aircraft p 192 A92-20136 Mechanical qualification tests for materials used in the

fabrication of aircraft parts [CEAT-M5-5443/01] p 195 N92-14042 The two-bay crack problem in fuselages built in GLARE and ARALL

[LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage

[LR-655] p 196 N92-14045 AIRCRAFT CONTROL Hydraulic pumps - The key to power generation

An alternative derivation of the modified gain function

of Song and Speyer p 232 A92-18464

Retrospective essay on nonlinearities in aircraft flight control p 204 A92-18601 Dynamics of hang-gliders p 204 A92-18608 Optimal control problems with maximum functional

p 232 A92-18616 Application of stochastic robustness to aircraft control systems p 204 A92-18620

The application of neural networks to drone control p 205 A92-19273

Electronic systems in transportation [TP-9983] p 189 N92-14009 Introduction to neural computing and categories of neural network applications to guidance, navigation and control p 234 N92-14674 AIRCRAFT DESIGN

- ASNT and aerospace What about the next 50 years? p 215 A92-17293 Operational design factors for NASP derived vehicles [AIAA PAPER 91-5081] p 210 A92-17851
- Dornier 328 first flight p 192 A92-19924 Technology in the lives of an aircraft designer [AIAA PAPER 91-3069] p 192 A92-20000
- Analysis technique for lightning attachment zoning of aircraft p 186 A92-20126
- The use of finite difference electromagnetic analysis in the design and verification of modern aircraft
- Direct-inverse transonic wing-design method in
- curvilinear coordinates including viscous interaction p 193 A92-20202 Four decades of transonic fighter design
- p 193 A92-20203 Review of aerodynamic design in the Netherlands
- Aerodynamic aircraft design methods and their notable
- applications: Survey of the activity in Japan p 193 N92-13930
- Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization
- p 194 N92-13948 Extended mapping and characteristics techniques for inverse aerodynamic design p 194 N92-13949 Application of direct inverse analogy method (DIVA) and viscous design optimization techniques
- p 176 N92-13951 Research on inverse methods and optimization in Italy
- p 202 N92-13956 An inverse method for the aerodynamic design of
- An inverse method for the aerodynamic design of three-dimensional aircraft engine nacelles p 194 N92-13958
- Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959 An inverse method with regularity condition for transonic
- airfoit design p 177 N92-13969 Analysis and design of planar and non-planar wings for induced drag minimization
- [NASA-CR-189509] p 179 N92-13999
- Avionics technology beyond 2000 p 200 N92-14058 Numerical investigations in three-dimensional internal
- flows [NASA-CR-189467] p.221 N92-14313
- Design and performance of duct acoustic treatment p 236 N92-14783
- Quiet aircraft design and operational characteristics p 236 N92-14763 p 236 N92-14787

AIRCRAFT ENGINES

- Numerical
   simulation
   for
   various
   flowfields
   of

   aero-engine
   components
   p
   200
   A92-17503
   Hydrogen
   A92-17503
   Events
   Flowfields
   of
   A92-17503
   Hydrogen
   A92-17503
   Flowfields
   of
   A92-17503
   Flowfields
   of
   A92-17503
   Flowfields
   of
   A92-17548
   A92-17848
   A92-1
- A probabilistic method for monitoring the remaining life of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 Large chord turbine cascade testing at engine Mach and Reynolds number p 173 A92-1871
- Short fatigue crack growth from blunt notches in an aero-engine alloy p 212 A92-19760 Thermo-mechanical fatigue crack growth in aircraft
- engine materials p 213 A92-19799 Performance improvements of an F-15 airplane with an integrated engine-flight control system
- p 205
   A92-20204

   Evaluation of a bounded high-resolution scheme for

   combustor flow computations
   p 201

   A92-20734

   Holographic-interferometry methods employed for
- vibration-strength testing of aviation-engine workpieces p 219 A92-20771 An inverse method for the aerodynamic design of
- three-dimensional aircraft engine nacelles p 194 N92-13958
- The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies
  - p 222 N92-14349

# AIRCRAFT MANEUVERS

Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424 Programs at Wright-Patterson Air Force Base p 228 N92-15092 Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 AIRCRAFT EQUIPMENT Autonomously aided strapdown attitude reference system p 204 A92-18610 AIRCRAFT FUELS Structural considerations for aircra Modification: P-3C zero fuel weight increase aircraft payload p 196 N92-15068 [AD-A242690] AIRCRAFT GUIDANCE DME growth elements and their use with MLS p 189 N92-14018 A unique approach to aircraft conflict resolution using artificial intelligence techniques p 190 N92-14029 Image-based ranging and guidance for rotorcraft [NASA-CR-184829] p 191 N92p 191 N92-14036 Rapid near-optimal aerospace plane trajectory generation and guidance p 205 N92-14066 NASA-CB-1894691 AIRCRAFT HAZARDS Nonlinear triggered lightning models for use in finite p 230 A92-20128 difference calculations Whole aircraft lightning indirect effects evaluation using p 192 A92-20134 low level injection techniques LEWICE/E: An Euler based ice accretion code p 179 N92-14001 [NASA-TM-105389] Study of the engine bird ingestion experience of the Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053 AIRCRAFT HYDRAULIC SYSTEMS Hydraulic pumps - The key to power generation p 215 A92-17348 AIRCRAFT ICING Heat transfer measurements from a smooth NACA 0012 p 218 A92-20215 airfoil Roughness effects on heat transfer from a NACA 0012 p 219 A92-20217 airfoil AIRCRAFT INDUSTRY Nondestructive testing developments in the aircraft industry p 214 A92-17288 International aviation (selected article) p 170 N92-13991 [AD-A240986] Application of MSC/DYNA to shock and impact problems in aircraft industry p 225 N92-14382 [MBB-UD-0593-91-PUB] AIRCRAFT INSTRUMENTS A state-of-the-art data acquisition system p 217 A92-19231 Pneumatic distortion compensation for aircraft surface pressure sensing devices p 218 A92-20206 AIRCRAFT LANDING New siting techniques for the ILS glide slope p 188 A92-17422 Nonlinear landing gear behavior at touchdown p 192 A92-19606 Fair weather convection and light aircraft accidents p 186 A92-20651 [IAF PAPER ST-91-004] A Taxi And Ramp Management And Control system p 207 N92-14027 (TARMAC) Neural network and fuzzy logic technology for naval flight control-[AD-A242650] p 206 N92-15074 AIRCRAFT MAINTENANCE Enhanced visual technique for rapid inspection of aircraft p 214 A92-17290 structures Rapid ultrasonic scanning of aircraft structures p 215 A92-17292 ASNT and aerospace - What about the next 50 years? p 215 A92-17293 National research program for nondestructive inspection p 169 A92-17294 of aging aircraft Some results on metal and composite patch reinforcement of aluminum honeycomb panel p 216 A92-18830 Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft Avionics modernization/upgrades in the late 1990s p 199 N92-14055 Fatigue of repaired composite structures p 214 N92-14411

- Methodology for assessment of skin repairs on Airbus aircraft p 226 N92-14428
- AIRCRAFT MANEUVERS Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838 2 Decider decide and for all for all for all for the set of the set
  - Z-Basic algorithm for collision avoidance system p 188 A92-18482 Analysis of aircraft performance during lateral
  - maneuvering for microburst avoidance p 205 A92-20207

# AIRCRAFT MODELS

Monitoring load experience of individual aircraft [NLR-TP-90084-U] p 196 N92-15065 AIRCRAFT MODELS

- Multidisciplinary modeling and simulation of a generic hypersonic vehicle
- (AIAA PAPER 91-5015) p 232 A92-17813 On the accuracy of an aircraft-borne ambient electric-field measuring system p 186 A92-20127
- The use of finite difference electromagnetic analysis in the design and verification of modern aircraft p 192 A92-20136 SATCOM antenna siting study on P-3C aircraft, volume
- [NASA-CR-189515] p 221 N92-14263

FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017

- Development and evaluation of a finite element model for a fiber composite helicopter fuselage [MBB-UD-0584-90-PUB] p 196 N92-15066
- AIRCRAFT NOISE
- Broadband shock-associated noise from supersonic jets in flight p 235 A92-18683 Human response to aircraft noise p 236 N92-14780 p 236 N92-14785 Interior noise Flyover-noise measurement and prediction p 236 N92-14786
- Propeller-driven-small airplane noise certification p 237 N92-14798 [LR-650]
- AIRCRAFT PARTS Tribology needs for future space and aeronautical systems
- p 214 N92-15191 NASA-TM-1045251 AIRCRAFT PERFORMANCE
- Analysis of aircraft performance during lateral maneuvering for microburst avoidance p 205 A92-20207
- AIRCRAFT PILOTS Analysis of changes in the pilot population and general
- p 187 A92-20722 aviation accidents AIRCRAFT RELIABILITY ASNT and aerospace - What about the next 50 years?
- p 215 A92-17293 National research program for nondestructive inspection of aging aircraft p 169 A92 17294
- Designing through test AIAA PAPER 91-3822] p 232 A92-17664 Damage tolerance of the fighter aircraft 37 Viggen. I -[AIAA PAPER 91-3822]
- Analytical assessment. II Experimental verification p 192 A92-19819 Methodology for the assessment of material quality
- effects on airframe fatigue durability p 213 A92-19820 Domier 328 first flight p 192 A92-19924 Aging aircraft programme entails major effort and
- p 169 A92-20023 expense F27 aging aircraft programme emphasizes corrosion p 186 A92-20024 prevention
- Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft
- AIRCRAFT RUNUP
- Heavy metal --- fighter aircraft test rigs p 207 A92-18100 AIRCRAFT SAFETY
- ASNT and aerospace What about the next 50 years? p 215 A92-17293 Analysis technique for lightning attachment zoning of
- p 186 A92-20126 aircraft Lightning protection requirements for aircraft: A proposed specification
- [RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92-14007 Passenger knowledge of airline safety information (CRANFIELD-AERO-9111) p 187 N92-15054 AIRCRAFT STABILITY

Regulation of relaxed static stability aircraft

	p 203	A92-18463
Dynamics of hang-gliders	p 204	A92-18608
Roll-performance criteria for high	augment	ed aircraft
, -	p 204	A92-18623
Flight research	p 194	N92-13981
Formulation of a strategy for mon	itoring cor	ntrol integrity
in critical digital control systems		
[NASA-TM-104158]	p 206	N92-15075
AIRCRAFT STRUCTURES		
Enhanced viewal toobaique for rat	id inspecti	on of aircraft

- p 214 A92-17290 structures Rapid ultrasonic scanning of aircraft structures p 215 A92-17292
- Cabin structural vibration and noise for transport p 192 A92-17876 aircraft p 216 A92-18005 Rolling in the tolerance
- Some results on metal and composite patch reinforcement of aluminum honeycomb panel p 216 A92-18830
- Fatigue and damage tolerance verification of aircraft p 217 A92-19677 structures
- A-4

1

- Aging aircraft programme entails major effort and p 169 A92-20023 expens Mechanical qualification tests for materials used in the
- fabrication of aircraft parts [CEAT-M5-5443/01] p 195 N92-14042
- Structural considerations for aircra Modification: P-3C zero fuel weight increase aircraft payload [AD-A242690] p 196 N92-15068
- AIRCRAFT TIRES Aircraft landing-induced tire spinup
- p 193 A92-20209 AIRCRAFT WAKES
- Analytical/numerical matching and periodic inversion: Two advances in free wake analysis p 178 N92-13994
- AIRFIELD SURFACE MOVEMENTS
- Electronic systems in transportation
- (TP-9983) p 189 N92-14009 A Taxi And Ramp Management And Control system (TARMAC) p 207 N92-14027
- AIRFOIL PROFILES calculation Eigenvalue procedure for an Euler/Navier-Stokes solver with application to flows over airfoils p 170 A92-17429
- Complex variable boundary element method for external potential flows p 172 A92-18353 Algebraic turbulence modeling for unstructured and p 216 A92-18362 adaptive meshes
- Numerical study on using sulfur hexafluoride as a wind tunnel test gas p 216 A92-18373 Influences of wind tunnel parameters on airfoil
- characteristics at high subsonic speeds p 173 A92-18769
- Heat transfer measurements from a smooth NACA 0012 p 218 A92-20215 airfoil
- Roughness effects on heat transfer from a NACA 0012 airfoil
- p 219 A92-20217 pretwisted aerofoil characteristics Vibration of cross-section blade packets under rotating conditions
- p 219 A92-20756 Review of aerodynamic design in the Netherlands
- p 193 N92-13929 Inverse airfoil design procedure using a multigrid p 193 N92-13932 Navier-Stokes method Analysis and design of transonic airfoils using treamwise coordinates p 194 N92-13955 streamwise coordinates
- Airfoil optimization with efficient gradient calculations p 177 N92-13960 Design optimization of transonic airfoils
  - p 177 N92-13961 The benchmark aeroelastic models
- program: Description and highlights of initial results p 185 N92-15049 [NASA-TM-104180]
- A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 AIRFOILS
- Inverse airfoil design procedure using a multigrid lavier-Stokes method p 193 N92-13932 Navier-Stokes method Application of direct inverse analogy method (DIVA) and viscous design optimization techniques
  - p 176 N92-13951 Study of a new airfoil used in reversible axial fans
- p 177 N92-13970 p 202 N92-13977 Aerodynamics Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391
- Results of an Icing test on a NACA 0012 airfoil in the NASA Lewis Icing Research Tunnel [NASA-TM-105374]
- p 185 N92-15051 AIRFRAME MATERIALS
- Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820 AIRFRAMES
- A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft p 210 A92-17825
- [AIAA PAPER 91-5036]
- Fatigue crack initiation and small crack growth in several p 212 A92-19754 airframe alloys AIRLINE OPERATIONS
- Aircraft accident report: Northwest Airlines, Inc., Elights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3 1990
- [PB91-910405] p 187 N92-14006 A strategy for exploiting the full potential of MLS based terminal procedures in Canada p 190 N92-14025 p 190 N92-14025 Quiet aircraft design and operational characteristics
- p 236 N92-14787 Passenger knowledge of airline safety information
- [CRANFIELD-AERO-9111] p 187 N92-15054 Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- [SCT-90RR-44] p 191 N92-15061 AIRPORTS
- Electronic systems in transportation [TP-9983] p 189 N92-14009

Operational survey: VFR heliport approaches and
departures
ALGORITHMS
Aerodynamic shape optimization of arbitrary hypersonic
vehicles p 194 N92-13954
streamwise coordinates p 194 N92-13955
Automated problem resolution prototype in automated
en route air traffic control p 190 N92-14028
artificial intelligence techniques p 190 N92-14029
Image-based ranging and guidance for rotorcraft
[NASA-CR-184829] p 191 N92-14036 Rapid pear-ontimal aerospace plane trajectory
generation and guidance
(NASA-CR-189469) p 205 N92-14066
[NASA-CR-4420] n 234 N92-14598
Progress with multigrid schemes for hypersonic flow
problems
A fast implicit upwind solution algorithm for
three-dimensional unstructured dynamic meshes
[NASA-TM-104186] p 185 N92-15050
computed centerline operations with the microwave
landing system
[AD-A242/57] p 191 N92-15058 Project of an adaptive multiavial autopilot with learning
pilot control
[ETN-92-90592] p 205 N92-15072
ALLOCATIONS National Aeronautics and Space Administration
p 238 N92-14927
ALTITUDE
departures
[SCT-91RR-26] p 190 N92-14033
ALUMINUM Some results on metal and composite patch
reinforcement of aluminum honeycomb panel
p 216 A92-18830
ALUMINUM ALLOYS Proof test and fatigue crack growth modeling on 2024-T3
aluminum alloy p 213 A92-19828
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE
aluminum alloy p 213 A92-19928 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044
aluminum alloy p 213 A92-19928 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft
aluminum alloy p 213 A92-19928 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigué cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045
aluminum alloy p 213 A92-19928 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston       propulsor         [AD-2424293]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system         A 124       217       A92
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston       propulsor         [AD-A2422493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       P 217       A92-19231
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston       propulsor         [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston       propulsor         [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small       angle of attack       p 172       A92-18385
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 173 A92-19068
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future firstorm
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19925 Model oscillations at high angle of attack in a low speed
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angle of attack p 172 A92-18385 Hypersonic flows over slender circular cones at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19925 Model oscillations at high angle of attack in a low speed wind tunnel test
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-18385         Hypersonic flows over slender circular cones at small angle of attack       p 173       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19025         Model oscillations at high angle of attack in a low speed       wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20649
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-18385         Hypersonic flows over slender circular cones at small angles of attack       p 173       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19255         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20649         Instabilities of flows over bodies at large incidence       p 176       A92-20738
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-196385         Hypersonic flows over slender circular cones at small angles of attack       p 192       A92-196385         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20649         Instabilities of flows over bodies at large incidence       p 176       A92-20738
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-19255         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20768         Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-207649       Instabilities of flows over bodies at large incidence
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-1926385         Hypersonic flows over slender circular cones at small angles of attack       p 173       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19025         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20768         Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-20768       Surface flow patterns on an ogive-cylinder at incidence         Mater-Stokes solutions       p 180       N92-14981       Navier-Stokes solutions       p 180       N92-14981
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-1926385         Hypersonic flows over slender circular cones at small angles of attack       p 192       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19064         Instabilities of flows over bodies at large incidence       p 176       A92-207649         Instabilities of flow patterns on an ogive-cylinder at incidence       p 176       A92-207649         Natabilities of flow patterns on an ogive-cylinder at incidence       p 176       A92-207649         Instabilities of flow patterns on an ogive-cylinder at incidence       p 176       A92-20768         Surface flow patterns on an ogive-cylinder at incidence       p 17
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19069         Instabilities of flows over bodies at large incidence       p 176       A92-20768         Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-20768         Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-20768         Murier-Stokes solutions       p 180       N92-14041         Navier-Stokes solutions       p 180       N92-14041
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angle of attack       p 172       A92-18385         Hypersonic flows over slender circular cones at small angles of attack       p 172       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-19025         Model oscillations at high angle of attack in a low speed wind turnel test       p 176       A92-20768         [IAF PAPER ST-91-001]       p 175       A92-20768       Surface flow patterns on an ogive-cylinder at incidence         my 176       p 176       A92-20768       Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-20768         Surface flow past delta wing flow simulated by Navier-Stokes solutions       p 180       N92-14984
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 172 A92-19385 Hypersonic flows over slender circular cones at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19385 Model oscillations at high angle of attack in a low speed wind tunnel test [IAF PAPER ST-91-001] p 175 A92-207649 Instabilities of flows over bodies at large incidence p 176 A92-20762 Hypersonic flow patterns on an ogive-cylinder at incidence p 176 A92-20762 Hypersonic flow patt delta wing flow simulated by Navier-Stokes solutions ANISOTROPIC PLATES Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 ANILLAR FLOW Experimental investigation of coannular jet flow with swith along a centerbody
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 172 A92-19385 Hypersonic flows over slender circular cones at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19925 Model oscillations at high angle of attack in a low speed wind tunnet test [IAF PAPER ST-91-001] p 175 A92-207649 Instabilities of flows over bodies at large incidence p 176 A92-20762 Hypersonic flow patterns on an ogive-cylinder at incidence p 176 A92-20762 Hypersonic flow patterns on an ogive-cylinder at incidence p 176 A92-20762 Hypersonic flow patt delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 ANISOTROPIC PLATES Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 ANNULAR FLOW Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18367 ANTENNA ARRAYS
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angles of attack p 172 A92-19385 Hypersonic flows over slender circular cones at small angles of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19255 Model oscillations at high angle of attack in a low speed wind tunnet test [IAF PAPER ST-91-001] p 175 A92-20649 Instabilities of flows over bodies at large incidence p 176 A92-20762 Hypersonic flow patterns on an ogive-cylinder at incidence p 176 A92-20768 Surface flow patterns on an ogive-cylinder at incidence p 176 A92-20768 Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 ANNULAR FLOW Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18365 ANTENNA ARRAYS Telemetry antenna patterns for single and mutivelement
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       Stratified flow around an axisymmetric body at small angles of attack       p 172       A92-19236         Hypersonic flows over slender circular cones at small angles of attack       p 173       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-20649         Instabilities of flows over bodies at large incidence       p 176       A92-20762         Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions       p 180       N92-14981         ANISOTROPIC PLATES       Flutter analysis of anisotropic panels with patched cracks       p 219       A92-20216 <t< td=""></t<>
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       p 172       A92-19231         ANGLE OF ATTACK       p 172       A92-19231         Angle of attack       p 173       A92-19236         Hypersonic flows over slender circular cones at small angle of attack       p 173       A92-19826         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20649         Instabilities of flows over bodies at large incidence       p 176       A92-20762       Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions         Surface flow patterns on an ogive-cylinder at incidence       p 176       A92-20762       Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions       p 180       N92-14981         ANIS
aluminum alloy       p 213       A92-19828         The two-bay crack problem in fuselages built in GLARE         and ARALL       [LR-653]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14044         Bulging of fatigue cracks in a pressurized aircraft         fuselage       [LR-655]       p 196       N92-14045         AMPHIBIOUS VEHICLES       High-temperature combustor and seal for a water piston         propulsor       [AD-A242493]       p 229       N92-15385         AMPLIFIERS       A state-of-the-art data acquisition system       p 217       A92-19231         ANGLE OF ATTACK       p 172       A92-19236         Stratified flow around an axisymmetric body at small angle of attack       p 173       A92-19068         Evaluations of X-29 high-AOA regime show promise for future fighters       p 192       A92-192649         Instabilities of flows over slender circular cones at small angles of attack       p 175       A92-20762         Model oscillations at high angle of attack in a low speed wind tunnel test       [IAF PAPER ST-91-001]       p 175       A92-20738         Surface flow past delta wing flow simulated by Navier-Stokes solutions       p 180       N92-14981         ANISOTROPIC PLATES
aluminum alloy p 213 A92-19828 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045 AMPHIBIOUS VEHICLES High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 AMPLIFIERS A state-of-the-art data acquisition system p 217 A92-19231 ANGLE OF ATTACK Stratified flow around an axisymmetric body at small angle of attack p 172 A92-18385 Hypersonic flows over slender circular cones at small angle of attack p 173 A92-19068 Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19925 Model oscillations at high angle of attack in a low speed wind tunnel test [IAF PAPER ST-91-001] p 175 A92-20649 Instabilities of flows over bodies at large incidence p 176 A92-20738 Surface flow past delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 ANISOTROPIC PLATES Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 ANNULAR FLOW Experimental investigation of coannular jet flow with swirl along a centerbody p 176 A92-20738 Telemetry antenna patterns for single and multi-element arrays p 188 A92-19216 ANTENNA DESIGN 1

p 190 N92-14025

A strategy for exploiting the full potential of MLS based

terminal procedures in Canada

- SATCOM antenna siting study on P-3C aircraft, volume [NASA-CR-189515]

- - p 221 N92-14263

Electronically steerable antenna for aircraft p 229 N92-15272 ANTENNA RADIATION PATTERNS Telemetry antenna patterns for single and multi-element p 188 A92-19216 arravs SATCOM antenna siting study on P-3C aircraft, volume [NASA-CR-189515] p 221 N92-14263 ANTIFRICTION BEARINGS The application of a cylindrical-spherical floating ring bearing as a device to control stability 01 p 224 N92-14371 turbogenerators APPLICATIONS PROGRAMS (COMPUTERS) Failure environment analysis tool (FEAT) development status [AIAA PAPER 91-3803] p 232 A92-17654 Application of the STAPAT II code to hypersonic vehicle aerothermodynamics [AIAA PAPER 91-5035] p 209 A92-17824 Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype flight hardware p 220 N92-14217 Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391 F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation [AD-A242637] p 206 N92-15073 Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code (DE92-000597) n 229 N92,15392 APPROACH Microwave landing system autoland system analysis [NASA-CR-189551] p 191 N92-15060 APPROACH CONTROL DME growth elements and their use with MLS p 189 N92-14018 A Taxi And Ramp Management And Control system (TARMAC) p 207 N92-14027 Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034 APPROACH INDICATORS Infra-red offers new landing aid competition p 198 A92-18937 APPROPRIATIONS National Aeronautics and Space Administration p 238 N92-14923 National Aeronautics and Space Administration p 238 N92-14925 National Aeronautics and Space Administration p 238 N92-14927 New Ways: Tiltrotor aircraft and magnetically levitated vehicles [OTA-SET-507] p 238 N92-14933 National Aeronautics and Space Administration research and development p 238 N92-15937 APPROXIMATION Design optimization of transonic airfoils p 177 N92-13961 Approximation methods for control of acoustic/structure models with piezoceramic actuators [NASA-CB-189578] p 234 N92-15658 ARCHITECTURE (COMPUTERS) Evolution of avionic systems architecture, from the p 198 N92-14047 1950's to the present Mixed approach towards modular avionics conflicting p 199 N92-14051 requirements Avionics software evolution p 199 N92-14052 Avionics technology beyond 2000 p 200 N92-14058 Architecture for Survivable System Processing (ASSP) p 220 N92-14210 Artificial Neural Network Approaches in Guidance and Control [AGARD-LS-179] p 234 N92-14673 Introduction to neural computing and categories of neural network applications to guidance, navigation and p 234 N92-14674 control AREA NAVIGATION The problem of multiple solutions in area navigation and computed centerline operations with the microwave [AD-A242757] p 191 N92-15058 ARIANE LAUNCH VEHICLE Computation of aerodynamic Hermes-Ariane5 configuration coefficients p 184 N92-15040 ARMED FORCES (UNITED STATES) Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 ARTIFICIAL INTELLIGENCE

An intelligent pilot vehicle interface for a day/night adverse weather pilotage system (D/NAPS) p 197 A92-17596 [AIAA PAPER 91-3729]

ASTROLOY (TRADEMARK) Crack initiation and the short-to-long crack growth transition in a Ni-base superalloy p 213 A92-19767 ATMOSPHERIC CIRCULATION Mesoscale dynamics of cold fronts - Structures described by dropsoundings in Fronts 87 p 230 A92-18902 ATMOSPHERIC SOUNDING Mesoscale dynamics of cold fronts - Structures described by dropsoundings in Fronts 87 p 230 A92-18902 ATMOSPHERIC TURBULENCE Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT, SAL code p 229 N92-15392 (DE92-000597) ATTITUDE CONTROL Autonomously aided strapdown attitude reference p 204 A92-18610 AUDITORY PERCEPTION Human response to aircraft noise p 236 N92-14780 AUTOMATED EN ROUTE ATC Automated problem resolution prototype in automated en route air traffic control p 190 N92-14028 AUTOMATED RADAR TERMINAL SYSTEM Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a ACD-3401 p 191 N92-14034 AUTOMATIC CONTROL A low-altitude breakthrough system using optimal path terrain following p 205 A92-20483 AUTOMATIC FLIGHT CONTROL Retrospective essay on nonlineal ities in aircraft flight p 204 A92-18601 control Microwave landing system autoland system analysis [NASA-CR-189551] p 191 N92-15060 AUTOMATIC PILOTS Enhanced autopilot design through hardware-in-the-loop simulation p 204 A92-19103 Project of an adaptive multiaxial autopilot with learning pilot control p 205 N92-15072 ETN-92-90592] AUTOMATIC TEST EQUIPMENT Fault Tree Interpreter --- expert system shell for rule-based expert systems development for control of ATE [AIAA PAPER 91-3789] p 232 A92-17645 AVIATION METEOROLOGY Fair weather convection and light aircraft accidents [IAF PAPER ST-91-004] p 186 A92-20651 AVIONICS Real-time microfocus radiography for electronic failure p 214 A92-17289 analysis An intelligent pilot vehicle interface for a day/night adverse weather pilotage system (D/NAPS) [AIAA PAPER 91-3729] p 197 A92-17596 Knowledge maintenance in an evolving system using a deep structure representation [AIAA PAPER 91-3941] p 231 A92-17605 Advanced avionics system development environment [AIAA PAPER 91-3944] p 231 A92-17608 Putting ten pounds of avionics in a one pound package (Can we do it again?) [AIAA PAPER 91-3766] p 197 A92-17628 Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 An alternative method for acquiring avionic bus data in a class I PCM telemetry system p 217 A92-19202 General aviation activity and avionics survey, calendar year 1989 [PB91-179234] p 169 N92-13926 Evolution of avionic systems architecture, from the 950's to the present p 198 N92-14047 1950's to the present Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 Historical perspective on the evolution of avionics p 198 N92-14049 standards Avionics standardization in Europe p 199 N92-14050 Mixed approach towards modular avionics conflicting p 199 N92-14051 requirements p 199 N92-14052 Avionics software evolution Common avionics baseline: The product of the joint p 199 N92-14053 integrated avionics working group Avionics systems development: Technological trends, conflicts, and cost issues in a changing Europear environment p 199 N92-14054 Avionics modernization/upgrades in the late 1990s p 199 N92-14055

Knowledge based system applications for guidance and

The effects of winglets on low aspect ratio wings at

p 205 N92-14065

p 178 N92-13996

control

[AGARD-AR-284]

[NASA-CB-4407]

upersonic Mach numbers

ASPECT RATIO

# **BODIES OF REVOLUTION**

Avionics reliability, durability, and integrity: Can they be p 200 N92-14056 independent of application? Avionics technology beyond 2000

p 200 N92-14058 Testing of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab

n 210 N92-14087 Architecture for Survivable System Processing (ASSP) p 220 N92-14210

The problem of multiple solutions in area navigation and computed centerline operations with the microwave

anding system p 191 N92-15058

- Structural considerations for aircra Modification: P-3C zero fuel weight increase aircraft payload [AD-A242690] p 196 N92-15068
- Development of a calibrated software reliability model for flight and supporting ground software for avionic systems p 234 N92-15870
- AXIAL FLOW Study of a new airfoil used in reversible axial fans

p 177 N92-13970 AXIAL FLOW TURBINES

- Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110

# AXISYMMETRIC BODIES

Stratified flow around an axisymmetric body at small angle of attack p 172 A92-18385 Formation of shocks within axisymmetric nozzles

p 176 A92-20760 A Navier-Stokes solution of Hull-ring wing-thruster interaction p 221 N92-14310

Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031

AXISYMMETRIC FLOW Similarity solutions for supersonic axisymmetric flows p 173 A92-18387

# В

BALANCING

Identification of dynamic characteristics of flexible rotors as dynamic inverse problem p 220 N92-13962 BASE FLOW

Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7

p 173 A92-18770 BASE PRESSURE

- Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for space vehicles p 181 N92-14992
- BASIC (PROGRAMMING LANGUAGE) Z-Basic algorithm for collision avoidance system p 188 A92-18482

BEARING (DIRECTION)

An alternative derivation of the modified gain function f Song and Speyer p 232 A92-18464 of Song and Speyer BEARINGS

Hydraulic actuator system for rotor control

p 224 N92-14363 BERNOULLI THEOREM

Structural considerations for aircra Modification: P-3C zero fuel weight increase aircraft payload p 196 N92-15068 [AD-A242690] BIODYNAMICS

Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-18611

### BIRD-AIRCRAFT COLLISIONS

Study of the engine	bird	ingestion	experi	ence	of	the
Boeing 737 aircraft						
[DOT/FAA/CT-89/16]			D 187	N92-	15	053

BLADE SLAP NOISE		•	
The application of	Eavoorimontal	ot etch	blada waka

interaction noise prediction [NASA-CR-189461] p 237 N92-14789

BLUNT BODIES

Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7 p 173 A92-18770

Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 BOATTAILS

Transonic Navier-Stokes computations for a spinning body of revolution

[AD-A241015] p 180 N92-14972 BODIES OF REVOLUTION

Three-dimensional linear stability approach to transition on wings and bodies of revolution at incidence

p 172 A92-18361 Surface flow patterns on an ogive-cylinder at incidence p 176 A92-20762

# **BODY KINEMATICS**

- Transonic Navier-Stokes computations for a spinning body of revolution [AD-A241015] p 180 N92-14972
- BODY KINEMATICS Representation of geometric stiffening in multibody
- system simulation or geometric summing in multiDody system simulation p 217 A92-19463 BODY-WING AND TAIL CONFIGURATIONS
- On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931
- BODY-WING CONFIGURATIONS Evaluation of Euler solvers for transonic wing-fuselage geometries p 174 A92-20214
- geometries Measurements of the flow around a lifting-wing/body junction p 175 A92-20726 Definition of the unsteady vortex flow over a wing/body configuration
- [NASA-CR-180083] p 178 N92-13995 BOEING 720 AIRCRAFT An integrated real-time turbine engine flight test
- system p 201 A92-19275 BOEING 737 AIRCRAFT
- Study of the engine bird ingestion experience of the Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053
- BOEING 747 AIRCRAFT A fast implicit upwind solution algorithm for
- three-dimensional unstructured dynamic meshes [NASA-TM-104186] p 185 N92-15050 BOLTZMANN TRANSPORT EQUATION
- Transitional flows around re-entry bodies p 184 N92-15035
- BOUNDARY CONDITIONS
- Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948
- Annular seals of high energy centrifugal pumps: Presentation of full scale measurement
- p 224 N92-14362 BOUNDARY ELEMENT METHOD
- Complex variable boundary element method for external potential flows p 172 A92-18353 BOUNDARY LAYER CONTROL
- Detection of flow state in an unsteady separating flow p 219 A92-20741
- BOUNDARY LAYER EQUATIONS
- Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211 Computational fluid dynamics p 177 N92-13979 Analysis tools of ONERA and DLR for the
- aerothermodynamics of reentry vehicles p 211 N92-14977 BOUNDARY LAYER FLOW
- Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage
- AD-A242656) p 185 N92-15045 BOUNDARY LAYER SEPARATION
- Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363 Wedge-induced turbulent boundary-layer separation on
- a roughened surface at Mach 6.0 p 175 A92-20379 Detection of flow state in an unsteady separating flow p 219 A92-20741
- Turbulent boundary-layer characteristics over a flat-plate/wedge configuration at Mach 6 p 176 A92-20761
- Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959 Navier-Stokes analysis of turbulent boundary layer and
- Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies p 221 N92-14309
- Flow over a delta wing at hypersonic speeds p 181 N92-14993
- BOUNDARY LAYER STABILITY
- Effect of suction on the stability of supersonic boundary layers, I - Second-mode waves. II - First-mode waves p 174 A92-19611
- Numerical simulation of swept-wing flows [NASA-CR-189457] p 180 N92-14969
- BOUNDARY LAYER TRANSITION A quiet-flow Ludwieg tube for experimental study of high
- speed boundary layer transition [AIAA PAPER 91-5026] p 207 A92-17819
- Effect of suction on the stability of supersonic boundary layers. I - Second-mode waves. II - First-mode waves p 174 A92-19611
- BOUNDARY LAYERS
- Analysis of an advanced ducted propeller subsonic inlet [NASA-TM-105393] p 179 N92-14002
- The aerodynamic effect of fillet radius in a low speed compressor cascade [NASA-TM-105347] p 202 N92-14063
- Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020

- BOUNDARY VALUE PROBLEMS
- Extended mapping and characteristics techniques for inverse aerodynamic design p 194 N92-13949 Hypersonic aerothermodynamic computations using a
- point-implicit TVD method p 183 N92-15006 BRAKES (FOR ARRESTING MOTION) Test results for rotordynamic coefficients of the SSME
- HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357
- BROADBAND
- Broadband shock-associated noise from supersonic jets in flight p 235 A92-18683 A survey of the broadband shock associated noise
- prediction methods [NASA-TM-105365] p 237 N92-14797
- BRUSH SEALS Army research concerns in engine sealing
  - p 228 N92-15089
  - Seal development activities at Allison Turbine Division p 228 N92-15093
  - Seal related development activities at EG/G p 228 N92-15095
- BURAN SPACE SHUTTLE Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results p 211 N92-14975
- BURNING RATE Nonstationary gasdynamics p 220 N92-13985
- BURNING TIME The influence of a retarding rocket on parameter limits
- for reentry trajectories p 211 N92-15037

# С

- C (PROGRAMMING LANGUAGE)
- Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 C-160 AIRCRAFT
- Analysis and modeling of lightning strikes to the F106B, CVF580, and C160 aircraft p 186 A92-20129 CALCULUS OF VARIATIONS
- Automated trajectory synthesis for hypersonic vehicles using energy management and variational calculus techniques p 210 A92-19061 CALIBRATING
- Development of a calibrated software reliability model for flight and supporting ground software for avionic systems p 234 N92-15870 CAMERAS
- Image-based ranging and guidance for rotorcraft [NASA-CR-184829] p 191 N92-14036
- CANARD CONFIGURATIONS On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931
- CANTILEVER PLATES
- Nonlinear stall flutter and divergence analysis of cantilevered graphite/epoxy wings p 219 A92-20746 CARRIER WAVES
- Whole aircraft lightning indirect effects evaluation using low level injection techniques p 192 A92-20134 CARTESIAN COORDINATES
- Universal weaving for turbine engine composite preforms
- [AD-A237667] p 202 N92-14059 CASCADE FLOW
- Large chord turbine cascade testing at engine Mach and Reynolds number p 173 A92-18771 Explicit Navier-Stokes computation of cascade flows using the k-epsilon turbulence model
- p 175 A92-20727 Time domain flutter analysis of cascades using a full-potential solver p 176 A92-20747
- Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 Design of transonic compressor cascades using
- hodograph method p 202 N92-13973 The aerodynamic effect of fillet radius in a low speed compressor cascade
- [NASA-TM-105347] p 202 N92-14063 Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage
- [AD-A242656] p 185 N92-15045 CAST ALLOYS
- Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405 CAUCHY INTEGRAL FORMULA
- Complex variable boundary element method for external potential flows p 172 A92-18353 CENTERBODIES
- Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18367 CENTRIFUGAL PUMPS
- Annular seals of high energy centrifugal pumps: Presentation of full scale measurement p 224 N92-14362

- CEPSTRAL ANALYSIS
- Removal of spurious reflections from computational fluid dynamic solutions with the complex cepstrum p 235 A92-20729
- CERAMIC COATINGS
  - Protective coatings of thermal barrier type p 214 A92-20349
- CERAMIC FIBERS Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424

### CERAMICS

- Ceramic regenerator program [NASA-CR-189053] p 225 N92-14374
- Probabilistic lifting approach for aero engine disks made of powder nickel base alloys containing ceramic defects
- p 226 N92-14424 CERTIFICATION
  - Flyover-noise measurement and prediction
- p 236 N92-14786 Propeller-driven-small airplane noise certification
- [LR-650] p 237 N92-14798 CHANNEL FLOW
- Compressibility effects in thin channels with injection p 216 A92-18369
- CHANNELS (DATA TRANSMISSION) An alternative method for acquiring avionic bus data in
- a class i PCM telemetry system p 217 A92-19202 MIL-STD-1553 data bus/PCM multiplexer system
  - p 188 A92-19211

SUBJECT INDEX

- CHAPLYGIN EQUATION Design of transonic compressor cascades using hodograph method p 202 N92-13973 CHEMICAL EQUILIBRIUM
- High enthalpy nozzle flows p 182 N92-15000 Influence of chemical modeling on the solution of
- hypersonic shock layers p 183 N92-15016 CHINA
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances

Putting ten pounds of avionics in a one pound package

Similarity solutions for supersonic axisymmetric flows

Hypersonic flows over slender circular cones at small

Flat-ended circular cylinder in hypersonic rarefied flow

Analysis of changes in the pilot population and general

General aviation activity and avionics survey, calendar

FAA statistical handbook of aviation: Calendar year

Operational survey: VFR heliport approaches and

Simulation of radar clutter and jet engine modulation

Whole aircraft lightning indirect effects evaluation using

Determination of rotordynamic coefficients for labyrinth

aerodynamic

Mesoscale dynamics of cold fronts - Structures

Z-Basic algorithm for collision avoidance system

and application to rotordynamic

DARPA high resolution display technologies

Infra-red offers new landing aid competition

CHIPS (ELECTRONICS)

CIRCULAR CONES

angles of attack

CIVIL AVIATION

vear 1989

1989 [PB91-202051]

CLUTTER

COCKPITS

seals

COEFFICIENTS

calculations

COLD FRONTS

COLD ROLLING

Computation

aviation accidents

[PB91-179234]

CLIMBING FLIGHT

COAXIAL CABLES

using digital guadrature modulator

of

described by dropsoundings in Fronts 87

low level injection techniques

Hermes-Ariane5 configuration

Rolling in the tolerance

COLLISION AVOIDANCE

departures [SCT-91RR-26]

CIRCULAR CYLINDERS

(Can we do it again?) [AIAA PAPER 91-3766] p 201 N92-13939

p 197 A92-17628

p 173 A92-18387

p 173 A92-19068

p 174 A92-20304

p 198 A92-18937

p 187 A92-20722

p 169 N92-13926

p 170 N92-13927

p 190 N92-14033

p 216 A92-19091

p 192 A92-20134

p 218 A92-19977

p 223 N92-14360

p 184 N92-15040

p 230 A92-18902

p 216 A92-18005

p 188 A92-18482

coefficients

desian

on

SUBJECT INDEX COLLISIONS Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990 [PB91-910405] p 187 N92-14006 COMBUSTION CHAMBERS Hypersonic airbreathing propulsion activities for Saenger [AIAA PAPER 91-5040] p 200 A92-17828 Evaluation of a bounded high-resolution scheme for p 201 A92-20734 combustor flow computations High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow p 212 N92-15877 modele COMBUSTION PHYSICS Effects of unsteady shock impingement on high-speed gaseous mixing [AIAA PAPER 91-5091] p 172 A92-17857 COMBUSTION PRODUCTS Nonstationary gasdynamics COMMAND GUIDANCE p 220 N92-13985 Control concept for maneuvering in hypersonic flight p 203 A92-17838 [AIAA PAPER 91-5055] COMMERCIAL AIRCRAFT International aviation (selected article) [AD-A240986] p 170 N92-13991 Quiet aircraft design and operational characteristics p 236 N92-14787 COMMUNICATION SATELLITES SATCOM antenna siting study on P-3C aircraft, volume [NASA-CR-189514] p 221 N92-14262 COMMUNITIES Reducing environmental noise impacts: A USAREUR noise management program handbook [AD-A240797] p p 237 N92-14791 COMMUTER AIRCRAFT On-board data acquisition system for Embraer's CBA123 p 198 A92-19251 COMPLEX VARIABLES Complex variable boundary element method for external potential flows p 172 A92-18353 COMPOSITE STRUCTURES Experimental and theoretical analysis of composite I-beams with elastic couplings p 216 A92-18377 Experimental investigation of periodically excited tating composite rotor blades p 218 A92-20213 Flutter analysis of anisotropic panels with patched rotating composite rotor blades cracks p 219 A92-20216 Universal weaving for turbine engine composite preforms AD-A2376671 p 202 N92-14059 COMPRESSIBILITY EFFECTS Compressibility effects in thin channels with injection p 216 A92-18369 COMPRESSIBLE BOUNDARY LAYER A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition [AIAA PAPER 91-5026] p 207 A92-17819 COMPRESSIBLE FLOW Aerodynamic sensitivity analysis methods for the compressible Euler equations p 233 A92-19619 Sonic eddy - A model for compressible turbulence p 176 A92-20739 Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356

COMPRESSOR BLADES

Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 COMPRESSORS

Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 The aerodynamic effect of fillet radius in a low speed compressor cascade [NASA-TM-105347] p 202 N92-14063

COMPUTATIONAL FLUID DYNAMICS Eigenvalue calculation procedure for an Euler/Navier-Stokes solver with application to flows over airfolis p170 A92-17429

CFD application to 2D/3D flow fields in Scramjet engine p 170 A92-17501 Supersonic inlet flow computation

p 171 A92-17502 Numerical simulation for various flowfields of aero-engine components p 200 A92-17503 Multidisciptinary modeling and simulation of a generic hypersonic vehicle

 [AIAA PAPER 91-5015]
 p 232
 A92-17813

 Three dimensional hypersonic inlets - Low speed performance
 Low speed

 [AIAA PAPER 91-5021]
 p 171
 A92-17817

A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition

 
 [AIAA PAPER 91-5026]
 p 207
 A92-17819

 Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic speeds
 [AIAA PAPER 91-5038]
 p 171
 A92-17826

 The value of sub-scale flight tests in the development of NASP vehicles
 [AIAA PAPER 91-5048]
 p 210
 A92-17834

 A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058]
 p 171
 A92-17834

 A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058]
 p 171
 A92-17841

 composite configurations
 p
 172
 A92-18352

 Complex variable boundary element method for external potential flows
 p
 172
 A92-18353

 Numerical prediction of subsonic turbulent flows over slender bodies at high incidence
 p
 172
 A92-18358

 Algebraic turbulence modeling for unstructured and adaptive meshes
 p
 216
 A92-18362

 Prediction of steady and unsteady asymmetric vortical
 p
 216
 X02-18362

flows around circular cones p 172 A92-18372 Similarity solutions for supersonic axisymmetric flows p 173 A92-18387 Analysis of spiraling vortical flows around slender delta wings moving in an inviscid medium p 173 A92-18900

Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110

Some Aspects of uncertainty in computational fluid dynamics results p 233 A92-19609 Aerodynamic sensitivity analysis methods for the compressible Euler equations p 233 A92-19619

A perspective on aerospace CFD p 169 A92-20145 CFD helps the Air Force fly right p 169 A92-20146 Soviet CFD - An international perspective p 233 A92-20150

Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211

Engineering calculations of three-dimensional inviscid hypersonic flowfields p 175 A92-20378 Removal of spurious reflections from computational fluid

dynamic solutions with the complex cepstrum p 235 A92-20729 Upwind scheme for solving the Euler equations on

unstructured tetrahedral meshes p 175 A92-20735 Nonequilibrium hypersonic inviscid steady flows p 176 A92-20737

Instabilities of flows over bodies at large incidence p 176 A92-20738

N92-13977

Aerodynamics p 202

Computational fluid dynamics p 177 N92-13979 Definition of the unsteady vortex flow over a wing/body configuration

[NASA-CR-180083] p 178 N92-13995 A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics

[NASA-TM-105321] p 179 N92-13998 A Navier-Stokes solution of Hull-ring wing-thruster interaction p 221 N92-14310

Aerothermodynamics for Space Vehicles [ESA-SP-318] p 180 N92-14973

Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980 A multiblock flow solver for inviscid hypersonic flows

p 181 N92-14986 Flow and temperature computations for space vehicles

using adaptive finite element techniques p 181 N92-14990

Linear acoustics in gas mixtures with rate processes p 238 N92-15013 Experimental research of the aerodynamics of nozzles

and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048

A fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes [NASA-TM-104186] p 185 N92-15050

[NASA-TM-104186] p 185 N92-15050 Industrial code development p 227 N92-15083 Development of a CFD code for analysis of fluid dynamic forces in seals p 228 N92-15084

COMPUTATIONAL GRIDS

Algebraic turbulence modeling for unstructured and adaptive meshes p 216 A92-18362 Upwind scheme for solving the Euler equations on unstructured tetrahedral meshes p 175 A92-20735 Design optimization of transonic airfoils

p 177 N92-13961 Computational fluid dynamics p 177 N92-13979 Analysis of an advanced ducted propeller subsonic inlet

[NASA-TM-105393] p 179 N92-14002 Progress with multigrid schemes for hypersonic flow problems

p 185 N92-15047

[NASA-CR-189579]

# **COMPUTER PROGRAMS**

A fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes [NASA-TM-104186] p 185 N92-15050

COMPUTER AIDED DESIGN Model based reasoning in the aerospace domain

[AIAA PAPER 91-3709] p 230 A92-17582

Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 Multidisciplinary modeling and simulation of a generic hypersonic vehicle

[AIAA PAPER 91-5015] p 232 A92-17813 Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences

(ICIDES-3) [NASA-CR-188125] p 170 N92-13928

Review of aerodynamic design in the Netherlands p 193 N92-13929

Aerodynamic aircraft design methods and their notable applications: Survey of the activity in Japan p 193 N92-13930

Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances

p 201 N92-13939 An inverse method for the aerodynamic design of

three-dimensional aircraft engine nacelles p 194 N92-13958

# COMPUTER GRAPHICS

Sensor fusion for synthetic vision [AIAA PAPER 91-3730] p 197 A92-17597 Mixed approach towards modular avionics conflicting requirements p 199 N92-14051

COMPUTER NETWORKS

Architecture for Survivable System Processing (ASSP) p 220 N92-14210 Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report

[DOT/FAA/CT-TN91/50] p 221 N92-14270 COMPUTER PROGRAM INTEGRITY

Cleanroom - An alternative software development process p 233 A92-19386 COMPUTER PROGRAMMING

Formal specification and verification of Ada software [AIAA PAPER 91-3713] p 230 A92-17585 Advanced avionics system development environment

[AIAA PAPER 91-3944] p 231 A92-17608 Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 Development of a calibrated software reliability model

for flight and supporting ground software for avionic systems p 234 N92-15870

# COMPUTER PROGRAMS

Analysis of cooling systems for hypersonic aircraft

- [AIAA PAPER 91-5063] p 216 A92-17843 Some Aspects of uncertainty in computational fluid
- dynamics results p 233 A92-19609 Aerodynamic aircraft design methods and their notable

applications: Survey of the activity in Japan p 193 N92-13930

On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931

LEWICE/E: An Euler based ice accretion code [NASA-TM-105389] p 179 N92-14001 Analysis of an advanced ducted propeller subsonic

inlet [NASA-TM-105393] p 179 N92-14002 Automated problem resolution prototype in automated

en route air traffic control p 190 N92-14028 A unique approach to aircraft conflict resolution using

artificial intelligence techniques p 190 N92-14029 Determination of rotordynamic coefficients for labyrinth

seals and application to rotordynamic design calculations p 223 N92-14360

Application of MSC/DYNA to shock and impact problems in aircraft industry

[MBB-UD-0593-91-PUB] p 225 N92-14382 A concept for the revisions of structural inspection schedules p 226 N92-14431

Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description

[AD-A242598] p 170 N92-14966 Viscous shock-layer equations for the calculation of

Viscous shock-layer equations for the calculation of reentry aerothermodynamics p 183 N92-15008 Development and evaluation of a finite element model

Development and evaluation of a many for a fiber composite helicopter fuselage [MBB-UD-0584-90-PUB] p 196 N92-15066 Project of an adaptive multiaxial autopilot with learning

pilot control [ETN-92-90592] p 205 N92-15072 The NASA Langley Research Center 0.3-meter transonic

royogenic tunnel microcomputer controller source code [NASA-CR-189556] p 209 N92-15077 Industrial code development p 227 N92-15083

# COMPUTER SYSTEMS DESIGN

Development of a calibrated software reliability model for flight and supporting ground software for avionic p 234 N92-15870 systems COMPUTER SYSTEMS DESIGN

- Advanced avionics system development environment [AIAA PAPER 91-3944] p 231 A92-17608 Cleanroom - An alternative software development p 233 A92-19386 process
- Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype flight hardware p COMPUTER SYSTEMS PERFORMANCE p 220 N92-14217
- Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype p 220 N92-14217 flight hardware
- Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report [DOT/FAA/CT-TN91/50] p 221 N92-14270
- Development of a calibrated software reliability model for flight and supporting ground software for avionic p 234 N92-15870 systems COMPUTER SYSTEMS SIMULATION
- Verification of flight software by embedding software simulation in simulation of external environment
- p 232 A92-19084 COMPUTER TECHNIQUES Analysis technique for lightning attachment zoning of
- aircraft p 186 A92-20126 Turbine engine diagnostics system study [DOT/FAA/CT-91/16] p 202 p 202 N92-14064
- Knowledge based system applications for guidance and control [AGARD-AR-284] p 205 N92-14065
- Artificial Neural Network Approaches in Guidance and Control [AGARD-LS-179] p 234 N92-14673
- COMPUTER VISION Sensor fusion for synthetic vision
- [AIAA PAPER 91-3730] p 197 A92-17597 COMPUTERIZED SIMULATION
- Numerical simulation for flowfields various of aero-engine components p 200 A92-17503 Verification of flight software by embedding software simulation in simulation of external environment
- p 232 A92-19084 A processor-in-the-loop simulation using an XANALOG pmputer p 232 A92-19094
- computer Enhanced autopilot design through hardware-in-the-loop simulation p 204 A92-19103
- MLS system error model identification and synthesis p 189 N92-14015 Mixed approach towards modular avionics conflicting
- p 199 N92-14051 requirements A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986
- CONDUCTIVE HEAT TRANSFER
- Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary layer p 215 A92-17823 [AIAA PAPER 91-5033]
- CONES Base pressure measurements on a cone at hypersonic
- Mach numbers: A contribution to aerothermodynamics for p 181 N92-14992 space vehicles CONFERENCES
- Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) p 170 N92-13928
- [NASA-CR-188125] Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 p 222 N92-14346
- [NASA-CP-31221 Proceedings of Damping 1991, volume 3 p 225 N92-14386 [AD-A241313]
- CONFORMAL MAPPING
- Airfoil optimization with efficient gradient calculations p 177 N92-13960
- CONGRESSIONAL REPORTS
  - National Aeronautics and Space Administration p 238 N92-14923
  - National Aeronautics and Space Administration p 238 N92-14925
  - National Aeronautics and Space Administration p 238 N92-14927
- New Ways: Tiltrotor aircraft and magnetically levitated rehicles (OTA-SET-507)
- p 238 N92-14933 National Aeronautics and Space Administration research and development p 238 N92-15937 CONICAL BODIES
- Prediction of steady and unsteady asymmetric vortical flows around circular cones p 172 A92 18372 CONICAL FLOW
- Asymmetric separated flows at supersonic speeds
- p 176 A92-20742

- CONTINUUM FLOW
- Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031
- Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles n 184 N92-15032
- CONTOURS
- Analysis and design of transonic airfoils using streamwise coordinates p 194 N92-13955 CONTROL SIMULATION
- Testing of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab p 210 N92-14087
- CONTROL STABILITY
- Application of stochastic robustness to aircraft control systems p 204 A92-18620 CONTROL SYSTEMS DESIGN
- A geometric approach to regulator and tracker design for an aerospace plane
- [AIAA PAPER 91-5054] p 203 A92-17837 Control concept for maneuvering in hypersonic flight
- [AIAA PAPER 91-5055] p 203 A92-17838 Regulation of relaxed static stability aircraft
  - p 203 A92-18463 Retrospective essay on nonlinearities in aircraft flight
- control p 204 A92-18601 Parameter insensitive control utilizing eigenspace methods --- for flutter suppression in aeroelastic vehicles
- p 204 A92-18615 Application of stochastic robustness to aircraft control p 204 A92-18620 systems
- Structure/control design synthesis of active flutter suppression system by goal programming
  - p 204 A92-18621
- Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations p 204 A92-18622
- Nonlinear control of a twin-lift helicopter configuration p 204 A92-18624
- A stochastic regulator for integrated communication and control systems. I - Formulation of control law, II - Numerical analysis and simulation p 233 A92-19605
- Performance improvements of an F-15 airplane with an integrated engine-flight control system p 205 A92-20204
- Control system design for the free drop test of external stores in a wind tunnel [IAF PAPER ST-91-002]
- n 207 A92-20650 A Taxi And Ramp Management And Control system
- p 207 N92-14027 (TARMAC) Hydraulic actuator system for rotor control
- p 224 N92-14363 Neural network and fuzzy logic technology for naval flight control
- [AD-A242650] p 206 N92-15074 CONTROL THEORY
  - Optimal control problems with maximum functional p 232 A92-18616 A stochastic regulator for integrated communication and
- control systems. I Formulation of control law. II Numerical analysis and simulation p 233 A92-19605 A low-altitude breakthrough system using optimal path terrain following p 205 A92-20483
- CONTROLLERS Enhancement of modal swept sine data by control of exciting forces p 215 A92-17562
- Formulation of a strategy for monitoring control integrity in critical digital control systems
- [NASA-TM-104158] p 206 N92-15075 The NASA Langley Research Center 0.3-meter transonic cryogenic tunnel microcomputer controller source code [NASA-CR-189556] p 209 N92-15077 p 209 N92-15077 CONVECTION
- Analytical/numerical matching and periodic inversion: Two advances in free wake analysis
- p 178 N92-13994 CONVECTIVE HEAT TRANSFER
- Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary layer
- [AIAA PAPER 91-5033] p 215 A92-17823 Roughness effects on heat transfer from a NACA 0012 p 219 A92-20217 airtoil Two-dimensional effects in a triangular convecting fin
- p 219 A92-20324 CONVERGENCE
- Progress with multigrid schemes for hypersonic flow problems [NASA-CR-189579] p 185 N92-15047
- CONVERGENT-DIVERGENT NOZZLES
- Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model [NASA-TM-105338] p 237 N92-14795

- COOLING SYSTEMS A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft [AIAA PAPER 91-5036] p 210 A92-17825 Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-1] p 216 A92-17843 CORROSION PREVENTION F27 aging aircraft programme nphasizes corrosior p 186 A92-20024 prevention CORROSION RESISTANCE High-temperature combustor and seal for a water piston nronulsor [AD-A242493] p 229 N92-15385 COST ANALYSIS Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 Rotorcraft low altitude IFR benefit/cost analysis: ISCT-9088-441 p 191 N92-15061 Historical perspective on the evolution of avionics p 198 N92-14049 Avionics standardization in Europe p 199 N92-14050 Potential hypersonic vehicles applications AIAA PAPER 91-5086] p 169 A92-17854 National Aeronautics and Space Administration p 238 N92-14923 COUNTER ROTATION Programs at Wright-Patterson Air Force Base p 228 N92-15092 Areas of seal R/D at GE p 228 N92-15094 CRACK INITIATION Fatigue crack initiation and small crack growth in several p 212 A92-19754 Crack initiation and the short-to-long crack growth p 213 A92-19767 Fatigue crack initiation and small crack growth in several p 212 A92-19754 Short fatigue crack growth from blunt notches in an p 212 A92-19760 Crack initiation and the short-to-long crack growth transition in a Ni-base superallov p 213 A92-19767 Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799 Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical p 217 A92-19812 investigations Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817 Proof test and fatigue crack growth modeling on 2024-T3 p 213 A92-19828 aluminum alloy Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fusela age p 196 N92-14045 (LR-6551 Review of investigations on aeronautical fatigue in the Federal Republic of Germany [ETN-92-90317] p 225 N92-14397 Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424 CRACKS The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044 Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow p 212 N92-15877 models CRASH INJURIES
- Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 CRITICAL TEMPERATURE
- A probabilistic method for monitoring the remaining life of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 CROSS FLOW
- Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211 Numerical simulation of swept-wing flows
- [NASA-CR-189457] p 180 N92-14969 CRYOGENIC COOLING
- Multicomponent sorption Joule-Thomson gas refrigeration
- [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203

- Operations analysis
  - COST EFFECTIVENESS
  - shrehnets
  - COST REDUCTION

  - COSTS

  - airframe allovs
  - transition in a Ni-base superalloy CRACK PROPAGATION
  - airframe alloys
  - aero-engine alloy

CRYOGENIC WIND TUNNELS

- The NASA Langley Research Center 0.3-meter transonic cryogenic tunnel microcomputer controller source code [NASA-CR-189556] n 209 N92-15077
- forces in seals p 228 N92-15084

CYLINDRICAL BODIES Development of a CFD code for analysis of fluid dynamic D DAMAGE ASSESSMENT Fatigue and damage tolerance verification of aircraft structures p 217 A92-19677 Damage tolerance of the fighter aircraft 37 Viggen. I -Analytical assessment, II - Experimental verification p 192 A92-19819 Study of the engine bird ingestion experience of the Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053 DAMPING A simplified method for predicting the stability of aerodynamically excited turbomachinery n 224 N92-14364 Proceedings of Damping 1991, volume 3 p 225 N92-14386 [AD-A241313] DAMPING TESTS Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391 DATA ACQUISITION A state-of-the-art data acquisition system p 217 A92-19231 On-board data acquisition system for Embraer's p 198 **CBA123** A92-19251 Implementation and usage of the RJ program Data Acquisition System Ground Station p 210 A92-19257 Design and implementation of a total flight test system p 189 A92-19278 Development of a calibrated software reliability model for flight and supporting ground software for avionic p 234 N92-15870 systems DATA BASES Common avionics baseline: The product of the joint p 199 N92-14053 integrated avionics working group DATA COMPRESSION Compression techniques for video telemetry p 188 A92-19214 DATA LINKS Reconfigurable Mobile System - Ground, sea and air p 218 A92-19986 applications DATA PROCESSING Implementation and usage of the RJ program Data Acquisition System Ground Station p 210 A92-19257 Avionics standardization in Europe o 199 N92-14050 Architecture for Survivable System Processing (ASSP) p 220 N92-14210 A concept for the revisions of structural inspection schedules p 226 N92-14431 DATA TRANSMISSION High rate PCM data receiving, recording and relying p 189 A92-19279 Processing complexity of two approaches to object p 234 N92-14677 detection and recognition DEATH Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 DEBRIS Filter debris analysis: A concrete approach to wear diagnosis [DREP-TM-88-20] p 222 N92-14345 **DECISION MAKING** New Ways: Tiltrotor aircraft and magnetically levitated vehicles p 238 N92-14933 [OTA-SET-507] DEFECTS Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424 DEFENSE PROGRAM Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 DEFLECTION Hypersonic inviscid flow field simulations around reentry p 184 N92-15025 vehicles with flap deflection DELAMINATING Application of MSC/DYNA to shock and impact problems in aircraft industry [MBB-UD-0593-91-PUB] p 225 N92-14382 DELTA WINGS Analysis of spiraling vortical flows around slender delta

wings moving in an inviscid medium p 173 A92-18900 Hypersonic flow past delta wing flow simulated by D 180 N92-14981 Navier-Stokes solutions Flow over a delta wing at hypersonic speeds

p 181 N92-14993

DEMOGRAPHY

Analysis of changes in the pilot population and general p 187 A92-20722 aviation accidents DESIGN ANALYSIS

Designing through test [AIAA PAPER 91-3822]

p 232 A92-17664 Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3)

- [NASA-CR-188125] p 170 N92-13928 Inverse airfoil design procedure using a multigrid avier-Stokes method p 193 N92-13932 Navier-Stokes method A comparison of two closely-related approaches to
- aerodynamic design optimization p 193 N92-13933 Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine
- aerodynamics: Review of Chinese advances p 201 N92-13939
- Extended mapping and characteristics techniques for inverse aerodynamic design p 194 N92-13949 Application of direct inverse analogy method (DIVA) and viscous design optimization techniques
- p 176 N92-13951 An inverse method with regularity condition for transonic p 177 N92-13969 airfoil design Design of transonic compressor cascades using hodograph method p 202 N92-13973
- Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades p 195 N92-14038 [NASA-CR-189018]
- Avionics reliability, durability, and integrity: Can they be independent of application? p 200 N92-14056 Proceedings of Damping 1991, volume 3
- [AD-A241313] p 225 N92-14386 Airbus Industrie A330/A340: Full scale fatigue test of p 226 N92-14425 center fuselage and wing
- Theoretical models for duct acoustic propagation and p 236 N92-14782 radiation Design and performance of duct acoustic treatment
- Analysis tools of ONERA and DLR for the arothermodynamics of the section of the s
- aerothermodynamics of reentry vehicles p 211 N92-14977 Aerothermodynamic challenges of the Saenger p 184 N92-15042
- space-transportation system solution algorithm for A fast implicit upwind three-dimensional unstructured dynamic meshes [NASA-TM-104186] p 185 N92-15050
- DESORPTION Multicomponent gas sorption Joule-Thomson
- refrigeration [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
- DETECTION Processing complexity of two approaches to object detection and recognition p 234 N92-14677
- DIFFERENTIAL EQUATIONS
- A fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes [NASA-TM-104186] p 185 N92-15050 DIFFUSION
- The aerodynamic effect of fillet radius in a low speed compressor cascade
- [NASA-TM-105347] p 202 N92-14063 DIFFUSION FLAMES
- An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861 DIGITAL DATA

Historical perspective on the evolution of avionics p 198 N92-14049 standards DIGITAL ELECTRONICS

Simulation of radar clutter and jet engine modulation p 216 A92-19091 using digital guadrature modulator DIGITAL SIMULATION

- Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 DIGITAL SYSTEMS
  - A review of digital flight control system upsets caused by electromagnetic interference
  - [AIAA PAPER 91-3765] p 215 A92-17627 Historical perspective on the evolution of avionics p 198 N92-14049 standards
  - Formulation of a strategy for monitoring control integrity in critical digital control systems
- p 206 N92-15075 [NASA-TM-104158] DIRICHLET PROBLEM
  - Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948
- DISPLAY DEVICES
  - DARPA high resolution display technologies p 218 A92-19977 Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a
  - [ACD-340] p 191 N92-14034

DY	NAMIC	CHARAC	TERISTICS	i
D:			(4 <b>D</b> 410	

Directing of operation	ance (AD	AM) system
description		TUTIC UQUAL
[AD-A242598]	p 170	N92-14966
Ferrundi Company supplies 4500 r	nodelhea	d up display
devices to India's MIG-21 aircraft		
[AD-A241044]	p 229	N92-15367
DISTANCE MEASURING EQUIPMEN	т	
Use of distance-measuring eq	uipment	(DME) for
correcting errors in position,	velocity,	and wind
measurements from aircraft inertial	navigation	n systems
DME growth planants and their	p 100	A92-101/2
DME growin elements and their u	58 WILD N	N02-14010
The problem of multiple solutions i	p 103	vigation and
computed centerline operations	with the	microwave
landing system		
[AD-A242757]	p 191	N92-15058
DISTORTION		
Vortex generator design for aircr	aft inlet o	distortion as
a numerical optimization problem	p 194	N92-13959
A study on vortex flow control on	inlet dist	ortion in the
re-engined /2/-100 center inlet duc	t using co	mputational
INIO OVIAMICS	n 170	NO2 12000
DIVERTERS	p 175	1032-10350
Scoping studies for small stearth	-state to	kamaks for
divertor testing	5	
(DE92-000740)	p 238	N92-15761
DORNIER AIRCRAFT		
Dornier 328 first flight	p 192	A92-19924
DRAG		
Results of an Icing test on a NAC	CA 0012 a	airfoil in the
NASA Lewis Icing Research Tunnel		
[NASA-1M-1053/4]	p 185	N92-15051
DRAG COEFFICIENTS		an aist-il
characteristics at high subsonia and	rameters	on airroil
characteristics at high subschic spe	n 173	492-18769
ORAG REDUCTION	p 170	102 10/03
Aerodynamic shape optimization o	f arbitrarv	hypersonic
vehicles	p 194	N92-13954
The effects of winglets on low a	, senect rai	io windo et
	1309991 IQI	io wings at
supersonic Mach numbers	appoor in	io wings at
supersonic Mach numbers (NASA-CR-4407)	p 178	N92-13996
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and	p 178 non-plan	N92-13996 ar wings for
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization	p 178 non-plan	N92-13996 ar wings for
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509]	p 178 non-plan p 179	N92-13996 ar wings for N92-13999
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts f	p 178 non-plan p 179 ior horizo	N92-13996 ar wings for N92-13999 ntal takeoff
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-CH-104202]	p 178 non-plan p 179 ior horizo	N92-13996 ar wings for N92-13999 ntal takeoff
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AUCOAST	p 178 non-plan p 179 ior horizo p 206	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network:	p 178 non-plan p 179 ior horizo p 206	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network	p 178 non-plan p 179 ior horizo p 206 s to drone p 205	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 control A92-19273
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS	p 178 non-plan p 179 ior horizo p 206 s to drone p 205	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts is single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free	p 178 non-plan p 179 ior horizo p 206 s to drone p 205 o drop test	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel	p 178 non-plan p 179 for horizo p 206 s to drone p 205 e drop tesi	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002]	p 178 non-plan p 179 ior horizo p 206 s to drone p 205 o drop tesi p 207	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesocrale dynamics of cold	p 178 non-plan p 179 ior horizo p 206 s to drone p 205 o drop tesi p 207 fronte	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] <b>DRONE AIRCRAFT</b> The application of neural network: <b>DROP TESTS</b> Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] <b>DROPSONDES</b> Mesoscale dynamics of cold described by drosseurofings in Eron	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18902
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18902
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow	p 178 non-plan p 179 ior horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures A92-18902 A92-18680
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop test p 207 fronts - ts 87 p 230 p 173 ated app	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures A92-18902 A92-18680 roaches to
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop test p 207 fronts - ts 87 p 230 p 173 ated appi p 193	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 9 control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on n energined 722 100 center joint durit	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 atted appi p 193 inlet disto	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933 ortion in the
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics	p 178 non-plan p 179 jor horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated appi p 193 inlet disto t using co	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933 ortion in the mputational
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duci fluid dynamics [NASA-TM-105211]	p 178 non-plan p 179 for horizo p 206 s to drone p 205 e drop tesi p 207 fronts - ts 87 p 230 p 173 ated appi p 193 inlet dista t using co	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 <i>e control</i> A92-19273 to f external A92-20850 Structures A92-18800 roaches to N92-13933 ortion in the mputational N92-13998
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS	p 178 non-plan p 179 for horizo p 206 s to drone p 205 e drop test p 207 fronts - ts 87 p 230 p 173 ated appi p 193 iniet disto t using co p 179	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures A92-18902 A92-18800 roaches to N92-13933 ortion in the mputational N92-13998
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duct fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 207 fronts - ts 87 p 230 p 173 atted appi p 179 atted appi p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933 prion in the mputational N92-13998 proaches to
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-ree	p 178 non-plan p 179 for horizo p 206 s to drone p 205 s to drone p 205 drop tesi p 207 fronts - ts 87 p 230 p 173 atted app p 193	N92-13996           ar wings for           N92-13999           ntal takeoff           N92-15076           a control           A92-19273           tof external           A92-20650           Structures           A92-18860           roaches to           N92-13933
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated app; p 173 ated app; p 179 inlet dista	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the moutational N92-13933 ortion in the
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts f single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rel aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid on vortex flow control on re-engined 727-100 center inlet duc fluid on vortex flow control on re-engined 727-100 center inlet duc fluid on vortex flow control on re-engined 727-100 center inlet duc fluid on vortex flow control on	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated appi p 193 inlet disto t using co	N92-13996 ar wings for N92-13999 ntal takeoff N92-15076 <i>e control</i> A92-19273 to f external A92-20650 Structures A92-18680 roaches to N92-13938 ordicin in the mputational N92-13933 ordion in the
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DROPS AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duct fluid dynamics [NASA-TM-105321] DUCTS	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop test p 207 fronts - ts 87 p 230 p 173 ated app p 193 inlet disto t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-15076 9 control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933 ortion in the mputational N92-13938 proaches to N92-13938
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURABLITY	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 atted appr p 193 inlet disto t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 a control A92-15076 a control A92-18273 t of external A92-20650 Structures A92-18800 coaches to N92-13933 ortion in the mputational N92-13938
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-re- aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURS	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated app p 193 inlet disto t using co p 179 elated app p 193 inlet disto t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 a control A92-19273 to f external A92-20650 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the mputational N92-13938 ortion in the mputational N92-13998 Can they be
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rel aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rel aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURABILITY Avionics reliability, durability, and i independent of application?	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated app p 173 ated app p 193 inlet disto t using co p 179 elated app p 193 inlet disto t using co p 179 inlet disto	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 <i>e control</i> A92-19273 to f external A92-20650 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the mputational N92-13998 oroaches to N92-13998 Can they be N92-14056
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DROPE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-re aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated app p 193 inlet distt t using co p 179 inlet distt t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-13076 e control A92-19273 t of external A92-20650 Structures A92-18680 roaches to N92-13933 ortion in the mputational N92-13998 oroaches to N92-13933 ortion in the mputational N92-13998 Can they be N92-13998
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURASLITY Avionics reliability, durability, and i independent of application? Dynamics and control of hypers	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 atted appi p 193 inlet diste t using co p 179 elated appi p 193 inlet diste t using co p 179 onic vehi	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the mputational N92-13938 oroaches to N92-13938 oroaches to N92-13938 croaches to N92-13958 croaches to N92-13555 croaches to N92-140555 croaches to N92-140555 croaches to N92-140555 croaches to N92-140555 croaches to N92-1405555 croaches to N92-1405555 croaches to N92-14055555 croaches to N92-140555555555555555555555555555555555555
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURABILITY Avionics reliability, durability, and i independent of application? DYNAMIC CHARACTERISTICS Dynamics and control of hyperso integration challenge for the 1990's [AlaA PEP 01-5671]	p 178 non-plan p 179 for horizo p 206 s to drone p 205 s to drone p 205 drop tesi p 207 fronts - ts 87 p 230 p 173 atted app p 193 inlet disto t using co p 179 stated app p 193 inlet disto t using co p 179 con con con con con p 179 stated app p 193 inlet disto t using co p 179 con con con con p 179 stated app p 193 inlet disto t using co p 179 con con con con p 205	N92-13996           Anyon and a second a s
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-169509] Trim drag reduction concepts 1 single-stage-to-Oritiv vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURSS [NASA-TM-105321] DURSBILITY Avionics reliability, durability, and i independent of application? DYNAMIC CHARACTERISTICS Dynamics and control of hypersc integration challenge for the 1990's [AIAA PAPER 91-5057] Mentification of theomatic character	p 178 non-plan p 179 for horizo p 206 s to drone p 205 s to drone p 205 s to drone p 205 s to drone p 205 fronts - ts 87 p 230 p 173 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 200 p 179 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 e control A92-19273 t of external A92-20650 Structures A92-18902 A92-18800 roaches to N92-13933 ortion in the mputational N92-13938 contaches to N92-13938 context to N92-13998 Can they be N92-14056 cles - The A92-17840 avible rotace
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-re aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS DUCTS DYNAMIC CHARACTERISTICS Dynamics and control of hypersor integration challenge for the 1990's [AIAA PAPER 91-5057] Identification of dynamic character as dynamic inverse problem	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated appi p 193 inlet disto t using co p 179 p 193 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179 inlet disto t using co p 179	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 <i>e control</i> A92-19273 to f external A92-20850 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the mputational N92-13998 contes to N92-13998 contes to N92-13933 ortion in the mputational N92-13998 con they be N92-14056 cles - The A92-17840 exible rotors
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts i single-stage-to-Orbit vehicles [NASA-TM-102687] DROPS AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duct fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rel aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duct fluid dynamics [NASA-TM-105321] DUCTS DYNAMIC CHARACTERISTICS Dynamics and control of hyperse integration challenge for the 1990's [AIAA PAPER 91-5057] Identification of dynamic character as dynamic inverse problem Experiment of static and dynamic Character as dynamic of dynamic character as dynamic of spolem	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 atted app p 193 inlet disto t using co p 179 elated app p 193 inlet disto t using co p 179 onic vehi p 200	N92-13996 ar wings at N92-13999 ntal takeoff N92-13999 ntal takeoff N92-15076 a control A92-19273 t of external A92-20650 Structures A92-18902 A92-18680 roaches to N92-13933 ortion in the mputational N92-13998 oraches to N92-13998 craches to N92-13995 craches to N92-13962 craches t
supersonic Mach numbers [NASA-CR-4407] Analysis and design of planar and induced drag minimization [NASA-CR-189509] Trim drag reduction concepts 1 single-stage-to-Orbit vehicles [NASA-TM-102687] DRONE AIRCRAFT The application of neural network: DROP TESTS Control system design for the free stores in a wind tunnel [IAF PAPER ST-91-002] DROPSONDES Mesoscale dynamics of cold described by dropsoundings in Fron DUCTED FLOW Noise-driven flow A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DUCTS A comparison of two closely-rela aerodynamic design optimization A study on vortex flow control on re-engined 727-100 center inlet duc fluid dynamics [NASA-TM-105321] DURABILITY Avionics reliability, durability, and i independent of application? DYNAMIC CHARACTERISTICS Dynamics and control of hyperso integration challenge for the 1990's [AIAA PAPER 91-5057] Identification of dynamic character as dynamic inverse problem Experiment of static and dynamic claracter as dynamic integration character as dynamic integration character	p 178 non-plan p 179 for horizo p 206 s to drone p 205 o drop tesi p 207 fronts - ts 87 p 230 p 173 ated app p 193 infet disto t using co p 179 elated app p 193 infet disto t using co p 179 onic vehi p 200 conic vehi p 200	N92-13996           Anyon and a second a s

shuttle main engine oxygen pump p 224 N92-14366 Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling machines p 224 N92-14370

# DYNAMIC LOADS

Effect of eccentricity on the static and dynamic performance of a turbulent hybrid bearing p 225 N92-14373

- DYNAMIC LOADS
- Monitoring load experience of individual aircraft p 196 N92-15065 (NLR-TP-90084-U) DYNAMIC PROGRAMMING
- A stochastic regulator for integrated communication and control systems. I - Formulation of control law. II - Numerical p 233 A92-19605 analysis and simulation
- DYNAMIC RESPONSE Rotor-to-stator partial rubbing and its effects on rotor
- p 224 N92-14367 dynamic response p 227 N92-15083 Industrial code development DYNAMIC STABILITY
- Dynamics of hang-gliders p 204 A92-18608 Dynamic characteristics and stability analysis of space p 224 N92-14366 shuttle main engine oxygen pump DYNAMIC STRUCTURAL ANALYSIS
- Representation of geometric stiffening in multibody p 217 A92-19463 system simulation Structural Dynamics Branch research and accomplishments for FY 1990
- [NASA-TM-103747] p 230 N92-15406 DYNAMICAL SYSTEMS Structural Dynamics Branch research and
- accomplishments for FY 1990 [NASA-TM-103747] p 230 N92-15406

# Ε

### EARTH ORBITAL ENVIRONMENTS

- Verification of flight software by embedding software simulation in simulation of external environment p 232 A92-19084 FCCENTRICITY
- Effect of eccentricity on the static and dynamic performance of a turbulent hybrid bearing p 225 N92-14373
- FDDY VISCOSITY A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052
- FIGENVALUES calculation procedure for Eigenvalue an Euler/Navier-Stokes solver with application to flows over p 170 A92-17429 airfoils
- ELASTIC BODIES Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414
- ELASTIC DEFORMATION Experimental and theoretical analysis of composite I-beams with elastic couplings p 216 A92-18377
- ELECTRA AIRCRAFT Aerobureau - Strategic television airmobile reports via
- p 218 A92-19988 eatellite ELECTRIC FIELD STRENGTH
- On the accuracy of an aircraft-borne ambient electric-field measuring system p 186 A92-20127 ELECTRIC MOTORS
- Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414 ELECTRIC WIRE
- Whole aircraft lightning indirect effects evaluation using low level injection techniques p 192 A92-20134
- ELECTROMAGNETIC FIELDS The use of finite difference electromagnetic analysis in the design and verification of modern aircraft
- p 192 A92-20136 ELECTROMAGNETIC INTERFERENCE A review of digital flight control system upsets caused
- by electromagnetic interference [AIAA PAPER 91-3765] p 215 A92-17627
- ELECTRON BEAMS PVD coatings for aircraft turbine blades
- p 216 A92-17950 ELECTRONIC CONTROL
- Electronically steerable antenna for aircraft p 229 N92-15272
- ELECTRONIC EQUIPMENT Real-time microfocus radiography for electronic failure analysis p 214 A92-17289
- Electronic systems in transportation p 189 N92-14009 [TP-9983]
- ELECTRONIC EQUIPMENT TESTS Radar troubleshooting assistant expert system [AIAA PAPER 91-3764] p 231 A92-17626
- Designing through test [AIAA PAPER 91-3822] p 232 A92-17664 Image-supported navigation for testing instrument
- p 189 N92-14012 landing systems ELECTRONIC PACKAGING
- Putting ten pounds of avionics in a one pound package (Can we do it again?) [AIAA PAPER 91-3766] p 197 A92-17628

### ELLIPSES

- Influence of chemical modeling on the solution of p 183 N92-15016 hypersonic shock layers ELLIPSOIDS
- Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with monoand multi-blocks including real gas effects, part 1
- p 227 N92-15030 ENGINE AIRFRAME INTEGRATION
- A configuration development strategy for the NASP [AIAA PAPER 91-5044] p 210 A92-17830 Dynamics and control of hypersonic vehicles - The
- integration challenge for the 1990's p 203 A92-17840 [AIAA PAPER 91-5057]
- Vortex generator design for aircraft inlet distortion as p 194 N92-13959 a numerical optimization problem ENGINE CONTROL
- Performance improvements of an F-15 airplane with an integrated engine-flight control system p 205 A92-20204
- ENGINE COOLANTS
- Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary layer p 215 A92-17823 [AIAA PAPER 91-5033]
- Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17843 ENGINE DESIGN
- International aviation (selected article)
- p 170 N92-13992 [AD-A240987] Theoretical models for duct acoustic propagation and p 236 N92-14782 radiation Study of the engine bird ingestion experience of the
- Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053
- Army research concerns in engine sealing p 228 N92-15089 ENGINE INLETS
- Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959 Analysis of an advanced ducted propeller subsonic inlet
- [NASA-TM-105393] p 179 N92-14002 Numerical investigations in three-dimensional internal
- flows NASA-CR-189467] p 221 N92-14313 ENGINE NOISE
- Design and performance of duct acoustic treatment
- p 236 N92-14783 Quiet aircraft design and operational characteristics
- p 236 N92-14787 A survey of the broadband shock associated noise prediction methods
- NASA-TM-105365] p 237 N92-14797 ENGINE PARTS
- Numerical simulation for various flowfields of p 200 A92-17503 aero-engine components Scramjet research at the National Aerospace Laboratory
- (AIAA PAPER 91-5076) p 200 A92-17849 Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpieces
- p 219 A92-20771 Turbine engine diagnostics system study [DOT/FAA/CT-91/16] p 202 N92-14064
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424
- p 228 N92-15094 Areas of seal B/D at GE ENGINE TESTING LABORATORIES Scramjet research at the National Aerospace
- Laboratory [AIAA PAPER 91-5076] p 200 A92-17849 ENGINE TESTS
- Scramjet research at the National Aerospace Laboratory [AIAA PAPER 91-5076] p 200 A92-17849
- Seal development activities at Allison Turbine Division p 228 N92-15093
- ENTHALPY High enthalpy nozzle flows p 182 N92-15000 High enthalpy testing in the Aachen (Fed. Republic of p 208 N92-15021 Germany) shock tunnel TH 2 ENVIRONMENT MANAGEMENT
- Reducing environmental noise impacts: A USAREUR
- noise management program handbook (AD-A240797) p 237 N92-14791 ENVIRONMENTAL SURVEYS
- Reducing environmental noise impacts: A USAREUR noise management program handbook AD-A2407971 p 237 N92-14791
- ENVIRONMENTAL TESTS
- Designing through test [AIAA PAPER 91-3822]
  - p 232 A92-17664 Environmental fatique tests with composite materials p 214 N92-14413

Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin

SUBJECT INDEX

- p 226 N92-14414 EQUILIBRIUM EQUATIONS
- Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with monoand multi-blocks including real gas effects, part 1 p 227 N92-15030

### ERROR ANALYSIS

- MLS system error model identification and synthesis p 189 N92-14015
- EULER EQUATIONS OF MOTION Effect of nose shape on three-dimensional stagnation region streamlines and heating rates
- [AIAA PAPER 91-5032] p 171 A92-17822 Aerodynamic sensitivity analysis methods for the
- p 233 A92-19619 compressible Euler equations Genuinely upwind algorithms for the multidimensional
- Euler equations p 175 A92-20733 Upwind scheme for solving the Euler equations on unstructured tetrahedral meshes p 175 A92-20735
- LEWICE/E: An Euler based ice accretion code p 179 N92-14001 [NASA-TM-105389]
- Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles
- p 211 N92-14977 A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986
- Steps towards an efficient and accurate method solving
- the Euler equations around a re-entry configuration at super- and hypersonic speed p 181 N92-14987
- Numerical simulations around models in hypersonic wind p 182 N92-14998 tunnels
- Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025
- Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with mono-
- and multi-blocks including real gas effects, part 1 p 227 N92-15030
- Grid impact on 3D hypersonic flows p 184 N92-15041
- EULER-CAUCHY EQUATIONS Limitations to the large strain theory
- p 219 A92-20356 EUROPE
- Avionics standardization in Europe

EXHAUST GASES

EXHAUST NOZZLES

EXPERT SYSTEMS

Saenger

ATE

control

AIAA PAPER 91-5075)

[AIAA PAPER 91-5024]

[AIAA PAPER 91-5040]

Jet noise suppression

[AIAA PAPER 91-3709]

[AIAA PAPER 91-3764]

[AIAA PAPER 91-3789]

en route air traffic control

Flight simulation

[AGARD-AR-284]

flight hardware

AD-A242598]

EXTRAPOLATION

EXTERNAL STORES

stores in a wind tunnel [IAF PAPER ST-91-002]

Computational fluid dynamics

description

a deep structure representation [AIAA PAPER 91-3941]

- p 199 N92-14050
- EUROPEAN SPACE AGENCY Aerothermodynamic challenges for ESA programmes
- p 180 N92-14974 EUROPEAN SPACE PROGRAMS
- Aerothermodynamic challenges for ESA programmes p 180 N92-14974

Hydrogen exhaust gas disposition by afterburning

Hypersonic airbreathing propulsion activities for

Knowledge maintenance in an evolving system using

Fault Tree Interpreter --- expert system shell for

Automated problem resolution prototype in automated n route air traffic control p 190 N92-14028

Knowledge based system applications for guidance and

Architecture for Survivable System Processing (ASSP)

Getting expert systems off the ground: Lessons learned

Aviation Diagnostics And Maintenance (ADAM) system

Control system design for the free drop test of external

preliminary concept of operation and functional

from integrating model-based diagnostics with prototype

rule-based expert systems development for control of

Model based reasoning in the aerospace domain

Radar troubleshooting assistant expert system

Thrust nozzle test facility at DLR Cologne

p 200 A92 17848

p 206 A92-17818

p 200 A92-17828

p 236 N92-14784

p 230 A92-17582

p 231 A92-17605

p 231 A92-17626

p 232 A92-17645

p 207 N92-13982

p 205 N92-14065

p 220 N92-14210

p 220 N92-14217

p 170 N92-14966

p 207 A92-20650

p 177 N92-13979

Numerical simulations around models in hypersonic wind p 182 N92-14998 tunnels

# F

# F-106 AIRCRAFT

- Analysis and modeling of lightning strikes to the F106B, CVF580, and C160 aircraft p 186 A92-20129 p 186 A92-20129 F-14 AIRCRAFT
- Flow separation patterns over an F-14A aircraft wing p 174 A92-20205

F-15 AIRCRAFT

- Performance improvements of an F-15 airplane with an integrated engine-flight control system p 205 A92-20204
- F-18 AIRCRAFT
- Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed
- p 179 N92-14968 [NASA-TP-3111] F/A-18 stabilator: Equivalent set of point forces required
- for pneumatic bag load case simulation p 206 N92-15073 [AD-A242637]
- F-2 AIRCRAFT
- Four decades of transonic fighter design p 193 A92-20203
- F-27 AIRCRAFT
- F27 aging aircraft programme emphasizes corrosion p 186 A92-20024 prevention FAILURE
- Turbine engine diagnostics system study
- [DOT/FAA/CT-91/16] p 202 N92-14064 Rotor-to-stator partial rubbing and its effects on rotor dynamic response p 224 N92-14367
- FAILURE ANALYSIS
- Real-time microfocus radiography for electronic failure analysis p 214 A92-17289 Failure environment analysis tool (FEAT) development status
- [AIAA PAPER 91-3803] p 232 A92-17654 Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program and test implantation
- p 195 N92-14043 [CEAT-S8-6551-PARTIEL-1-PT-] Development and evaluation of a finite element model
- for a fiber composite helicopter fuselage p 196 N92-15066 [M8B-UD-0584-90-PUB] FAR FIFLDS
- Direct computation of turbulence and noise
- p 236 N92-14788 [NASA-CR-187616] FAST FOURIER TRANSFORMATIONS
- Enhancement of modal swept sine data by control of exciting forces p 215 A92-17562 FATIGUE (MATERIALS)
- Fatigue of repaired composite structures
- p 214 N92-14411 Environmental fatigue tests with composite materials p 214 N92-14413
- Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin p 226 N92-14414
- Monitoring load experience of individual aircraft p 196 N92-15065 [NLR-TP-90084-U] FATIGUE LIFE
- Fatigue and damage tolerance verification of aircraft p 217 A92-19677 structures Multiaxial load spectra in a cooled gas turbine blade
- under in-service conditions p 201 A92-19696 Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817 Damage tolerance of the fighter aircraft 37 Viggen. 1 -
- Analytical assessment. II Experimental verification
- p 192 A92-19819 Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820
- Proof test and fatigue crack growth modeling on 2024-T3 p 213 A92-19828 aluminum allov Bulging of fatigue cracks in a pressurized aircraft
- fuselage [LR-655] p 196 N92-14045
- Review of investigations on aeronautical fatigue in the Federal Republic of Germany [ETN-92-90317] p 225 N92-14397
- Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424 Airbus Industrie A330/A340: Full scale fatigue test of
- p 226 N92-14425 center fuselage and wing p 226 N92-14425 Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code
- [DE92-000597]
- p 229 N92-15392

# FATIGUE TESTS

- High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796 Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerica p 217 investigations A92-19812
  - Fatigue testing of a gas turbine fan disc p 217 A92-19818 Review of investigations on aeronautical fatigue in the
- Federal Republic of Germany [ETN-92-90317] p 225 N92-14397 Low cycle fatigue of cast nickel base turbine rotors
- p 226 N92-14405 Fatigue of repaired composite structures
- p 214 N92-14411 Environmental fatique tests with composite materials
- p 214 N92-14413 Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin
- p 226 N92-14414 Airbus Industrie A330/A340: Full scale fatigue test of p 226 N92-14425 center fuselage and wing Methodology for assessment of skin repairs on Airbus
- ircraft p 226 N92-14428 F/A-18 stabilator: Equivalent set of point forces required aircraft for pneumatic bag load case simulation
- [AD-A242637] p 206 N92-15073 FAULT TREES
- Fault Tree Interpreter --- expert system shell for rule-based expert systems development for control of ATE
- [AIAA PAPER 91-3789] p 232 A92-17645 FEASIBILITY ANALYSIS
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034
- FEDERAL BUDGETS
  - National Aeronautics and Space Administration p 238 N92-14923 National Aeronautics and Space Administration
  - p 238 N92-14925 National Aeronautics and Space Administration
  - p 238 N92-14927 National Aeronautics and Space Administration research p 238 N92-15937 and development
- FEEDBACK CONTROL
- A geometric approach to regulator and tracker design for an aerospace plane p 203 A92-17837 [AIAA PAPER 91-5054]
- Regulation of relaxed static stability aircraft p 203 A92-18463
- Parameter insensitive control utilizing eigenspace methods --- for flutter suppression in aeroelastic vehicles
- p 204 A92-18615 Structure/control design synthesis of active flutter suppression system by goal programming
- p 204 A92-18621 Nonlinear control of a twin-lift helicopter configuration
- p 204 A92-18624 Approximation methods for control of acoustic/structure
- models with piezoceramic actuators [NASA-CR-189578] p 234 N92-15658 FIBER COMPOSITES
  - Some results on metal and composite patch reinforcement of aluminum honeycomb panel
- p 216 A92-18830 Current stabilizing of fastened composite joints to improve non-sparking lightning current performance
- p 213 A92-20130 Development and evaluation of a finite element model for a fiber composite helicopter fuselage
- [MBB-UD-0584-90-PUB] p 196 N92-15066 Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 p 229 N92-15402
- FIBERS
- Universal weaving for turbine engine composite preforms [AD-A237667] p 202 N92-14059
- FIGHTER AIRCRAFT
- Heavy metal --- fighter aircraft test rigs p 207 A92-18100
- Damage tolerance of the fighter aircraft 37 Viggen. I -Analytical assessment, II - Experimental verification p 192 A92-19819
- Four decades of transonic fighter design
- p 193 A92-20203 Evolution of avionic systems architecture, from the p 198 N92-14047 1950's to the present
- Avionics technology beyond 2000 p 200 N92-14058
- Monitoring load experience of individual aircraft p 196 N92-15065 [NLR-TP-90084-U]
- Ferrundi Company supplies 4500 model head up display devices to India's MIG-21 aircraft p 229 N92-15367
- [AD-A241044]

FILLETS

The aerodynamic effect of fillet radius in a low speed compressor cascade

FLIGHT CONTROL

- [NASA-TM-105347] p 202 N92-14063 FINITE DIFFERENCE THEORY
- Nonlinear triggered lightning models for use in finite difference calculations p 230 A92-20128 The use of finite difference electromagnetic analysis in the design and verification of modern aircraft
- p 192 A92-20136 Analysis and design of transonic airfoils using reamwise coordinates p 194 N92-13955 streamwise coordinates
- Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies p 221 N92-14309
- A Navier-Stokes solution of Hull-ring wing-thruster teraction p 221 N92-14310 interaction
- FINITE ELEMENT METHOD Multidisciplinary modeling and simulation of a generic
- hypersonic vehicle [AIAA PAPER 91-5015] p 232 A92-17813
- Resonance prediction for slotted circular wind tunnel sing finite element p 235 A92-18388 using finite element
- Static aeroelastic analysis for generic configuration p 174 A92-20201 wina
- Flutter analysis of anisotropic panels with patched
- p 219 A92-20216 cracks Incompressible steady aerodynamics using a standard nite element code p 174 A92-20218
- finite element code Formation of shocks within axisymmetric nozzles p 176 A92-20760
- Variational formulation of hybrid problems for fully 3-D p 176 N92-13953 transonic flow with shocks in rotor
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit
- p 222 N92-14348 Determination of rotordynamic coefficients for labyrinth seals and application to rotordynamic design
- alculations p 223 N92-14360 Flow and temperature computations for space vehicles calculations using adaptive finite element techniques

for a fiber composite helicopter fuselage

Three-dimensional calculation

unsteady transonic flow in axial turbine stages

Ultrasonic motor utilizing elastic fin rotor

[MBB-UD-0584-90-PUB]

[NASA-TM-105336]

FINNED BODIES

FLEXIBLE BODIES

flight vehicles

FLEXIBLE WINGS

FLIGHT CONTROL

[AIAA PAPER 91-3729]

[AIAA PAPER 91-3730]

[AIAA PAPER 91-3765]

[AIAA PAPER 91-5055]

[AIAA PAPER 91-5056]

fliaht vehicles

system simulation

FINS

FINITE VOLUME METHOD

FLAPS (CONTROL SURFACES)

vehicles with flap deflection

[AIAA PAPER 91-5056]

Development and evaluation of a finite element model

Analysis of aircraft engine blade subject to ice impact

Asymmetric separated flows at supersonic speeds

A multiblock flow solver for inviscid hypersonic flows

Two-dimensional effects in a triangular convecting fin

Hypersonic inviscid flow field simulations around reentry

Aeroservoelastic stabilization techniques for hypersonic

Representation of geometric stiffening in multibody

The stability of the steady state and bistable response

of a flexible rotor supported on squeeze film dampers

minimum-state unsteady aerodynamic approximations

Formal specification and verification of Ada software [AIAA PAPER 91-3713] p 230 A92-17585 An intelligent pilot vehicle interface for a day/night

A review of digital flight control system upsets caused

Control concept for maneuvering in hypersonic flight

Aeroservoelastic stabilization techniques for hypersonic

Performance improvements of an F-15 airplane with an

Application of aeroservoelastic

adverse weather pilotage system (D/NAPS)

Sensor fusion for synthetic vision

integrated engine-flight control system

by electromagnetic interference

p 181 N92-14990

p 196 N92-15066

p 229 N92-15402

p 174 A92-19110

p 176 A92-20742

p 181 N92-14986

p 215 A92-17414

p 219 A92-20324

p 184 N92-15025

p 203 A92-17839

p 217 A92-19463

p 222 N92-14350

modeling using

p 204 A92-18622

A92-17596

p 197 A92-17597

p 215 A92-17627

p 203 A92-17838

p 203 A92-17839

p 205 A92-20204

A-11

p 197

low-frequency

of

# FLIGHT ENVELOPES

- A low-altitude breakthrough system using optimal path terrain following p 205 A92-20483 DME growth elements and their use with MLS
- p 189 N92-14018 Knowledge based system applications for guidance and control
- [AGARD-AR-284] p 205 N92-14065 Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027 Neural network and fuzzy logic technology for naval flight
- (AD-A242650) p 206 N92-15074 Formulation of a strategy for monitoring control integrity
- in critical digital control systems [NASA-TM-104158] p 206 N92-15075
- Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076
- FLIGHT ENVELOPES A geometric approach to regulator and tracker design for an aerospace plane
- [AIAA PAPER 91-5054] p 203 A92-17837 Evolution and development of hypersonic configurations 1958-1990
- [AD-A242768] p 197 N92-15069 FLIGHT OPERATIONS
- Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067 FLIGHT PATHS
- Regulation of relaxed static stability aircraft p 203 A92-18463 FLIGHT SAFETY
- Analysis of aircraft performance during lateral maneuvering for microburst avoidance
- p 205 A92-20207 Aircraft accident/incident summary report: Midair collision involving Lycoming Air Services Piper Aerostar PA-60 and Sun Company Aviation Department Bell 412, Merion, Pennsylvania, April 4, 1991
- [PB91-910407] p 187 N92-15055 FLIGHT SIMULATION
- Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838 Verification of flight software by embedding software simulation in simulation of external environment

	p 232	A92-19084
Flight research	p 194	N92-13981
Flight simulation	p 207	N92-13982
Numerical simulations around m	odels in hyp	oreonic wind

- tunnels p 182 N92-14998 Review of the European hypersonic wind tunnel
- performance and simulation requirements p 209 N92-15043 FLIGHT TESTS
- The value of sub-scale flight tests in the development of NASP vehicles

[AIAA PAPER 91-5048]	p 210	A92-17834
Implementation and usage of the	RJ pro	gram Data
Acquisition System Ground Station	p 210	A92-19257
An integrated real-time turbine	engine	flight test
system	p 201	A92-19275
Design and implementation of a tot	al flight	test system
	p 189	A92-19278
Dornier 328 first flight	p 192	A92-19924
Evaluations of X-29 high-AOA regin	ne show	promise for
future fighters	p 192	A92-19925
Flight test of a half-scale unmanned	d air vel	nicle
• •	p 193	A92-20208
Heat transfer measurements from a	smooth	NACA 0012
airfoil	p 218	A92-20215
Elight research	n 194	N92-13981

- Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results p 211 N92-14975 FALKE and COBRA technology development in
- aerodynamics and aerothermodynamics p 183 N92-15017
- FLIGHT TRAINING
- Aircraft accident/incident summary report: Midair collision involving Lycoming Air Services Piper Aerostar PA-60 and Sun Company Aviation Department Bell 412, Merion, Pennsylvania, April 4, 1991 [PB91-910407] p 187 N92-15055
- FLIR DETECTORS Infra-red offers new landing aid competition
- p 198 A92-18937
- A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition [AIAA PAPER 91-5026] p 207 A92-17819
- [AIAA PAPER 91-5026] p 207 A92-17819 FLOW CHARACTERISTICS
- Detection of flow state in an unsteady separating flow p 219 A92-20741

# FLOW COEFFICIENTS

- Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356
- FLOW DEFLECTION
- Surface flow patterns on an ogive-cylinder at incidence p 176 A92-20762 FLOW DISTRIBUTION
- CFD application to 2D/3D flow fields in Scramjet engine p 170 A92-17501 Numerical simulation for various flowfields of
- aero-engine components p 200 A92-17503 Three dimensional hypersonic inlets - Low speed performance [AIAA PAPER 91-5021] p 171 A92-17817
- LDV measurements and investigation of flow field through radial turbine guide vanes p 217 A92-19618 Evaluation of Euler solvers for transonic wina-fuselane
- geometries p 174 A92-20214 Incompressible steady aerodynamics using a standard finite element code p 174 A92-20218
- Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736 Instabilities of flows over bodies at large incidence
  - p 176 A92-20738 Supercritical blade design on stream surfaces of
- revolution with an inverse method p 220 N92-13950 Variational formulation of hybrid problems for fully 3-D
- Vanational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953 Analysis and design of transonic airfoils using
- streamwise coordinates p 194 N92-13955 Research on inverse methods and optimization in Italy p 202 N92-13956
- An inverse method for the aerodynamic design of three-dimensional aircraft engine nacelles
- p 194 N92-13958 Airfoil optimization with efficient gradient calculations o 177 N92-13960
- Design optimization of transonic airfoils p 177 N92-13961
- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics
- [NASA-TM-105321] p 179 N92-13998 The aerodynamic effect of fillet radius in a low speed compressor cascade
- [NASA-TM-105347] p 202 N92-14063 Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356
- Direct computation of turbulence and noise [NASA-CR-187616] p 236 N92-14788
- Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 Simulation requirements for RCS plume: Flowfield
- interaction modelling on a winged reentry vehicle p 181 N92-14985 Steps towards an efficient and accurate method solving
- the Euler equations around a re-entry configuration at super- and hypersonic speed p 181 N92-14987 Base pressure measurements on a cone at hypersonic
- Mach numbers: A contribution to aerothermodynamics for space vehicles p 181 N92-14992
- Flow over a delta wing at hypersonic speeds p 181 N92-14993 -
- Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique p 182 N92-14994
- Experimental investigation of transverse jet effects related to hypersonic space vehicles
- p 182 N92-14995 Numerical simulations around models in hypersonic wind tunnels p 182 N92-14998 SIMOUN and Scirocco wind tunnel nozzle viscous flow
- study p 208 N92-14999 High enthalpy nozzle flows p 182 N92-15000 Short time force measurement system
- p 208 N92-15001 Infrared measurements of aerodynamic heating in
- hypersonic wind tunnel p 208 N92-15002 Verification and application of the NSFLEX method for hypersonic flow conditions p 182 N92-15005
- Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15015
- hypersonic shock layers p 183 N92-15016 Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025
- Progress with multigrid schemes for hypersonic flow problems [NASA-CR-189579] p 185 N92-15047
- [NASA-CR-189579] p 185 N92-15047 Experimental research of the aerodynamics of nozzles and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048
- FLOW EQUATIONS
- Inviscid drag prediction for transonic transport wings using a full-potential method p 174 A92-20212

Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948

SUBJECT INDEX

- The research progress on Hodograph Method of aerodynamic design at Tsinghua University p 177 N92-13974
- Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031

### FLOW GEOMETRY

- Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363 Compressibility effects in thin channels with injection
- p 216 A92-18369 Stratified flow around an axisymmetric body at small
- angle of attack p 172 A92-18385
- Surface flow patterns on an ogive-cylinder at incidence p 176 A92-20762
- FLOW MEASUREMENT
- Measurements of the flow around a lifting-wing/body junction p 175 A92-20726

# FLOW STABILITY

- Three-dimensional linear stability approach to transition on wings and bodies of revolution at incidence p 172 A92-18361
  - Instabilities of flows over bodies at large incidence
    - p 176 A92-20738
- Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354
- FLOW THEORY Effect of suction on the stability of supersonic boundary layers. I - Second-mode waves. II - First-mode waves p 174 A92-19611

### FLOW VELOCITY

- Newton's method solver for high-speed viscous separated flowfields p176 A92-20736 Simple method of supersonic flow visualization using smoke p219 A92-20764
- Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 FLOW VISUALIZATION
- Simple method of supersonic flow visualization using smoke p 219 A92-20764 Flow over a delta wing at hypersonic speeds
- p 181 N92-14993 Infrared measurements of aerodynamic heating in hypersonic wind tunnel p 208 N92-15002 FLUID DYNAMICS
- An inverse method with regularity condition for transonic airfoil design p 177 N92-13969 Analytical/numerical matching and periodic inversion:
- Two advances in free wake analysis
- Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow models p 212 N92-15877
- FLUID FILMS Seal development activities at Allison Turbine Division
- FLUID FILTERS
- Filter debris analysis: A concrete approach to wear diagnosis
- [DREP-TM-88-20] p 222 N92-14345 FLUID FLOW
- Industrial code development p 227 N92-15083 Development of a CFD code for analysis of fluid dynamic
- forces in seals p 228 N92-15084 Redesign of flight space shuttle main engine nozzle G-15
- seal area based on the thermal analysis and flow models p 212 N92-15877 FLUTTER

Resonance prediction for slotted circular wind tunnel

Flutter analysis of anisotropic panels with patched

Nonlinear stall flutter and divergence analysis of

Time domain flutter analysis of cascades using a

Genuinely upwind algorithms for the multidimensional

Wind tunnel investigation of vortex flows on F/A-18

Flutter suppression via piezoelectric actuation

Nonlinear landing gear behavior at touchdown

configuration at subsonic through transonic speed

Description and highlights of initial results

cantilevered graphite/epoxy wings

models program:

p 185 N92-15049

p 235 A92-18388

p 219 A92-20216

p 219 A92-20746

p 176 A92-20747

p 197 N92-15070

p 175 A92-20733

p 192 A92-19606

p 179 N92-14968

# The benchmark aeroelastic

cracks

[NASA-TM-104180]

using finite element

full-potential solver

[NASA-TM-104120]

FOLDING STRUCTURES

Euler equations

[NASA-TP-31111

FORFRODIES

FLUX VECTOR SPLITTING

FLUTTER ANALYSIS

# FRACTURE MECHANICS

Review of investigations on aeronautical fatigue in the Federal Republic of Germany [ETN-92-90317] p 225 N92-14397

FRACTURE STRENGTH Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical investigations p 217 A92-19812

# FRANCE

Recent progress in inverse methods in France p 201 N92-13938

### FREE FLIGHT

FALKE and COBRA technology development in aerodynamics and aerothermodynamics

p 183 N92-15017

# FREE FLOW

High enthalpy testing in the Aachen (Fed. Republic of p 208 N92-15021 Germany) shock tunnel TH 2 FREE MOLECULAR FLOW

- Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031
- Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles

p 184 N92-15032 FRICTION

- Rotor-to-stator partial rubbing and its effects on rotor p 224 N92-14367 dynamic response p 227 N92-15083 Industrial code development Tribology needs for future space and aeronautical systems
- [NASA-TM-104525] p 214 N92-15191 FRICTION FACTOR
- Proceedings of Damping 1991, volume 3 [AD-A241313]
- p 225 N92-14386 FRICTION WELDING Inertia-friction welding of an advanced rapidly solidified
- p 212 A92-18898 titanium alloy FUEL COMBUSTION
- An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream p 212 A92-17861 [AIAA PAPER 91-5102]
- FUEL CONSUMPTION Trim drag reduction concepts for horizontal takeoff
- single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076 FUEL PUMPS
- Nonlinear rotordynamics analysis --- Space Shuttle Main Engine turbopumps
- [NASA-CR-184263] p 221 N92-14344 FUEL SYSTEMS
- Model based reasoning in the aerospace domain [AIAA PAPER 91-3709] p 230 A92-17582
- FULL SCALE TESTS Annular seals of high energy centrifugal pumps:
- Presentation of full scale measurement p 224 N92-14362

### FUSELAGES

- Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical investigations p 217 A92-19812
- Proof test and fatigue crack growth modeling on 2024-T3 p 213 A92-19828 aluminum allov Numerical solution of the boundary-layer equations for
- a general aviation fuselage p 174 A92-20211 Definition of the unsteady vortex flow over a wing/body configuration
- p 178 N92-13995 [NASA-CR-180083] The two-bay crack problem in fuselages built in GLARE
- and ARALL [LR-653] p 196 N92-14044
- Bulging of fatigue cracks in a pressurized aircraft fuselage p 196 N92-14045 [LR-655]
- Airbus Industrie A330/A340: Full scale fatioue test of p 226 N92-14425 center fuselage and wing
- Development and evaluation of a finite element model for a fiber composite helicopter fuselage
- [MBB-UD-0584-90-PUB] p 196 N92-15066 FUZZY SYSTEMS
- Neural network and fuzzy logic technology for naval flight
- [AD-A242650] p 206 N92-15074

# G

# GAS DISSOCIATION

- Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and p 235 A92-20301 Herzfeld GAS DYNAMICS
- Nonstationary gasdynamics n 220 N92-13985 Parallelization of a Direct Simulation Monte Carlo (DSMC) code for fluid dynamics p 227 N92-15033

# GAS EXPANSION

- sorption Multicomponent Joule-Thomson gas refrigeration
- [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203 GAS FLOW
- Seal related development activities at EG/G p 228 N92-15095
- GAS JETS An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861
- GAS MIXTURES
- Linear acoustics in gas mixtures with rate processes p 238 N92-15013 Multicomponent gas sorption Joule-Thomson
- refrigeration [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
- GAS TURBINE ENGINES A probabilistic method for monitoring the remaining life
- of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 Fatigue testing of a gas turbine fan disc
- p 217 A92-19818 High temperature static strain gage development
- [NASA-CR-189044] p 195 N92-14037 Rub induced rotor/stator vibration analysis on CF700 engine
- [NRC-TR-ENG-007] p 202 N92-14060 Army research concerns in engine sealing
- p 228 N92-15089 Programs at Wright-Patterson Air Force Base p 228 N92-15092
- Seal development activities at Allison Turbine Division p 228 N92-15093
- Seal related development activities at EG/G p 228 N92-15095
- GAS TURBINES
  - Recent progress in inverse methods in France p 201 N92-13938 Seal related development activities at EG/G
- p 228 N92-15095 GENERAL AVIATION AIRCRAFT
- General aviation activity and avionics survey, calendar vear 1989
- [PB91-179234] p 169 N92-13926 FAA statistical handbook of aviation: Calendar year 1989
- [PB91-202051] p 170 GEOMETRICAL THEORY OF DIFFRACTION p 170 N92-13927 SATCOM antenna siting study on P-3C aircraft, volume
- [NASA-CR-189514] p 221 N92-14262
- SATCOM antenna siting study on P-3C aircraft, volume 2
- p 221 N92-14263 [NASA-CR-189515] GLIDE PATHS
- New siting techniques for the ILS glide slope p 188 A92-17422 GLIDERS
- Review of aerodynamic design in the Netherlands p 193 N92-13929
- GLOBAL POSITIONING SYSTEM
- Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and wind velocity, and wind measurements from aircraft inertial navigation systems p 188 A92-18172
- Navsat A civil complement to GPS and Glonass p 188 A92-18505 [IAF PAPER 91-490] GOAL THEORY
- Structure/control design synthesis of active flutter suppression system by goal programming
- p 204 A92-18621 GRADIENTS
- A comparison of two closely-related approaches to p 193 N92-13933 aerodynamic design optimization GRAPH THEORY
- Failure environment analysis tool (FEAT) development status [AIAA PAPER 91-3803]
- p 232 A92-17654 **GRAPHITE-EPOXY COMPOSITES**
- Experimental and theoretical analysis of composite I-beams with elastic couplings p 216 A92-18377 Nonlinear stall flutter and divergence analysis of
- cantilevered graphite/epoxy wings p 219 A92-20746 Review of investigations on aeronautical fatigue in the Federal Republic of Germany p 225 N92-14397 [ETN-92-90317]
- Environmental fatigue tests with composite material p 214 N92-14413
- **GRID GENERATION (MATHEMATICS)** 
  - Three-dimensional solution-adaptive grid generation on p 172 A92-18352 p 169 A92-20146 composite configurations CFD helps the Air Force fly right Flow and temperature computations for space vehicles
  - using adaptive finite element techniques p 181 N92-14990

# HEAT TRANSFER COEFFICIENTS

Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with monoand multi-blocks including real gas effects, part 1

p 227 N92-15030 Grid impact on 3D hypersonic flows p 184 N92-15041

GROOVES

- Experiment of static and dynamic characteristics of spiral grooved seals p 223 N92-14361
- GROUND BASED CONTROL Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration
- test report [DOT/FAA/CT-TN91/50] p 221 N92-14270
- GROUND STATIONS Implementation and usage of the RJ program Data
- Acquisition System Ground Station p 210 A92-19257 GROUND SUPPORT EQUIPMENT
- Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report
- [DOT/FAA/CT-TN91/50] p 221 N92-14270 GROUND TESTS
  - ASNT and aerospace What about the next 50 years? p 215 A92-17293
  - Conducting the NASP ground test [AIAA PAPER 91-5029] program p 209 A92-17820 **GUIDANCE (MOTION)**
  - Knowledge based system applications for guidance and control
  - [AGARD-AR-284] p 205 N92-14065 Artificial Neural Network Approaches in Guidance and Control
  - [AGARD-LS-179] p 234 N92-14673 Introduction to neural computing and categories of
  - neural network applications to guidance, navigation and control p 234 N92-14674 GUIDE VANES LDV measurements and investigation of flow field

A simplified method for predicting the stability of

Н

FAA statistical handbook of aviation: Calendar year

Enhanced autopilot design through hardware-in-the-loop

Architecture for Survivable System Processing (ASSP)

Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067

Adaptive suppression of biodynamic interference in

Ferrundi Company supplies 4500 model head up display devices to India's MIG-21 aircraft

Crack initiation and the short-to-long crack growth

High temperature low cycle fatigue of single crystal nickel ase superalloys p 213 A92-19796

Four decades of transonic fighter design

helmet-mounted displays and head teleoperation

Infra-red offers new landing aid competition

Protective coatings of thermal barrier type

measurements in reentry body heat shields

temperature

Recent progress in inverse methods in France

Heat transfer measurements from a smooth NACA 0012

p 217 A92-19618

p 224 N92-14364

p 170 N92-13927

p 204 A92-18608

p 204 A92-19103

p 220 N92-14210

p 196 N92-15067

p 193 A92-20203

p 197 A92-18611

p 198 A92-18937

p 229 N92-15367

p 213 A92-19767

p 214 A92-20349

p 227 N92-15004

p 201 N92-13938

p 218 A92-20215

from a NACA 0012

p 219 A92-20217

A-13

for flight

sensors

through radial turbine guide vanes

aerodynamically excited turbomachinery

GYROSCOPIC STABILITY

HANDBOOKS

[PB91-202051]

HARMONIC CONTROL

Dynamics of hang-gliders

HANG GLIDERS

HARDWARE

simulation

HAWK MISSILE

HEAD MOVEMENT

HEAD-UP DISPLAYS

[AD-A241044]

base superallovs

HEAT SHIELDING

HEAT TRANSFER

airfoil

airfoil

Ablation and

HEAT RESISTANT ALLOYS

transition in a Ni-base superalloy

HEAT TRANSFER COEFFICIENTS

Roughness effects on heat transfer

1989

p 174 A92-20304

p 175 A92-20378

Flat-ended circular cylinder in hypersonic rarefied flow

Engineering calculations of three-dimensional inviscid

Nonequilibrium hypersonic inviscid steady flows

hypersonic flowfields

u	EI.	10	EC
м	EL	ະ	EЭ

- Experiment of static and dynamic characteristics of spiral p 223 N92-14361 arooved seals HELICOPTER CONTROL
- Nonlinear control of a twin-lift helicopter configuration p 204 A92-18624 Helicopter air resonance modeling and suppression using active control p 204 A92-18625
- Time-periodic control of a multi-blade helicopter p 204 A92-18626 p 194 N92-13981 Flight research
- HELICOPTER DESIGN
- Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades p 195 N92-14038 [NASA-CR-189018]
- Development and evaluation of a finite element model for a fiber composite helicopter fuselage p 196 N92-15066 [MBB-UD-0584-90-PUB]
- HELICOPTER PERFORMANCE p 194 N92-13981 Flight research
- Operational survey: VFR heliport approaches and departures
- (SCT-91RR-26) p 190 N92-14033 HELICOPTER WAKES
- The application of experimental data to blade wake interaction noise prediction [NASA-CR-189461] p 237 N92-14789
- HELICOPTERS
- Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 Operational survey: VFR heliport approaches and departures
- p 190 N92-14033 [SCT-91RR-26] Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades
- [NASA-CR-189018] p 195 N92-14038 HELIPORTS
- Operational survey: VFR heliport approaches and departures (SCT-918B-26) p 190 N92-14033
- HELMET MOUNTED DISPLAYS
- Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-18611
- HELMETS
- International aviation (selected article) p 170 N92-13992 (AD-A2409871
- HERMES MANNED SPACEPLANE coefficients Computation of aerodynamic OD Hermes-Ariane5 configuration p 184 N92-15040
- Review of the European hypersonic wind tunnel performance and simulation requirements p 209 N92-15043 HIGH ALTITUDE
- Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031
- HIGH ALTITUDE ENVIRONMENTS
- International aviation (selected article) [AD-A240987] p p 170 N92-13992 HIGH DEFINITION TELEVISION
- DARPA high resolution display technologies p 218 A92-19977
- HIGH PRESSURE OXYGEN Test results for rotordynamic coefficients of the SSME HPOTP turbine interstage seal with two swirl brakes
- p 223 N92-14357 Dynamic characteristics and stability analysis of space p 224 N92-14366 shuttle main engine oxygen pump HIGH REYNOLDS NUMBER
- Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7
- p 173 A92-18770 HIGH SPEED Technology needs for high speed rotorcraft (3)
- p 195 N92-14039 [NASA-CB-177592] HIGH TEMPERATURE
- High temperature static strain gage development p 195 N92-14037 (NASA-CR-1890441 HIGH TEMPERATURE GASES
- Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow models p 212 N92-15877 HIGHLY MANEUVERABLE AIRCRAFT
- Roll-performance criteria for high augmented aircraft
- p 204 A92-18623 HISTORIES Evolution of avionic systems architecture, from the
- p 198 N92-14047 1950's to the present Historical perspective on the evolution of avionics standards p 198 N92-14049 HODOGRAPHS
- Extended mapping and characteristics techniques for inverse aerodynamic design p 194 N92-13949 Design of transonic compressor cascades using hodograph method p 202 N92-13973

The research progress on Hodograph Method of aerodynamic design at Tsinghua University p 177 N92-13974

- HOLOGRAPHIC INTERFEROMETRY Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpieces p 219 A92-20771
- HONEYCOMB STRUCTURES Some results on metal and composite patch reinforcement of aluminum honeycomb panel
- p 216 A92-18830 HORIZONTAL FLIGHT
- Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076
- HOT SURFACES Effect of nose shape on three-dimensional stagnation
- region streamlines and heating rates p 171 A92-17822 [AIAA PAPER 91-5032]
- HOVERING Flight operations for higher harmonic control research p 196 N92-15067 [AD-A242478]
- HUMAN FACTORS ENGINEERING Evolution of avionic systems architecture, from the
- p 198 N92-14047 1950's to the present HUMAN PERFORMANCE
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-1 p 187 N92-15054 HUMAN REACTIONS
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-15054 HUMIDITY
- Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin
- p 226 N92-14414 HYDRAULIC CONTROL
- Hydraulic pumps The key to power generation p 215 A92-17348
- HYDRAULIC EQUIPMENT Hydraulic pumps - The key to power generation
  - p 215 A92-17348 Hydraulic actuator system for rotor control p 224 N92-14363
- HYDRODYNAMICS
- A Navier-Stokes solution of Hull-ring wing-thruster p 221 N92-14310 interaction HYDROGEN FUELS
- Hydrogen exhaust gas disposition by afterburning [AIAA PAPER 91-5075] p 200 A92-17848
- An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861
- HYPERSONIC BOUNDARY LAYER Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique
- p 182 N92-14994 HYPERSONIC COMBUSTION
- Effects of unsteady shock impingement on high-speed gaseous mixing [AIAA PAPER 91-5091] p 172 A92-17857
- HYPERSONIC FLIGHT
- Three dimensional hypersonic inlets Low speed performance [AIAA PAPER 91-5021] p 171 A92-17817
- Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic speeds [AIAA PAPER 91-5038]
- n 171 A92-17826 The value of sub-scale flight tests in the development of NASP vehicles
- [AIAA PAPER 91-5048] p 210 A92-17834 Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838
- Hypersonic materials p 212 A92-18002 Control of hypersonic aerodynamic forces with surface p 172 A92-18363 blowing
- Some Aspects of uncertainty in computational fluid p 233 A92-19609 dynamics results
- FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017
- Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027
- Evolution and development of hypersonic configurations 1958-1990 AD-A2427681
- p 197 N92-15069 HYPERSONIC FLOW
- Similarity solutions for supersonic axisymmetric flows p 173 A92-18387 Hypersonic flows over slender circular cones at small angles of attack p 173 A92-19068 Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and lerzfeld p 235 A92-20301

p 176 A92-20737 Turbulent boundary-layer characteristics over a flat-plate/wedge configuration at Mach 6 p 176 A92-20761 Numerical investigations in three-dimensional internal flows [NASA-CR-189467] p 221 N92-14313 Aerothermodynamics for Space Vehicles [ESA-SP-318] p 180 N92-14973 Hypersonic flow past delta wing flow simulated by p 180 N92-14981 Navier-Stokes solutions A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986 Flow and temperature computations for space vehicles using adaptive finite element techniques p 181 N92-14990 Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for p 181 N92-14992 space vehicles Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 Verification and application of the NSFLEX method for hypersonic flow conditions p 182 N92-15005 Hypersonic aerothermodynamic computations using a p 183 N92-15006 point-implicit TVD method Hypersonic viscous shock layer in thermochemical p 183 N92-15014 nonequilibrium Influence of chemical modeling on the solution of p 183 N92-15016 hypersonic shock layers Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025 Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031 Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles p 184 N92-15032 Transitional flows around re-entry bodies p 184 N92-15035 Grid impact on 3D hypersonic flows p 184 N92-15041 Progress with multigrid schemes for hypersonic flow problems [NASA-CR-189579] p 185 N92-15047 Experimental research of the aerodynamics of nozzles and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048 HYPERSONIC HEAT TRANSFER Application of the STAPAT II code to hypersonic vehicle aerothermodynamics [AIAA PAPER 91-5035] p 209 A92-17824 HYPERSONIC INLETS Three dimensional hypersonic inlets - Low speed performance [AIAA PAPER 91-5021] p 171 A92-17817 HYPERSONIC NOZZLES Thrust nozzle test facility at DLR Cologne p 206 A92-17818 [AIAA PAPER 91-5024] HYPERSONIC REENTRY Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at p 181 N92-14987 super- and hypersonic speed Verification and application of the NSELEX method for hypersonic flow conditions p 182 N92-15005 HYPERSONIC SPEED History of EPOS air-launched spaceplane project p 211 N92-14103 Flow over a delta wing at hypersonic speeds p 181 N92-14993 Experimental research of the aerodynamics of nozzles and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048 HYPERSONIC VEHICLES Solving the structures problem for hypersonic vehicles p 209 A92-17349 CFD application to 2D/3D flow fields in Scramjet engine p 170 A92-17501 'Spaceplanes' R&D status of Japan p 209 A92-17802 [AIAA PAPER 91-5002]

- Multidisciplinary modeling and simulation of a generic hypersonic vehicle
- [AIAA PAPER 91-5015] p 232 A92-17813 Application of the STAPAT II code to hypersonic vehicle aerothermodynamics
- p 209 A92-17824 [AIAA PAPER 91-5035] Hypersonic airbreathing propulsion activities for
- Saenger [AIAA PAPER 91-5040] p 200 A92-17828

Aeroservoelastic stabilization techniques for hypersonic flight vehicles

p 203 A92-17839 [AIAA PAPER 91-5056] Dynamics and control of hypersonic vehicles - The integration challenge for the 1990's

p 203 A92-17840 [AIAA PAPER 91-5057] Engineering method for calculating surface pressures and heating rates on vehicles with embedded shocks p 171 A92-17842 [AIAA PAPER 91-5060]

Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17843

Potential hypersonic vehicles applications [AIAA PAPER 91-5086] p 169 p 169 A92-17854

Automated trajectory synthesis for hypersonic vehicles using energy management and variational calculus p 210 A92-19061 techniques

Aerodynamic shape optimization of arbitrary hypersonic chicles p 194 N92-13954 vehicles Numerical investigations in three-dimensional internal

p 221 N92-14313 [NASA-CR-189467]

- Interference heating near fin/body junctions on hypersonic vehicles p 182 N92-14996 Parallelization of a Direct Simulation Monte Carlo
- (DSMC) code for fluid dynamics p 227 N92-15033 Evolution and development of hypersonic configurations 1958-1990

[AD-A242768] p 197 N92-15069 Trim drag reduction concepts for horizontal takeoff

single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076

HYPERSONIC WIND TUNNELS Numerical simulations around models in hypersonic wind p 182 N92-14998 tunnels Infrared measurements of aerodynamic heating in

p 208 N92-15002 hypersonic wind tunnel Review of the European hypersonic wind tunnel

performance and simulation requirements p 209 N92-15043 HYPERSONICS

Numerical investigations in three-dimensional internal flows

[NASA-CR-189467] p 221 N92-14313 HYPERVELOCITY WIND TUNNELS

Drag balance for hypervelocity impulse facilities p 207 A92-18375

# I

### I REAMS

Experimental and theoretical analysis of composite p 216 A92-18377 I-beams with elastic couplings ICE

LEWICE/E: An Euler based ice accretion code p 179 N92-14001 [NASA-TM-105389]

- Results of an Icing test on a NACA 0012 airfoil in the NASA Lewis Icing Research Tunnel p 185 N92-15051 [NASA-TM-105374]
- A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402
- p 229 N92-15402 ICE FORMATION
- LEWICE/E: An Euler based ice accretion code p 179 N92-14001 [NASA-TM-105389] p 179 N92-14001 Results of an Icing test on a NACA 0012 airfoil in the

NASA Lewis Icing Research Tunnel [NASA-TM-105374] p 185 N92-15051

ICE PREVENTION Heat transfer measurements from a smooth NACA 0012 airfoil p 218 A92-20215

ILLUMINATING

Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990 ----

[PB91-910405]	p 18/	N92-14006
IMAGE ANALYSIS		
Image-based ranging and guidant	ce for rote	orcraft

- [NASA-CR-184829] p 191 N92-14036 Analysis of objects in binary images [NASA-CR-4420]
- p 234 N92-14598 IMAGE MOTION COMPENSATION

Numerical calculation of modulation transfer functions for low frequency mechanical vibrations p 235 A92-19982

IMAGE PROCESSING

Numerical calculation of modulation transfer functions for low frequency mechanical vibrations

•	p 235	A92-19982
Reconfigurable Mobile System	<ul> <li>Ground,</li> </ul>	sea and air
applications	p 218	A92-19986
Image-supported navigation f	or testing	instrument
landing systems	p 189	N92-14012

Analysis of objects in binary images p 234 N92-14598 [NASA-CB-4420] IMAGING TECHNIQUES

Analysis of objects in binary images [NASA-CR-4420] p 234 N92-14598

IMPACT DAMAGE

- Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 IMPACT LOADS
- Application of MSC/DYNA to shock and impact problêms in aircraft industry [MBB-UD-0593-91-PUB] p 225 N92-14382
- Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 IMPELLERS
- Study of a new airfoil used in reversible axial fans p 177 N92-13970
- IMPROVEMENT Avionics modernization/upgrades in the late 1990s
- p 199 N92-14055 INCOMPRESSIBLE FLOW
- Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18367
- Incompressible steady aerodynamics using a standard finite element code p 174 A92-20218
- An inverse method with regularity condition for transonic p 177 N92-13969 airfoil design
- INCONEL (TRADEMARK)
- Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799 INERTIAL NAVIGATION
- Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and win measurements from aircraft inertial navigation systems and wind p 188 A92-18172
- Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft
- Testing of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab p 210 N92-14087
- INFORMATION PROCESSING (BIOLOGY)
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-19 p 187 N92 15054 INFORMATION SYSTEMS
- Historical perspective on the evolution of avionics p 198 N92-14049 standards Architecture for Survivable System Processing (ASSP) p 220 N92-14210

INFRARED IMAGERY

- Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique p 182 N92-14994
- INFRARED PHOTOGRAPHY
- Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared p 208 N92-15003 thermography
- INFRARED SCANNERS
- Infrared measurements of aerodynamic heating in p 208 N92-15002 hypersonic wind tunnel INGESTION (ENGINES)
- Study of the engine bird ingestion experience of the Boeing 737 aircraft
- p 187 N92-15053 [DOT/FAA/CT-89/16] INLET FLOW
- Supersonic inlet flow computation
- p 171 A92-17502 LDV measurements and investigation of flow field p 217 A92-19618 through radial turbine guide vanes Numerical investigations in three-dimensional internal
- flows [NASA-CR-189467] p 221 N92-14313 INLET PRESSURE
- Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354
- INSPECTION Enhanced visual technique for rapid inspection of aircraft p 214 A92-17290 structures
- A concept for the revisions of structural inspection p 226 N92-14431 schedules
- INSTRUMENT FLIGHT BULES Rotorcraft low altitude IFR benefit/cost analysis:
- Operations analysis (SCT-90RR-44) p 191 N92-15061
- INSTRUMENT LANDING SYSTEMS New siting techniques for the ILS glide slope
- p 188 A92-17422 Image-supported navigation for testing instrument p 189 N92-14012 landing systems Evaluation of triple simultaneous parallel ILS approaches
- spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034
- Microwave landing system autoland system analysis p 191 N92-15060 [NASA-CR-189551]

# INTAKE SYSTEMS

A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics

JET AIRCRAFT NOISE

- p 179 N92-13998 [NASA-TM-105321] INTERACTIONAL AERODYNAMICS
- Confined normal-shock/turbulent-boundary-layer interaction followed by an adverse pressure gradient
- p 172 A92-18365 Helicopter air resonance modeling and suppression sing active control p 204 A92-18625 using active control
- CFD helps the Air Force fly right p 169 A92-20146 Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction
- p 193 A92-20202 Three-dimensional thermal structural analysis of a swept
- cowl leading edge subjected to skewed shock-shock interference heating p 174 A92-20306 Formation of shocks within axisymmetric nozzles
- p 176 A92-20760 Wind tunnel investigation of vortex flows on F/A-18
- configuration at subsonic through transonic speed [NASA-TP-3111] p 179 N92-14968
- Simulation requirements for RCS plume: Flowfield interaction modelling on a winged reentry vehicle p 181 N92-14985
- Experimental investigation of transverse jet effects related to hypersonic space vehicles
- p 182 N92-14995 INTERMETALLICS
- Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799 INTERNATIONAL COOPERATION
- Soviet CFD An international perspective
- p 233 A92-20150 INTERPOLATION p 177 N92-13979
- Computational fluid dynamics p INTERPROCESSOR COMMUNICATION Putting ten pounds of avionics in a one pound package
- (Can we do it again?) [AIAA PAPER 91-3766] p 197 A92-17628
- INVENTORY CONTROLS
- Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description
- JAD-A2425981 p 170 N92-14966 INVERSIONS

INVISCID FLOW

Analytical/numerical matching and periodic inversion: Two advances in free wake analysis p 178 N92-13994

Analysis of spiraling vortical flows around slender delta

Inviscid drag prediction for transonic transport wings

Engineering calculations of three-dimensional inviscid

A multiblock flow solver for inviscid hypersonic flows

Hypersonic inviscid flow field simulations around reentry

A turbulence model for iced airfoils and its validation

Aerodynamic aircraft design methods and their notable

J

Aerodynamic aircraft design methods and their notable

Implementation and usage of the RJ program Data

Ferrundi Company supplies 4500 model head up display

Aeroacoustics of flight vehicles: Theory and practice.

Quiet aircraft design and operational characteristics

Direct computation of turbulence and noise

applications: Survey of the activity in Japan

applications: Survey of the activity in Japan

'Spaceplanes' R&D status of Japan

Acquisition System Ground Station

devices to India's MIG-21 aircraft

Nonequilibrium hypersonic inviscid steady flows

p 169 A92-20146

p 174 A92-20212

p 175 A92-20378

p 176 A92-20737

p 181 N92-14986

p 184 N92-15025

p 186 N92-15052

p 193 N92-13930

p 193 N92 13930

p 209 A92-17802

p 210 A92-19257

p 229 N92-15367

p 235 N92-14779

p 236 N92-14784

p 236 N92-14787

p 236 N92-14788

A-15

wings moving in an inviscid medium p 173 A92-18900

CFD helps the Air Force fly right

using a full-potential method

vehicles with flap deflection

hypersonic flowfields

[NASA-TM-105373]

JAPANESE SPACECRAFT

[AIAA PAPER 91-5002]

JET AIRCRAFT

[AD-A241044]

JET AIRCRAFT NOISE

[NASA-CR-187616]

Volume 2: Noise control [NASA-RP-1258-VOL-2]

Jet noise suppression

ITERATION

JAPAN

# JET CONTROL

# JET CONTROL

Experimental investigation of transverse jet effects related to hypersonic space vehicles

p 182 N92-14995

Simulation of radar clutter and jet engine modulation using digital quadrature modulator p 216 A92-19091 Recent progress in inverse methods in France p 201 N92-13938

A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics

[NASA-TM-105321] p 179 N92-13998 Stability of intershaft squeeze film dampers p 222 N92-14351

### JET EXHAUST

- Direct computation of turbulence and noise [NASA-CR-187616] p 236 N92-14788 JET FLOW
- Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18367 Experimental investigation of transverse jet effects
- related to hypersonic space vehicles p 182 N92-14995

### JET IMPINGEMENT

- Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic speeds
- [AIAA PAPER 91-5038]
   p 171
   A92-17826

   Effects of unsteady shock impingement on high-speed gaseous mixing

   [AIAA PAPER 91-5091]
   p 172
   A92-17857
- [AIAA PAPER 91-5091] p 172 A92-17857 JET MIXING FLOW
- Effects of unsteady shock impingement on high-speed gaseous mixing
- [AIAA PAPER 91-5091] p 172 A92-17857 Jet noise suppression p 236 N92-14784 Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence
- model [NASA-TM-105338] p 237 N92-14795 JET THRUST
- Experimental investigation of transverse jet effects related to hypersonic space vehicles
- p 182 N92-14995 JOINTS (JUNCTIONS)
- Current stabilizing of fastened composite joints to improve non-sparking lightning current performance p 213 A92-20130

# JOULE-THOMSON EFFECT

- Multicomponent gas sorption Joule-Thomson refrigeration [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
- JOURNAL BEARINGS Determination of rotordynamic coefficients for labyrinth
- seals and application to rotordynamic design calculations p 223 N92-14360 Annular seals of high energy centrifugal pumps:
- Presentation of full scale measurement p 224 N92-14362 Effect of eccentricity on the static and dynamic
- performance of a turbulent hybrid bearing p 225 N92-14373

# Κ

- K-EPSILON TURBULENCE MODEL
- Explicit Navier-Stokes computation of cascade flows using the k-epsilon turbulence model p 175 A92-20727
- Evaluation of a bounded high-resolution scheme for combustor flow computations p 201 A92-20734 Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model
- [NASA-TM-105338] p 237 N92-14795 KALMAN FILTERS
- An alternative derivation of the modified gain function of Song and Speyer p 232 A92-18464 Autonomously aided strapdown attitude reference
- system p 204 A92-18610 Formulation of a strategy for monitoring control integrity in critical digital control systems
- [NASA-TM-104158] p 206 N92-15075 KNOWLEDGE BASES (ARTIFICIAL INTELLIGENCE)
- Radar troubleshooting assistant expert system [AIAA PAPER 91-3764] p 231 A92-17626 Industrial code development p 227 N92-15083 KNOWLEDGE REPRESENTATION
- Knowledge maintenance in an evolving system using a deep structure representation
- (AIAA PAPER 91-3941) p 231 A92-17605

KUTTA-JOUKOWSKI CONDITION

- Analysis and design of planar and non-planar wings for induced drag minimization
- [NASA-CR-189509] p 179 N92-13999

# L

### LABYRINTH SEALS

- Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354 Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356
- Determination of rotordynamic coefficients for labyrinth seals and application to rotordynamic design calculations p 223 N92-14360
- Development of a CFD code for analysis of fluid dynamic forces in seals p 228 N92-15084 LAMINAR BOUNDARY LAYER
- Effect of suction on the stability of supersonic boundary layers. 1 - Second-mode waves. II - First-mode waves p 174 A92-19611

### LAMINAR FLOW

- A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition
- [AIAA PAPER 91-5026] p 207 A92-17819 Effect of nose shape on three-dimensional stagnation
- region streamlines and heating rates [AIAA PAPER 91-5032] p 171 A92-17822
- LAMINAR MIXING
- Supersonic combustion studies p 211 N92-14984
- The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044
- Bulging of fatigue cracks in a pressurized aircraft fuselage
- [LR-655] p 196 N92-14045 Fatigue of repaired composite structures
- p 214 N92-14411 Development and evaluation of a finite element model for a fiber composite helicopter fuselage
- [MBB-UD-0584-90-PUB] p 196 N92-15066 Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 LANDING AIDS
  - Infra-red offers new landing aid competition
- p 198 A92-18937 Neural network and fuzzy logic technology for naval flight
- control [AD-A242650] p 206 N92-15074
- LANDING GEAR Nonlinear landing gear behavior at touchdown
  - p 192 A92-19606 Aircraft landing-induced tire spinup
- p 193 A92-20209 Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program
- and test implantation [CEAT-S8-6551-PARTIEL-1-PT-] p 195 N92-14043
- LANDING SITES
- New siting techniques for the ILS glide slope p 188 A92-17422 LANDING SPEED
- Aircraft landing-induced tire spinup
- p 193 A92-20209
- LDV measurements and investigation of flow field through radial turbine guide vanes p 217 A92-19618 LASER GYROSCOPES
- Retrofit provides navigation enhancement for older aircraft p 198 A92-20025 LATERAL CONTROL
- Analysis of aircraft performance during lateral maneuvering for microburst avoidance
- p 205 A92-20207
- Model oscillations at high angle of attack in a low speed wind tunnel test
- [IAF PAPER ST-91-001] p 175 A92-20649 LEADING EDGES
- Three-dimensional thermal structural analysis of a swept cowl leading edge subjected to skewed shock-shock interference heating p 174 A92-20306 Supercritical blade design on stream surfaces of
- revolution with an inverse method p 220 N92-13950 Definition of the unsteady vortex flow over a wing/body configuration [NASA-CR-180083] p 178 N92-13995
- Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed
- [NASA-TP-3111] p 179 N92-14968 Numerical simulation of swept-wing flows [NASA-CR-189457] p 180 N92-14969

LEAKAGE Army research concerns in engine	sealing
Seal development activities at Allis	p 228 N92-15089
	p 228 N92-15093
seal area based on the thermal	analysis and flow
models	p 212 N92-15877
Project of an adaptive multiaxial au	topilot with learning
pilot control [FTN-92-90592]	p 205 N92-15072
LIFE (DURABILITY)	p 200 1102 10012
LIFE CYCLE COSTS	p 228 N92-15094
Aviation Diagnostics And Maintenar	nce (ADAM) system
description	and functional
[AD-A242598] LIFT	p 170 N92-14966
A lifting line theory for superson	ic flow applications
A unified viscous theory of lift and dra	ag of 2-D thin airfoils
and 3-D thin wings [NASA-CR-4414]	p 178 N92-13997
LIFT AUGMENTATION	,
Nonlinear control of a twin-lift nelice	p 204 A92-18624
LIFT DRAG RATIO On a clobal aerodynamic optimizatio	n of a civil transport
aircraft	p 193 N92-13931
Measurements of the flow around	a lifting-wing/body
junction Navier-Stokes analysis of turbulent	p 175 A92-20726
wake for two-dimensional lifting bodie	s
Evolution and development of hyper	p 221 N92-14309 sonic configurations
1958-1990	- 107 N02 15060
LIGHT AIRCRAFT	p 197 1192-13009
Fair weather convection and ligh	t aircraft accidents p 186 A92-20651
LIGHT GAS GUNS	
LIGHT SOURCES	p 220 N92-13985
The acoustic flashlight	n 239 N92-15938
LIGHTNING	p 200 1102-10000
Analysis technique for lightning att aircraft	achment zoning of p 186 A92-20126
Nonlinear triggered lightning mode	is for use in finite
difference calculations Analysis and modeling of lightning st	p 230 A92-20128 trikes to the F106B.
CVF580, and C160 aircraft	p 186 A92-20129
improve non-sparking lightning current	composite joints to
	p 213 A92-20130
proposed specification	s for aircraft: A
[RAE-TM-FS(F)-632-REV-ISSUE]	p 187 N92-14007
Whole aircraft lightning indirect effect	ts evaluation using
low level injection techniques The use of finite difference electron	p 192 A92-20134
the design and verification of modern	aircraft
LINEAR PROGRAMMING	p 192 A92-20136
A low-altitude breakthrough system	using optimal path
LINEAR QUADRATIC GAUSSIAN CON	TROL
Parameter insensitive control util methods for flutter suppression in a	lizing eigenspace
	p 204 A92-18615
Application of stochastic robustness systems	p 204 A92-18620
Structure/control design synthes	sis of active flutter
suppression system by goal programm	nng p 204 A92-18621
LINEAR QUADRATIC REGULATOR	acquetic / str. stur-
models with piezoceramic actuators	acousuer structure
[NASA-CR-189578]	p 234 N92-15658
High-temperature combustor and sea	al for a water piston
propulsor [AD-A242493]	p 229 N92-15385
of a flexible rotor supported on squee:	o distable response ze film dampers
The employee of a sub-dation of	p 222 N92 14350
The application of a cylindrical-sph	ierical floating ring

p 224 N92-14371

turbogenerators

Effect	of	eccentricity	on	the	static	and	dynamic
performa	nce	of a turbule	nt hy	brid b	earing		
					D 22	5 N	92-14373

### LOAD TESTS

Experimental and theoretical analysis of composite p 216 A92-18377 1-beams with elastic couplings Multiaxial load spectra in a cooled gas turbine blade p 201 A92-19696 under in-service conditions Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817 LOADING MOMENTS

### Short time force measurement system

p 208 N92-15001

# LOADS (FORCES)

F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation p 206 N92-15073 [AD-A2426371 p 227 N92-15083 Industrial code development LOGIC DESIGN

Neural network and fuzzy lo	ogic technology fo	or naval flight
control		
[AD-A242650]	p 206	N92-15074
LOW ALTITUDE		
• • • • • • • • • • • • • • • • • • •	4	

A multidimensional terrain model for low altitude tracking p 205 A92-19107 scenarios Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis [SCT-90RR-44] p 191 N92-15061

LOW ASPECT RATIO WINGS The effects of winglets on low aspect ratio wings at supersonic Mach numbers [NASA-CR-4407] p 178 N92-13996 LOW SPEED WIND TUNNELS Model oscillations at high angle of attack in a low speed wind tunnel test

p 175 A92-20649 [JAF PAPER ST-91-001] LUBRICATING OILS Filter debris analysis: A concrete approach to wear diagnosis [DREP-TM-88-20] p 222 N92-14345

LUBRICATION Programs at Wright-Patterson Air Force Base p 228 N92-15092 Tribology needs for future space and aeronautical [NASA-TM-104525] p 214 N92-15191

# Μ

### MACH CONES

Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7 p 173 A92-18770

MACH NUMBER

Large chord turbine cascade testing at engine Mach p 173 A92-18771 and Reynolds number

Wedge-induced turbulent boundary-layer separation on a roughened surface at Mach 6.0 p 175 A92-20379 The effects of winglets on low aspect ratio wings at

supersonic Mach numbers [NASA-CR-4407] p 178 N92-13996

Numerical investigations in three-dimensional internal flows [NASA-CR-189467] p 221 N92-14313

MACHINERY Determination of rotordynamic coefficients for labyrinth

and application to rotordynamic seals desian MAGNETIC FIELD CONFIGURATIONS Nondestructive

Nondestructive testing developments in the aircraft industry MAGNETIC LEVITATION VEHICLES p 214 A92-17288

New Ways: Tiltrotor aircraft and magnetically levitated vohiclas

- [OTA-SET-507] p 238 N92-14933 MAGNETIZATION
- Nondestructive testing developments in the aircraft industry p 214 A92-17288
- MAGNETOMETERS Autonomously aided strapdown attitude reference p 204 A92-18610 evetem

MAGNUS EFFECT Transonic Navier-Stokes computations for a spinning

- body of revolution [AD-A241015] p 180 N92-14972 MAINTENANCE
- Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description
- (AD-A242598) p 170 N92-14966 MAN MACHINE SYSTEMS

An intelligent pilot vehicle interface for a day/night adverse weather pilotage system (D/NAPS) p 197 A92-17596 [AIAA PAPER 91-3729]

Sensor fusion for synthetic vision p 197 A92-17597 [AIAA PAPER 91-3730] MAN-COMPUTER INTERFACE

An intelligent pilot vehicle interface for a day/night adverse weather pilotage system (D/NAPS)

[AIAA PAPER 91-3729] p 197 A92-17596 Evolution of avionic systems architecture, from the p 198 N92-14047 1950's to the present MANUFACTURING

International aviation (selected article) p 170 N92-13991 [AD-A240986] MAPPING

Extended mapping and characteristics techniques for p 194 N92-13949 inverse aerodynamic design MARINE TRANSPORTATION

Electronic systems in transportation

[TP-9983] p 189 N92-14009 MASSIVELY PARALLEL PROCESSORS

Optical computing at NASA Arnes Research Center [AIAA PAPER 91-3779] p 231 A92-17637 p 231 A92-17637 MATHEMATICAL MODELS

- Extended mapping and characteristics techniques for p 194 N92-13949 inverse aerodynamic design MLS system error model identification and synthesis
- p 189 N92-14015 Theoretical models for duct acoustic propagation and p 236 N92-14782 radiation

Simulation requirements for RCS plume: Flowfield interaction modelling on a winged reentry vehicle p 181 N92-14985

Hypersonic viscous shock layer in thermochemical p 183 N92-15014 nonequilibrium

Influence of chemical modeling on the solution of p 183 N92-15016 hypersonic shock layers

Flutter suppression via piezoelectric actuation [NASA-TM-104120] p 197 N92-15070 Approximation methods for control of acoustic/structure

models with piezoceramic actuators p 234 N92-15658 [NASA-CR-189578] MAXWELL EQUATION

Nonlinear triggered lightning models for use in finite difference calculations p 230 A92-20128

### MECHANICAL MEASUREMENT Short time force measurement system

p 208 N92-15001 **MECHANICAL PROPERTIES** 

- Inertia-friction welding of an advanced rapidly solidified titanium allov p 212 A92-18898 Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpieces
- p 219 A92-20771 Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program and test implantation
- p 195 N92-14043 [CEAT-S8-6551-PARTIEL-1-PT-] MECHANICAL SHOCK
- Application of MSC/DYNA to shock and impact problems in aircraft industry
- p 225 N92-14382 [MBB-UD-0593-91-PUB]

MESOSCALE PHENOMENA Mesoscale dynamics of cold fronts - Structures described by dropsoundings in Fronts 87

p 230 A92-18902 METAL FATIGUE

- Short fatigue crack growth from blunt notches in an p 212 A92-19760 aero-engine alloy Crack initiation and the short-to-long crack growth transition in a Ni-base superalloy p 213 A92-19767 High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796 Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799
- Low cycle fatique of cast nickel base turbine rotors p 226 N92-14405
- METAL MATRIX COMPOSITES p 212 A92-18002 Hypersonic materials Current stabilizing of fastened composite joints to improve non-sparking lightning current performance

p 213 A92-20130 METAL POWDER

- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424
- **METEOROLOGICAL PARAMETERS** Fair weather convection and light aircraft accidents [IAF PAPER ST-91-004] p 186 A92-20651 p 186 A92-20651

METHOD OF CHARACTERISTICS Extended mapping and characteristics techniques for

inverse aerodynamic design p 194 N92-13949 **MICROBURSTS (METEOROLOGY)** 

Analysis of aircraft performance during lateral maneuvering for microburst avoidance p 205 A92-20207

# MULTISENSOR APPLICATIONS

м

M

м

м

М

м

CROCOMPUTERS		
The NASA Langley Research Cent	er 0.3-me	ter transonic
[NASA-CR-189556]	p 209	N92-15077
CROPHONES	•	
The acoustic flashlight		
[MBB-2-0359-90-P0B]	p 239	N92-15938
Protective coatings of thermal bar	rier type	
riolective coatings of thermal bai	p 214	A92-20349
ICROWAVE LANDING SYSTEMS		
Electronic systems in transportation	on	
[17-9983]	p 189	N92-14009
MLS system error model identifica	ation and n 189	Synthesis
DMF growth elements and their u	se with N	115
	p 189	N92-14018
A strategy for exploiting the full po	tential of	MLS based
terminal procedures in Canada	p 190	N92-14025
The problem of multiple solutions is	n area na	vigation and
landing system	with the	microwave
[AD-A242757]	p 191	N92-15058
Microwave landing system auto	and syst	tem analysis
[NASA-CR-189551]	p 191	N92-15060
Aircraft accident/incident sum	mary re	nort <sup>.</sup> Midair
collision involving Lycoming Air Sei	vices Pip	per Aerostar
PA-60 and Sun Company Aviation I	Departme	ent Bell 412,
(PR91-910407)	n 187	N92-15055
ILITARY OPERATIONS	p 107	102-10000
Reducing environmental noise in	pacts: A	USAREUR
noise management program handbo	iok	NO0 14701
	p 237	N92-14791
Avionics technology beyond 2000		
	p 200	N92-14058
INIMUM DRAG		
induced drag minimization	non-plar	ar wings for
INASA CD 1005001	- 470	100 40000
[INAGV-CU-199209]	p1/9	N92-13999
ISALIGNMENT	p 1/9	N92-13999
INASA-CR 189509] ISALIGNMENT The effects of manufacturing tolera	p 179 Inces on	the vibration
ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemb	p 179 Inces on blies p 222	N92-13999 the vibration N92-14349
INAJACH 183009 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL	p 179 Inces on blies p 222	N92-13999 the vibration N92-14349
INASA-Chr (18500) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through	p 179 Inces on Dies p 222 hardware	N92-13999 the vibration N92-14349 e-in-the-loop
INASA-Chr Ibsolog ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODUI ARITY	p 179 ances on blies p 222 hardware p 204	N92-13999 the vibration N92-14349 e-in-the-loop A92-19103
INASA-Chromotogy ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe	p 179 ances on blies p 222 hardware p 204	N92-13999 the vibration N92-14349 9-in-the-loop A92-19103
INASACH IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe	p 179 Inces on Dies p 222 hardware p 204 p 199	N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050
INASACH IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO	p 179 ances on blies p 222 hardware p 204 p 199 N	N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050
INASA-Che Tastologi ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati	p 179 ances on obles p 222 hardward p 204 p 199 N on transf ons	N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions
INASACH IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati	p 179 ances on i blies p 222 hardward p 204 p 199 N on transf ons p 235	N92-13999 the vibration N92-14349 a-in-the-loop A92-19103 N92-14050 er functions A92-19982
INSA-CH 183001 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS	p 179 ances on i blies p 222 hardware p 204 p 199 N on transf ons p 235	N92-13999 the vibration N92-14349 a-in-the-loop A92-19103 N92-14050 fer functions A92-19982
INASA-Chr Ibsolog ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je ueing digital quadrative modulator	p 179 ances on blies p 222 hardware p 204 p 199 N on transf ons p 235 et engine	N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation
INASA-Chr IB3009 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES	p 179 ances on blies p 222 hardware p 204 p 199 N on transf ons p 235 et engine p 216	N92-13999 the vibration N92-14349 a-in-the-loop A92-19103 N92-14050 der functions A92-19982 modulation A92-19091
INASA-Cherasology ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula	p 179 ances on olies p 222 hardware p 204 p 199 N on transf ons p 235 et engine p 216 r avionic:	N92-13999 the vibration N92-14349 a-in-the-loop A92-19103 N92-14050 ter functions A92-19982 modulation A92-19091 s conflicting
INASA-Charaboog ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements	p 179 ances on olies p 222 hardware p 204 p 199 N on transf ons p 235 et engine p 216 r avionic: p 199	the vibration N92-13999 the vibration N92-14349 a-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19091 s conflicting N92-14051
INASA-Charaboog ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS	p 179 ances on olies p 222 hardward p 204 p 199 N on transf ons p 235 et engine p 216 r avionic: p 199	the vibration N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19091 s conflicting N92-14051
INASACH IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16]	p 179 ances on olies p 222 hardward p 204 p 199 N on transf ons p 235 at engine p 216 r avionic: p 199 n study p 202	the vibration N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19991 s conflicting N92-14051 N92-14064
INANCH IBJUE ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD	p 179 ances on olies p 222 hardware p 204 p 199 N on transf ons p 235 at engine p 216 r avionic: p 199 n study p 202	the vibration N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19091 s conflicting N92-14064
INARCH 185001 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air	p 179 ances on blies p 222 hardware p 204 p 199 N on transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-born	the vibration N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19981 s conflicting N92-14051 N92-14064
INARCH 183007 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONTICAS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simul	p 179 ances on olies p 222 hardware p 204 p 199 N on transf ons p 235 at engine p 216 r avionic: p 199 n study p 202 craft-borr p 186	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14064           en ambient           A92-20127
INARACIN IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics	p 179 ances on olies p 222 hardware p 204 p 199 N on transf ons p 216 r avionic: p 199 n study p 202 craft-borr p 186 hation M p 227	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14054           ne ambient           A92-20127           onte Carlo           N92-15033
INARCH 183001 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry	p 179 ances on olies p 222 hardware p 204 p 199 N oon transf ons p 216 r avionic: p 199 n study p 202 craft-borr p 186 ilation M p 227	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14064           ne ambient           A92-20127           onte Carlo           N92-15033
INARCH IBSUE) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an airr electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry	p 179 ances on olies p 222 hardware p 204 p 199 N oon transf ons p 216 r avionic: p 199 n study p 202 craft-borr p 186 lation M p 227 bodies p 184	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14054           e ambient           A92-20127           onte Carlo           N92-15033
INARCH IBSUBJ ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY	p 179 ances on olies p 222 hardware p 204 p 199 N oon transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 ilation M p 227 bodies p 184 rack growth	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19082           modulation           A92-19091           s conflicting           N92-14051           N92-14051           N92-14051           N92-14054           ne ambient           A92-20127           ionte Carlo           N92-15033           N92-15035           thin squared
INARACIN IBSUB) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULARITY Avionics standardization in Europe ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ON the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small cr airframe alloys	p 179 ances on olies p 222 hardward p 204 p 199 N on transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 ilation M p 227 bodies p 184 rack grow p 212	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-15033           N92-15035           th in several           A92-19754
INARACIN ISSUE) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONT the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small cr airframe alloys OTION SICKNESS	p 179 ances on obies p 222 hardward p 204 p 199 No on transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 hation M p 227 bodies p 186 rack grow p 212	the vibration N92-13999 the vibration N92-14349 e-in-the-loop A92-19103 N92-14050 er functions A92-19982 modulation A92-19982 s conflicting N92-14051 N92-14051 N92-14051 N92-14064 A92-20127 Ionte Carlo N92-15033 N92-15035 th in several A92-19754
INARCH IBSUD) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small cal airframe alloys OTION SICKNESS Flight simulation	p 179 ances on obies p 222 hardward p 204 p 199 on transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 hation M p 227 bodies p 184 rack grow p 212 p 207	N92-13999           the vibration           N92-14349           e-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14053           N92-15033           N92-15035           thin several           A92-19754           N92-13982
INARCH 185001 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an air electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small co airframe alloys OTION SIMULATION Elicht simulation OTION SIMULATION	p 179 p 179 ances on olies p 222 hardward p 204 a p 199 N on transf ons p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 lation M p 227 bodies p 184 rack grow p 212 p 207 p 207 p 207	N92-13999           the vibration           N92-14349           e-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-15033           N92-15035           th in several           A92-19754           N92-13982           N92-12982
INKJACH IBJUEJ SALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt <b>ISSILE CONTROL</b> Enhanced autopilot design through simulation <b>ODULATION TRANSFER FUNCTIO</b> Numerical calculation of modulati for low frequency mechanical vibrati <b>ODULATION TRANSFER FUNCTIO</b> Numerical calculation of modulati for low frequency mechanical vibrati <b>ODULATORS</b> Simulation of radar clutter and je using digital quadrature modulator <b>ODULES</b> Mixed approach towards modula requirements <b>ONITORS</b> Turbine engine diagnostics system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry <b>ORPHOLOGY</b> Fatigue crack initiation and small cr airframe alloys <b>OTION SICKNESS</b> Flight simulation <b>OTION SIMULATION</b> Flight simulation <b>ULITIGRID METHODS</b>	p 179 ances on olies p 222 hardware p 204 p 199 N on transfors p 216 r avionic: p 199 n study p 202 craft-borr p 186 rlation M p 227 bodies p 184 rack grow p 212 p 207	N92-13999           the vibration           N92-14349           >-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           -modulation           A92-19091           s conflicting           N92-14051           N92-14054           -ne ambient           A92-20127           onte Carlo           N92-15033           N92-15035           thin several           A92-19754           N92-13982           N92-13982
INSALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONTIORS Turbine engine diagnostics system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small cr airframe alloys OTION SICKNESS Flight simulation OTION SIMULATION Flight simulation ULTIGRID METHODS Inverse airfoil design procedure	p 179 ances on olies p 222 hardware p 204 p 199 N on transfors p 216 r avionic: p 199 n study p 202 craft-borr p 186 hation M p 227 bodies p 184 rack grow p 212 p 207 re using	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14054           no conflicting           N92-14064           ne ambient           A92-20127           onte Carlo           N92-15033           N92-15035           th in several           A92-13982           N92-13982           a multigrid
INARACIN ISSUE) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an airr electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small ca airframe alloys OTION SICKNESS Flight simulation OLINGRID METHODS Inverse airfoil design procedur Navier-Stokes method	p 179 p 179 ances on olies p 222 hardware p 204 p 199 N on transfors p 235 at engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 lation M p 222 craft-borr p 189 n study p 202 craft-borr p 184 rack grow p 212 p 207 re using p 193	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14054           er ambient           A92-20127           onte Carlo           N92-15033           N92-15035           th in several           A92-13982           a multigrid           N92-13982           a multigrid
INARACIN ISSUE) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an airr electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small ca airframe alloys OTION SICKNESS Flight simulation ULTIGRID METHODS Inverse airfoil design procedur Navier-Stokes method Progress with multigrid schemes probleme	p 179 p 179 ances on olies p 222 hardware p 204 p 199 No on transfors p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 lation M p 227 bodies p 184 rack grow p 212 p 207 re using p 193 for hype	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14054           ne ambient           A92-19033           N92-14064           ne ambient           A92-15033           N92-15035           th in several           A92-13982           N92-13982           a multigrid           N92-13932           rsonic flow
INARACIN ISSUE) ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULETORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an airr electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small ca airframe alloys OTION SIGULATION Flight simulation OTION SIMULATION Flight simulation ULTIGRID METHODS Inverse airfoil design procedur Navier-Stokes method Progress with multigrid schemes problems	p 179 p 179 ances on blies p 222 hardware p 204 p 199 N on transfors p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 lation M p 227 bodies p 184 rack grow p 207 re using p 193 for hype p 185	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19982           modulation           A92-19091           s conflicting           N92-14051           N92-14054           e ambient           A92-20127           onte Carlo           N92-15033           N92-15035           thin several           A92-13982           a multigrid           N92-13982           a multigrid           N92-13982           N92-13982           N92-13982           N92-13982           N92-13982           Amultigrid           N92-13982
INARCH 199001 ISALIGNMENT The effects of manufacturing tolera of aero-engine rotor-damper assemt ISSILE CONTROL Enhanced autopilot design through simulation ODULATION TRANSFER FUNCTIO Numerical calculation of modulati for low frequency mechanical vibrati ODULATORS Simulation of radar clutter and je using digital quadrature modulator ODULES Mixed approach towards modula requirements ONITORS Turbine engine diagnostics system [DOT/FAA/CT-91/16] ONTE CARLO METHOD On the accuracy of an airr electric-field measuring system Parallelization of a Direct Simu (DSMC) code for fluid dynamics Transitional flows around re-entry ORPHOLOGY Fatigue crack initiation and small co airframe aloys OTION SICKNESS Flight simulation ULTIGRID METHODS Inverse airfoil design procedur Navier-Stokes method Progress with multigrid schemes problems [NASA-CR-189579] ULTIPLEXING	p 179 ances on olies p 222 hardware p 204 p 199 No on transfors p 235 et engine p 216 r avionic: p 199 n study p 202 craft-borr p 186 ilation M p 227 bodies p 184 rack grow p 212 p 207 p 207 re using p 193 for hype p 185	N92-13999           the vibration           N92-14349           a-in-the-loop           A92-19103           N92-14050           er functions           A92-19082           modulation           A92-19091           s conflicting           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-14051           N92-15033           N92-15035           th in several           A92-19754           N92-13982           N92-13982           a multigrid           N92-13047

p 188 A92-19211 MULTISENSOR APPLICATIONS

Sensor fusion for synthetic vision

[AIAA PAPER 91-3730] p 197 A92-17597 Ν

# NACELLES

An inverse method for the aerodynamic design of three-dimensional aircraft engine nacelles p 194 N92-13958

NAP-OF-THE-EARTH NAVIGATION

- Image-based ranging and guidance for rotorcraft [NASA-CR-184829] p 191 N92-14036 NASA PROGRAMS
- National Aeronautics and Space Administration p 238 N92-14923
- National Aeronautics and Space Administration p 238 N92-14925
- p 238 N92-14927 Branch resource National Aeronautics and Space Administration Structural. Dynamics
- accomplishments for FY 1990 p 230 N92-15406 [NASA-TM-103747]
- National Aeronautics and Space Administration research and development p 238 N92-15937 NASTRAN
- Static aeroelastic analysis for generic configuration p 174 A92-20201 wing Incompressible steady aerodynamics using a standard
- finite element code A92-20218 p 174 NATIONAL AEROSPACE PLANE PROGRAM
- Conducting the NASP ground test program [AIAA PAPER 91-5029] p 209 p 209 A92-17820
- A configuration development strategy for the NASP p 210 A92-17830 [AIAA PAPER 91-5044] The value of sub-scale flight tests in the development of NASP vehicles
- p 210 A92-17834 (AIAA PAPER 91-5048) Operational design factors for NASP derived vehicles
- [AIAA PAPER 91-5081] p 210 A92-17851 Rapid near-optimal aerospace plane trajectory generation and guidance
- p 205 N92-14066 NASA-CB-1894691 NATIONAL AIRSPACE SYSTEM
- Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report
- [DOT/FAA/CT-TN91/50] p 221 N92-14270 Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- [SCT-9088-44] p 191 N92-15061 NAVIER-STOKES EQUATION
- calculation procedure Eigenvalue for an Euler/Navier-Stokes solver with application to flows over p 170 A92-17429 airfoils
- Flow separation patterns over an F-14A aircraft wing p 174 A92-20205 Explicit Navier-Stokes computation of cascade flows
- using the k-epsilon turbulence model p 175 A92-20727
- Asymmetric separated flows at supersonic speeds p 176 A92-20742
- Inverse airfoil design procedure using a multigrid Navier-Stokes method p 193 N92-13932 Analysis of an advanced ducted propeller subsonic
- inlet [NASA-TM-105393] p 179 N92-14002 Navier-Stokes analysis of turbulent boundary layer and
- wake for two-dimensional lifting bodies p 221 N92-14309
- A Navier-Stokes solution of Hull-ring wing-thruster p 221 N92-14310 interaction Transonic Navier-Stokes computations for a spinning
- body of revolution p 180 N92-14972 [AD-A241015]
- Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles p 211 N92-14977
- Hypersonic flow past delta wing flow simulated by p 180 N92-14981 Navier-Stokes solutions
- Flow and temperature computations for space vehicles using adaptive finite element techniques p 181 N92-14990
- SIMOUN and Scirocco wind tunnel nozzle viscous flow p 208 N92-14999 study
- Verification and application of the NSFLEX method for hypersonic flow conditions p 182 N92-15005
- Hypersonic aerothermodynamic computations using a point-implicit TVD method p 183 N92-15006 Viscous shock-layer equations for the calculation of
- p 183 N92-15008 reentry aerothermodynamics Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with mono-
- and multi-blocks including real gas effects, part 1 p 227 N92-15030 Seal development activities at Allison Turbine Division
- p 228 N92-15093

# NAVIGATION

- Knowledge based system applications for guidance and contro
- (AGARD-AR-2841 p 205 N92-14065 Artificial Neural Network Approaches in Guidance and Control
- [AGARD-LS-179] p 234 N92-14673 Introduction to neural computing and categories of neural network applications to guidance, navigation and
- p 234 N92-14674 control NAVIGATION AIDS Navsat - A civil complement to GPS and Glonass
- [IAF PAPER 91-490] p 188 A92-18505 NAVIGATION SATELLITES
- Navsat A civil complement to GPS and Glonass
- [IAF PAPER 91-490] p 188 A92-18505 NETHERLANDS
- Review of aerodynamic design in the Netherlands p 193 N92-13929 NETWORK CONTROL
- Neural network and fuzzy logic technology for naval flight control
- (AD-A2426501 p 206 N92-15074 NEURAL NETS
- The application of neural networks to drone control p 205 A92-19273 Artificial Neural Network Approaches in Guidance and
- Control [AGARD-LS-179] p 234 N92-14673
- Introduction to neural computing and categories of neural network applications to guidance, navigation and p 234 N92-14674 control Processing complexity of two approaches to object
- p 234 N92-14677 detection and recognition Neural network and fuzzy logic technology for naval flight control
- [AD-A242650] p 206 N92-15074 NEWS MEDIA
- Aerobureau Strategic television airmobile reports via satellite p 218 A92-19988
- NEWTON METHODS
- Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736 NICKEL ALLOYS
- Short fatigue crack growth from blunt notches in an aero-engine alloy p 212 A92-19760 High temperature low cycle fatigue of single crystal nicke
- p 213 A92-19796 base superallovs Low cycle fatigue of cast nickel base turbine rotors
  - p 226 N92-14405 Probabilistic lifing approach for aero engine disks made
- of powder nickel base alloys containing ceramic defects p 226 N92-14424 NITROGEN
- Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and p 235 A92-20301
- Herzfeld NOISE MEASUREMENT
- Flyover-noise measurement and prediction p 236 N92-14786
- NOISE POLLUTION
- Flyover-noise measurement and prediction p 236 N92-14786 Reducing environmental noise impacts: A USAREUR
- noise management program handbook p 237 N92-14791 [AD-A240797]
- NOISE PREDICTION Aeroacoustics of flight vehicles: Theory and practice.
- Volume 2: Noise control
- [NASA-RP-1258-VOL-2] p 235 N92-14779 The application of experimental data to blade wake interaction noise prediction
- [NASA-CR-189461] p 237 N92-14789 NOISE PREDICTION (AIRCRAFT)
  - Flyover-noise measurement and prediction p 236 N92-14786
  - Quiet aircraft design and operational characteristics
- p 236 N92-14787 A survey of the broadband shock associated noise prediction methods
- [NASA-TM-105365] p 237 N92-14797 NOISE PROPAGATION
- Aeroacoustics of flight vehicles: Theory and practice. Volume 2: Noise control p 235 N92-14779 [NASA-RP-1258-VOL-2]
- Theoretical models for duct acoustic propagation and N92-14782 radiation p 236 Interior noise p 236 N92-14785
- Flyover-noise measurement and prediction p 236 N92-14786

# NOISE REDUCTION

- Cabin structural vibration and noise for transport aircraft p 192 A92-17876 Aeroacoustics of flight vehicles: Theory and practice.
- Volume 2: Noise control [NASA-RP-1258-VOL-2] p 235 N92-14779

Design and performance of duct acoustic treatment

	P	236	N92-1	478
Jet noise suppression	p	236	N92-1	4784
Interior noise Direct computation of turbulance of	<u>р</u>	236	N92-1	4785
[NASA-CR-187616]	na n	236	N92-1	4788
Reducing environmental noise imp	pad	ts: A	USAF	REUF
noise management program handboo	ok			
Propeller-driven-small airplane nois	р А	237 certifir	N92-1	4/91
[LR-650]	p	237	N92-1	4798
Approximation methods for control of	of a	icoust	ic/stru	cture
INASA-CR-1895781	n	234	N92.1	5655
NOISE SPECTRA	۳	20,		
Direct computation of turbulence and	nd	noise		
NOISE TOLERANCE	p	236	N92-1	4788
Human response to aircraft noise	р	236	N92-1	4780
NONCONSERVATIVE FORCES	· • *			
by flow in labyrinth seals	100 D	223	N92-1	useo 4354
NONDESTRUCTIVE TESTS				
Nondestructive testing developm	en	ts in	the ai	rcraft
Real-time microfocus radiography f	for	elect	ronic fa	ailure
analysis	р	214	A92-1	7289
Enhanced visual technique for rapid i structures	ins	pectic	n of ai	rcraft 7200
Rapid ultrasonic scanning of aircraf	۲ fts	tructu	res	1230
	Р	215	A92-1	7292
ASN1 and aerospace - What about	th n	e nex 215	t 50 ye A92-1	ars? 7293
National research program for nonde	est	ructive	inspe	ction
of aging aircraft	р	169	A92-1	7294
Numerical simulation of thermochem	nica	al non	-eauilit	nium
viscous flows around reentry bodies				
NONEOUU IRRIUM ELOW	p.	227	N92-1	5029
Nonequilibrium hypersonic inviscid :	ste	adv fi	ows	
	р	176	A92-2	0737
Aerodynamic heating on AFE due to with variable entropy at boundary lays	nc	nequi	librium	flow
with variable entropy at boundary laye	P	183	N92-1	5020
Numerical simulation of thermochem	nica	ai non	-equilit	nium
viscous flows around reentry bodies	n -	997	N92.1	5020
NONEQUILIBRIUM THERMODYNAMIC	ŝ		1132-1	502.5
Linear acoustics in gas mixtures wit	in i	ate p	ocess	es
Hypersonic viscous shock layer in	p∶ ∖t	238 herm	N92-1: ochen	5013 nical
nonequilibrium	p	183	N92-1	5014
NONLINEAR EQUATIONS			<i></i>	
Noninear control of a twin-int hence	D	er cor 204	11gura A92-18	3624
NONLINEAR FEEDBACK				
Retrospective essay on nonlinearit	ies n	: in ai 204	rcraft 1 A92-18	flight
NONLINEAR SYSTEMS	μ.	204	~9 <b>2</b> •10	5001
Regulation of relaxed static stability	ai	rcraft		
Nonlinear rotordynamics analysis	p : So	203 ace S	A92-18 huttle i	3463 Main
Engine turbopumps				
[NASA-CR-184263]	p á	221	N92-14	1344
Confined normal-shock/turbu	ler	nt-bou	ndarv-l	aver
interaction followed by an adverse pre	ss	ure gi	adient	-,
NOTCH TESTS	P	172	A92-18	3365
Short fatigue crack growth from b	lur	not	ches i	nал
aero-engine alloy	p 3	212	A92-19	9760
A quiet-flow Ludwieg tube for experir	-	ntalet	untint	high
speed boundary layer transition	ne	11121 50	uuy oi	ngn
[AIAA PAPER 91-5026]	p 3	207	A92-17	7819
Computation of supersonic jet mi	xir	ід по	ise fo	r an
model	μa			nce
[NASA-TM-105338]	p 2	237	N92-14	1795
NOZZLE FLOW			flow	Gold
through radial turbine guide vanes	ра	217	A92-19	9618
Numerical simulations around models	з іл	hype	rsonic	wind
tunnels SIMOUN and Sciences wind tunnels	<b>P</b> 1	182	N92-14	1998
study	но: р 2	208	5000S N92-14	1999
High enthalpy nozzle flows	р 1	82	N92-15	5000
Experimental research of the aerody	yna	amics	of noz	zles
and plumes at hypersonic speeds [NASA-CR-187316]	р 1	85	N92-14	5048
NOZZLE GEOMETRY	r '			
A comparison of cooling methods for	th	e airfra	ame no	zzle
or a single-stage-to-orbit aircraft [AIAA PAPER 91-5036]	0	210	A92-17	7825
	~ ~			

Formation of shocks within axisymmetric nozzles p 176 A92-20760

NUCLEATE BOILING Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary layer

p 215 A92-17823 [AIAA PAPER 91-5033]

# 0

OCCUPATIONAL DISEASES

- Fatal occupational injury related to helicopters in the p 186 A92-20720 United States 1980-1985 OGIVES
- Surface flow patterns on an ogive-cylinder at p 176 A92-20762 incidence

OILS Stability of intershaft squeeze film dampers

p 222 N92-14351 **ONBOARD DATA PROCESSING** On-board data acquisition system for Embraer's

- **CBA123** p 198 A92-19251 OPTICAL COMPUTERS.
- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 **OPTICAL CORRELATORS**
- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 OPTICAL DATA PROCESSING
- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 OPTICAL MEASURING INSTRUMENTS
- Ablation and temperature sensors for flight
- measurements in reentry body heat shields p 227 N92-15004
- OPTIMAL CONTROL
- Optimal control problems with maximum functional p 232 A92-18616
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances
  - p 201 N92-13939

# OPTIMIZATION

- Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3)
- p 170 N92-13928 (NASA-CR-188125) On a global aerodynamic optimization of a civil transport p 193 N92-13931 aircraft
- A comparison of two closely-related approaches to p 193 N92-13933 aerodynamic design optimization
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances
- p 201 N92-13939 Design of 3-dimensional complex airplane configurations
- with specified pressure distribution via optimization p 194 N92-13948
- Application of direct inverse analogy method (DIVA) and viscous design optimization techniques p 176 N92-13951
- Aerodynamic shape optimization of arbitrary hypersonic
- p 194 N92-13954 vehicles Research on inverse methods and optimization in Italy
- p 202 N92-13956 Vortex generator design for aircraft inlet distortion as
- a numerical optimization problem p 194 N92-13959 Airfoil optimization with efficient gradient calculations
- p 177 N92-13960 Design optimization of transonic airfoils p 177 N92-13961
- Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades
- [NASA-CR-189018] p 195 N92-14038 Optimization of the calculation margins of landing gears
- under extreme loads. Rupture static tests. Part 1: Program and test implantation [CEAT-S8-6551-PARTIEL-1-PT-] p 195 N92-14043
- Avionics standardization in Europe p 199 N92-14050
- OSCILLATIONS
- Identification of dynamic characteristics of flexible rotors p 220 N92-13962 as dynamic inverse problem

# Ρ

- P-3 AIRCRAFT
- SATCOM antenna siting study on P-3C aircraft, volume
- p 221 N92-14263 [NASA-CR-189515] PACKINGS (SEALS)
- Rotor-to-stator partial rubbing and its effects on rotor dvnamic response p 224 N92-14367

- PANEL METHOD (FLUID DYNAMICS)
- Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948
- Analysis and design of planar and non-planar wings for induced drag minimization p 179 N92-13999
- [NASA-CR-189509] Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles
- p 211 N92-14977 A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 PANELS
  - Design and performance of duct acoustic treatment p 236 N92-14783
- The influence of a retarding rocket on parameter limits p 211 N92 15037 for reentry trajectories PARACHUTES
- The influence of a retarding rocket on parameter limits for reentry trajectories p 211 N92-15037 PARALLEL PLATES
- Compressibility effects in thin channels with injection p 216 A92-18369
- PARALLEL PROCESSING (COMPUTERS) A processor-in-the-loop simulation using an XANALOG p 232 A92-19094 computer A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986 Parallelization of a Direct Simulation Monte Carlo
- p 227 N92-15033 (DSMC) code for fluid dynamics PASSENGER AIRCRAFT Implementation and usage of the RJ program Data
- equisition System Ground Station p 210 A92-19257 Aging aircraft programme entails major effort and p 169 A92-20023 expense PASSENGERS
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-15054
- PATTERN RECOGNITION Optical computing at NASA Ames Research Center
- [AIAA PAPER 91-3779] p 231 A92-17637 Analysis of objects in binary images [NASA-CR-4420] p 234 N92-14598
- Processing complexity of two approaches to object detection and recognition p 234 N92-14677 PAYLOADS
- Structural considerations for aircraft payload Modification: P-3C zero fuel weight increase p 196 N92-15068 [AD-A242690]
- PCM TELEMETRY An alternative method for acquiring avionic bus data in
  - a class I PCM telemetry system p 217 A92-19202 MIL-STD-1553 data bus/PCM multiplexer system p 188 A92-19211
  - Compression techniques for video telemetry p 188 A92-19214
  - A state-of-the-art data acquisition system p 217 A92-19231
  - Design and implementation of a total flight test system p 189 A92-19278
- High rate PCM data receiving, recording and relying p 189 A92-19279
- PENALTY FUNCTION Airfoil optimization with efficient gradient calculations p 177 N92-13960

### PERFORMANCE PREDICTION

- p 220 N92-13985 Nonstationary gasdynamics The effects of winglets on low aspect ratio wings at supersonic Mach numbers
- [NASA-CR-4407] p 178 N92-13996 Design and performance of duct acoustic treatment
- p 236 N92-14783 PERFORMANCE TESTS
- Review of the European hypersonic wind tunnel performance and simulation requirements
- p 209 N92-15043 PERTURBATION THEORY
- Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling p 224 N92-14370 machines
- PHYSIOLOGICAL EFFECTS p 207 N92-13982 Flight simulation Human response to aircraft noise p 236 N92-14780
- PIEZOELECTRIC CERAMICS Ultrasonic motor utilizing elastic fin rotor
- p 215 A92-17414 Approximation methods for control of acoustic/structure models with piezoceramic actuators [NASA-CR-189578] p 234 N92-15658
- PIEZOELECTRICITY
- Flutter suppression via piezoelectric actuation [NASA-TM-104120] p 197 NS p 197 N92-15070 PILOTLESS AIRCRAFT
  - Flight test of a half-scale unmanned air vehicle p 193 A92-20208

body of revolution
[AD-A241015] p 180 N92-14972
Grid impact on 3D hypersonic flows
p 184 N92-15041
Scoping studies for small steady-state tokamaks for
divertor testing
[DE92-000740] p 238 N92-15761
The IPS plasma wind tunnels for the investigation of
thermal protection materials for reentry vehicles
p 208 N92-15009
PLASMA HEATING
Scoping studies for small steady-state tokamaks for divertor testing
[DE92-000740] p 238 N92-15761
LASMA INTERACTIONS
Scoping studies for small steady-state tokamaks for
(DE92-000740) p 238 N92-15761
PLASMA JET WIND TUNNELS
The IRS plasma wind tunnels for the investigation of
thermal protection materials for reentry vehicles
p 200 N92-15009
Experimental research of the aerodynamics of nozzles
and plumes at hypersonic speeds
[NASA-CR-187316] p 185 N92-15048
Pneumatic distortion compensation for aircraft surface
pressure sensing devices p 218 A92-20206
F/A-18 stabilator: Equivalent set of point forces required
for pneumatic bag load case simulation
POLICIES
New Ways: Tiltrotor aircraft and magnetically levitated
vehicles
[01A-SE1-507] p 238 N92-14933 POSITION (LOCATION)
SATCOM antenna siting study on P-3C aircraft, volume
2
[NASA-CH-189515] p 221 N92-14263
Use of distance-measuring equipment (DME) for
correcting errors in position, velocity, and wind
measurements from aircraft inertial navigation systems
POTENTIAL FLOW
Complex variable boundary element method for external
potential flows p 1/2 A92-18353
using a full-potential method p 174 A92-20212
Time domain flutter analysis of cascades using a
full-potential solver p 176 A92-20747
Probabilistic lifing approach for aero engine disks made
of powder nickel base alloys containing ceramic defects
p 226 N92-14424
Design and performance of duct acoustic treatment
p 236 N92-14783
The application of experimental data to blade wake
[NASA-CR-189461] p 237 N92-14789
A survey of the broadband shock associated noise
prediction methods
Aerodynamic heating on AFE due to nonequilibrium flow
with variable entropy at boundary layer edge
p 183 N92-15020
Seal development activities at Allison Turbine Division
REDICTIONS
Turbine engine diagnostics system study
[DOT/FAA/CT-91/16] p 202 N92-14064
aerodynamically excited turbomachinery
p 224 N92-14364
REFORMS
Universal weaving for turbine engine composite
[AD-A237667] p 202 N92-14059
RESSURE DISTRIBUTION
Effect of nose shape on three-dimensional stagnation
[AIAA PAPER 91-5032] p 171 A92-17822
Engineering method for calculating surface pressures
and heating rates on vehicles with embedded shocks
[AIAA PAPER 91-5060] n 171 A02-17942

- Large chord turbine cascade testing, at engine Mach p 173 A92-18771 and Revnolds number
- Evaluation of Euler solvers for transonic wing-fuselage p 174 A92-20214 aeometries

# PRESSURE DISTRIBUTION

# PITCHING MOMENTS

- Stokes computations for a spir
- 6

  - 1

### 6

- F

### F

1

6

F

6

F

s,

F

# PRESSURE GRADIENTS

Inverse airfoil design procedure using a multigrid Navier-Stokes method p 193 N92-13932 Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92-13948 An inverse method for the aerodynamic design of three-dimensional aircraft engine nacelles p 194 N92-13958 An inverse method with regularity condition for transonic p 177 N92-13969 airfoil design Definition of the unsteady vortex flow over a wing/body configuration p 178 N92-13995 [NASA-CR-180083] Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354 Transonic Navier-Stokes computations for a spinning body of revolution p 180 N92-14972 [AD-A241015] PRESSURE GRADIENTS normal-shock/turbulent-boundary-layer Confined interaction followed by an adverse pressure gradient p 172 A92-18365 PRESSURE HEADS The aerodynamic effect of fillet radius in a low speed compressor cascade p 202 N92-14063 [NASA-TM-105347] PRESSURE MEASUREMENT Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7 p 173 A92-18770 Pneumatic distortion compensation for aircraft surface p 218 A92-20206 pressure sensing devices Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for p 181 N92-14992 space vehicles Flow over a delta wing at hypersonic speeds p 181 N92-14993 benchmark aeroelastic models program: The Description and highlights of initial results p 185 N92-15049 [NASA-TM-104180] PRESSURE REDUCTION Vortex generator design for aircraft inlet distortion as p 194 N92-13959 a numerical optimization problem PRESSURE SENSORS Pneumatic distortion compensation for aircraft surface p 218 A92-20206 pressure sensing devices PRESSURIZED CABINS Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical investigations p 217 A92-19812 Proof test and fatigue crack growth modeling on 2024-T3 p 213 A92-19828 aluminum alloy PROBABILITY THEORY Some Aspects of uncertainty in computational fluid p 233 A92-19609 dynamics results PROBLEM SOLVING Automated problem resolution prototype in automated p 190 N92-14028 en route air traffic control PRODUCT DEVELOPMENT Technology in the lives of an aircraft designer [AIAA PAPER 91-3069] p 192 A p 192 A92-20000 PRODUCTION MANAGEMENT Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description

[AD-A242598] p 170 N92-14966 PROGRAM VERIFICATION (COMPUTERS)

Formal specification and verification of Ada software [AIAA PAPER 91-3713] p 230 A92-17585 Cleanroom - An alternative software development process p 233 A92-19386 Hypersonic aerothermodynamic computations using a point-implicit TVD method p 183 N92-15006

PROGRAMMING LANGUAGES Avionics systems development: Technological trends,

conflicts, and cost issues in a changing European environment p 199 N92-14054 PROGRESS

Recent progress in inverse methods in France p 201 N92-13938 PROJECT PLANNING

PROJECT PLANNING		
Avionics technology beyond 2000		
	p 200	N92-14058

PROJECTILES		
Transonic Navier-Stokes comp	utations fo	r a spinning
body of revolution		
[AD-A241015]	p 180	N92-14972
PROPELLANT COMBUSTION		
Nonstationary gasdynamics	p 220	N92-13985

Nonstationary gasdynamics	p 220	N92-1398
PROPELLER BLADES		
Study of a new airfoil used in re	versible ax	ial fans

p 177 N92-13970 Analysis of aircraft engine blade subject to ice impact (NASA-TM-105336) p 229 N92-15402

**PROPELLER DRIVE** Propeller-driven-small airplane noise certification [LR-650]

p 237 N92-14798 PROPELLER FANS Analysis of aircraft engine blade subject to ice impact (NASA-TM-105336) p 229 N92-15402 p 229 N92-15402

- p 202 N92-13977 Aerodynamics A Navier-Stokes solution of Hull-ring wing-thruster p 221 N92-14310 interaction PROPULSION SYSTEM CONFIGURATIONS
- Hypersonic airbreathing propulsion activities for Saenger
- [AIAA PAPER 91-5040] p 200 A92-17828 Potential hypersonic vehicles applications [AIAA PAPER 91-5086] p 169 A92-17854 High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385 PROPULSION SYSTEM PERFORMANCE High-temperature combustor and seal for a water piston
- propulsor [AD-A242493] p 229 N92-15385
- PROPULSIVE EFFICIENCY Technology needs for high speed rotorcraft (3) [NASA-CR-177592] p 195 N9 p 195 N92-14039
- PROTECTION Lightning protection requirements for aircraft: A
- proposed specification [RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92-14007
- **PROTECTIVE CLOTHING** International aviation (selected article)
- p 170 N92-13992 [AD-A240987] **PROTECTIVE COATINGS**
- PVD coatings for aircraft turbine blades
- p 216 A92-17950 Protective coatings of thermal barrier type p 214 A92-20349
- High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385
- PULSE CODE MODULATION A new 1553 all-bus instrumentation monitor
- p 198 A92-19252 PULSE COMMUNICATION
- High rate PCM data receiving, recording and relying p 189 A92-19279
- PUMP SEALS Test results for rotordynamic coefficients of the SSME
- HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357
- Dynamic characteristics and stability analysis of space shuttle main engine oxygen pump p 224 N92-14366 PUMPS
- Hydraulic pumps The key to power generation p 215 A92-17348

# Q

- QUALITY CONTROL
- Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820 Mechanical qualification tests for materials used in the fabrication of aircraft parts
- [CEAT-M5-5443/01] p 195 N92-14042 Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description [AD-A242598]

p 170 N92-14966

# R

### RADAR

- Radar troubleshooting assistant expert system [AIAA PAPER 91-3764] p 231 A92-17626 Avionics modernization/upgrades in the late 1990s p 199 N92-14055
- RADIOGRAPHY Real-time microfocus radiography for electronic failure
- analysis p 214 A92-17289 RAIL TRANSPORTATION
- Electronic systems in transportation (TP-9983) p 189 N92-14009 RAMJET ENGINES
- Thrust nozzle test facility at DLR Cologne [AIAA PAPER 91-5024] p 206 A92-17818 Hypersonic airbreathing propulsion activities Saenger [AIAA PAPER 91-5040] p 200 A92-17828
- Ceramic regenerator program [NASA-CR-189053] p 225 N92-14374

RANDOM LOADS

- Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code
- (DE92-000597) p 229 N92-15392 RANGEFINDING
- Image-based ranging and guidance for rotorcraft [NASA-CR-184829] p 191 N92-RAPID QUENCHING (METALLURGY) p 191 N92-14036
- Inertia-friction welding of an advanced rapidly solidified p 212 A92-18898
- titanium alloy RAREFIED GAS DYNAMICS
  - Flat-ended circular cylinder in hypersonic rarefied flow p 174 A92-20304 Transitional flows around re-entry bodies p 184 N92-15035
- **BAREFIED GASES** 
  - Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles n 184 N02-15032

# RE

	P 107	1102-10002
REACTION KINETICS	•	
Rate parameters for coupled vibrat	tion-diss	ociation in a
generalized SSH approximation Sc	hwarz, S	Slawsky, and
Herzfeld	p 235	A92-20301
Linear acoustics in gas mixtures wi	ith rate (	processes
-	p 238	N92-15013
Hypersonic viscous shock layer	in the	rmochemical
nonequilibrium	ʻp 183	N92-15014
Influence of chemical modeling	on the	solution of
hypersonic shock layers	p 183	N92-15016
Numerical simulation of thermocher	nical no	n-equilibrium
viscous flows around reentry bodies		
	p 227	N92-15029
REAL GASES		
Equilibrium solution of the Euler	and N	avier-Stokes
equations around a double ellipsoida	I shape	with mono-
and multi-blocks including real gas ef	fects, pa	art 1
	p 227	N92-15030
REAL TIME OPERATION	(l	nania daikuna
Heal-ume microrocus radiography i		
Analysis Cana far real time systems develo	p 214	A92-17209
TAIAA DADED 01,37261	o 221	A02 17504
A processor in the loop simulation	p zo i usino or	A92-17594
computer	0 232	A02-10004
A new 1553 all-bus instrumentation	monito	r r
A new 1500 air-bus instrumentation	n 198	A92-19252
An integrated real-time turbine	engine	flight test
system	p 201	A92-19275
Reconfigurable Mobile System - G	iround.	sea and air
applications	p 218	A92-19986
Image-based ranging and guidance	for roto	rcraft
[NASA-CR-184829]	p 191	N92-14036
Rapid near-optimal aerospace	plane	trajectory
generation and guidance	•	
[NASA-CR-189469]	p 205	N92-14066

- **RECONNAISSANCE AIRCRAFT** Avionics systems development: Technological trends. conflicts, and cost issues in a changing European environment p 199 N92-14054 RECTANGULAR WINGS
- Nonlinear stall flutter and divergence analysis of cantilevered graphite/epoxy wings REENTRY EFFECTS p 219 A92-20746
- Viscous shock-layer equations for the calculation of reentry aerothermodynamics p 183 N92-15008 Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027
- REENTRY SHIELDING The IRS plasma wind tunnels for the investigation of
- thermal protection materials for reentry vehicles p 208 N92-15009

### REENTRY TRAJECTORIES

- The influence of a retarding rocket on parameter limits for reentry trajectories p 211 N92-15037 REENTRY VEHICLES
  - Potential hypersonic vehicles applications [AIAA PAPER 91-5086] p 169 A92-17854
- Aerothermodynamics for Space Vehicles [ESA-SP-318] ESA-SP-318} p 180 N92-14973 Analysis tools of ONERA and DLR for the
- aerothermodynamics of reentry vehicles

  - p 211 N92-14977 Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980 Simulation requirements for RCS plume: Flowfield
  - interaction modelling on a winged reentry vehicle p 181 N92-14985
  - Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at super- and hypersonic speed p 181 N92-14987 Flow and temperature computations for space vehicles
  - using adaptive finite element techniques p 181 N92-14990

- PROPELLERS

# SUB IECT IND

SUBJECT INDEX	
Ablation and temperature sensors for	flight
measurements in reentry body heat shields 227 N92	2-15004
The IRS plasma wind tunnels for the investiga	ation of F
thermal protection materials for reentry vehicles. p 208 N92	-15009
Hypersonic inviscid flow field simulations around	reentry
Vehicles with flap deflection p 184 N92 Numerical simulation of thermochemical non-enu	-15025 n ilibrium
viscous flows around reentry bodies	
p 227 N92 Behaviour and modelling of the aerothermodyna	mics of R
ballistic entry vehicles in the high altitude flow reg	imes
Applicability of bridging methods to hypersonic	rarefied
flow aerodynamics of reentry vehicles	15022
Transitional flows around re-entry bodies	-15032 R
p 184 N92	-15035
PVD coatings for aircraft turbine blades	R
p 216 A92	-17950
Hypersonic materials p 212 A92	-18002
REFRIGERATORS Multicomponent gas scrotion Joule-Th	nomson R
refrigeration	
[NASA-CASE-NPO-17569-1-CU] p 228 N92 REGENERATORS	-15203 <b>H</b>
Ceramic regenerator program	14274 B
REGRESSION ANALYSIS	-14574 1
Use of distance-measuring equipment (DM correction errors in position velocity and	E) for . wind R
measurements from aircraft inertial navigation sys	tems
p 188 A92 REGULARITY	-18172
An inverse method with regularity condition for tra	ansonic R
REGULATIONS	-13969
A strategy for exploiting the full potential of MLS	based R
REINFORCED PLATES	-14025
Some results on metal and composite reinforcement of aluminum honevcomb panel	patch R
p 216 A92	-18830
Avionics reliability, durability, and integrity: Can t	they be
independent of application? p 200 N92	-14056 B
Operational design factors for NASP derived v	ehicles
[AIAA PAPER 91-5081] p 210 A92 Development of a calibrated software reliability	-17851 model
for flight and supporting ground software for	avionic
systems p 234 N92 REMOTE SENSING	-15870
Aerobureau - Strategic television airmobile rep	orts via
REMOTELY PILOTED VEHICLES	-19988
Flight test of a half-scale unmanned air vehicle	20209
REQUIREMENTS	-20200
Lightning protection requirements for aircr proposed specification	aft: A
[RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92	-14007
performance and simulation requirements	tunnel
p 209 N92	-15043
On the accuracy of an aircraft-borne a	mbient
electric-field measuring system p 186 A92 RESEARCH AND DEVELOPMENT	-20127
'Spaceplanes' R&D status of Japan	47000
Soviet CFD - An international perspective	-17802
p 233 A92	-20150
[JPRS-USP-91-007] p 211 N92	-14101
National Aeronautics and Space Administration	-14925 -
Seal development activities at Allison Turbine D	ivision R
p 228 N92 Areas of seal R/D at GE p 228 N92	-15093 -15094
RESEARCH FACILITIES	
p 180 N92	-14974
Structural Dynamics Branch research	and
[NASA-TM-103747] p 230 N92	-15406 🖪
RESEARCH PROJECTS Review of aerodynamic design in the Netherland	ds
p 193 N92	-13929

**RESEARCH VEHICLES** 

Conducting the NASP	ground test p	rogram	
[AIAA PAPER 91-5029]		p 209	A92-17820

Numerical investigations in three-dimensional internal flows [NASA\_CP.180467] n 221 N02-14313

[11/0/-01-10	3407 ]		PLLI	1102-14010
ESIDUAL STR	ENGTH			
Bulging of t	latigue cracks	in a pr	essuriz	ed aircraft
fuselage				

- [LR-655] p 196 N92-14045 RESILIENCE
- Mechanical qualification tests for materials used in the fabrication of aircraft parts [CEAT-M5-5443/01] p 195 N92-14042
- RESONANCE Field telemetry of blade-rotor coupled torsional vibration
- at Matuura Power Station Number 1 unit p 222 N92-14348
- The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies p 222 N92-14349
- **RESONANT FREQUENCIES**
- Resonance prediction for slotted circular wind tunnel sing finite element p 235 A92-18388 using finite element RETROFITTING
- Ferrundi Company supplies 4500 model head up display devices to India's MIG-21 aircraft
- [AD-A241044] p 229 N92-15367 RETROROCKET ENGINES The influence of a retarding rocket on parameter limits
- p 211 N92-15037 for reentry trajectories REVERSING
- Study of a new airfoil used in reversible axial fans p 177 N92-13970 REYNOLDS NUMBER
- Large chord turbine cascade testing at engine Mach and Reynolds number p 173 A92-16771 **RIGID WINGS**
- aeroelastic models program: The benchmark Description and highlights of initial results p 185 N92-15049 [NASA-TM-104180]
- RING WINGS A Navier-Stokes solution of Hull-ring wing-thruster p 221 N92-14310 interaction
- ROBOT DYNAMICS Representation of geometric stiffening in multibody
- p 217 A92-19463 system simulation ROBUSTNESS (MATHEMATICS)
- Application of stochastic robustness to aircraft control p 204 A92-18620 evetome ROLLING MOMENTS
- Roll-performance criteria for high augmented aircraft p 204 A92-18623
- ROTARY STABILITY Nonlinear rotordynamics analysis --- Space Shuttle Main Engine turbopumps
- p 221 N92-14344 [NASA-CR-184263] The stability of the steady state and bistable response of a flexible rotor supported on squeeze film dampers
- p 222 N92-14350 Experiment of static and dynamic characteristics of spiral grooved seals p 223 N92-14361 A simplified method for predicting the stability of
- aerodynamically excited turbomachinery p 224 N92-14364 Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling
- p 224 N92-14370 machines The application of a cylindrical-spherical floating ring bearing as a device to control stability of turbogenerators p 224 N92-14371 Effect of eccentricity on the static and dynamic
- performance of a turbulent hybrid bearing p 225 N92-14373
- ROTARY WING AIRCRAFT
- Image-based ranging and guidance for rotorcraft p 191 N92-14036 [NASA-CR-184829]
- Technology needs for high speed rotorcraft (3) [NASA-CR-177592] p 195 N92-14039
- Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- (SCT-90RR-441 p 191 N92-15061 ROTARY WINGS
- Time-periodic control of a multi-blade helicopte p 204 A92-18626 Experimental investigation of periodically excited p 218 A92-20213 rotating composite rotor blades Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades
- p 195 N92-14038 [NASA-CR-189018] ROTATING BODIES
- Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions p 219 A92-20756

**ROTATING SHAFTS** 

Stability of intershaft squeeze film dampers p 222 N92-14351

Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354 Hydraulic actuator system for rotor control

- p 224 N92-14363 Rotor-to-stator partial rubbing and its effects on rotor
- dynamic response p 224 N92-14367 Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling machines p 224 N92-14370
- The application of a cylindrical-spherical floating ring bearing as a device to control stability turbogenerators p 224 N92-14371
- Programs at Wright-Patterson Air Force Base p 228 N92-15092
- ROTATION
  - Identification of dynamic characteristics of flexible rotors as dynamic inverse problem p 220 N92-13962
  - Turbine engine diagnostics system study [DOT/FAA/CT-91/16] p 203 p 202 N92-14064 **RÖTOR AERODYNAMICS**
  - Helicopter air resonance modeling and suppression using active control p 204 A92-18625
  - Time-periodic control of a multi-blade helicopter p 204 A92-18626
  - Analytical/numerical matching and periodic inversion: Two advances in free wake analysis
    - p 178 N92-13994
  - Experimental investigation of periodically excited rotating composite rotor blades p 218 A92-20213 Time domain flutter analysis of cascades using a
  - p 176 A92-20747 full-notential solver ROTOR BLADES (TURBOMACHINERY)
    - Recent progress in inverse methods in France
    - p 201 N92-13938 Rub induced rotor/stator vibration analysis on CF700 engine
    - p 202 N92-14060 [NRC-TR-ENG-007] Low cycle fatigue of cast nickel base turbine rotors
  - p 226 N92-14405 ROTOR BODY INTERACTIONS Helicopter air resonance modeling and suppression
  - sing active control p 204 A92-18625 ROTOR DYNAMICS
  - Limit cycle vibrations in turbomachinery
  - [NASA-TP-3181] p 211 N92-14108 Nonlinear rotordynamics analysis ----Space Shuttle Main Engine turbopumps
  - [NASA-CR-184263] p 221 N92-14344 Rotordynamic Instability Problems in High-Performance
  - Turbomachinery, 1990 [NASA-CP-3122] p 222 N92-14346 The stability of the steady state and bistable response
  - of a flexible rotor supported on squeeze film dampers p 222 N92-14350 Evaluation of rotordynamic coefficients of look-through
  - labyrinths by means of a three volume bulk flow model p 223 N92-14356 Determination of rotordynamic coefficients for labyrinth
  - seals and application to rotordynamic p 223 N92-14360 calculations
  - Annular seals of high energy centrifugal pumps: Presentation of full scale measurement
  - p 224 N92-14362 A simplified method for predicting the stability of aerodynamically excited turbomachinery
    - p 224 N92-14364 Rotor-to-stator partial rubbing and its effects on rotor
  - dynamic response p 224 N92-14367 Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling
  - machines p 224 N92-14370 The application of a cylindrical-spherical floating ring
  - bearing as a device to control stability of turbogenerators p 224 N92-14371 ROTORCRAFT AIRCRAFT
  - Analytical/numerical matching and periodic inversion: Two advances in free wake analysis
    - p 178 N92-13994
  - ROTORS Ultrasonic motor utilizing elastic fin rotor
    - p 215 A92-17414 Variational formulation of hybrid problems for fully 3-D
  - p 176 N92-13953 transonic flow with shocks in rotor Identification of dynamic characteristics of flexible rotors
  - p 220 N92-13962 as dynamic inverse problem Integration of dynamic, aerodynamic, and structural
  - optimization of helicopter rotor blades p 195 N92-14038 [NASA-CR-189018]
  - Limit cycle vibrations in turbomachinery [NASA-TP-3181] p 21 p 211 N92-14108
  - Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit
    - p 222 N92-14348

ROTOR BLADES

Rub induced rotor/stator vibration analysis on CF700

SIGNATURE ANALYSIS

# RUNWAY CONDITIONS

- The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies . p 222 N92-14349
- The stability of the steady state and bistable response of a flexible rotor supported on squeeze film dampers p 222 N92-14350
- Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354
- Experiment of static and dynamic characteristics of spiral grooved seals p 223 N92-14361 Hydraulic actuator system for rotor control
- p 224 N92-14363 Rotor-to-stator partial rubbing and its effects on rotor dynamic response p 224 N92-14367
- Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling machines p 224 N92-14370
- Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067 Development of a CFD code for analysis of fluid dynamic
- forces in seals p 228 N92-15084 High-temperature combustor and seal for a water piston propulsor
- [AD-A242493] p 229 N92-15385 Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code
- [DE92-000597] p 229 N92-15392 RUNWAY CONDITIONS
- Aircraft landing-induced tire spinup p 193 A92-20209
- RUNWAYS
- New siting techniques for the ILS glide slope p 188 A92-17422
- Electronic systems in transportation [TP-9983] p 189 N92-14009

# S

- SAFETY FACTORS
- Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990 [PB91-910405] p 187 N92-14006
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-15054 SATELLITE TELEVISION
- Aerobureau Strategic television airmobile reports via satellite p 218 A92-19988
- SATELLITE TRACKING
- Navsat A civil complement to GPS and Glonass [IAF PAPER 91-490] p 188 A92-18505 SCALE MODELS
- Flight test of a half-scale unmanned air vehicle p 193 A92-20208
- SEALING
- Army research concerns in engine sealing p 228 N92-15089 Areas of seal R/D at GE p 228 N92-15094 Seal related development activities at EG/G p 228 N92-15095 Redesign of flight space shuttle main engine nozzle G-15
- seal area based on the thermal analysis and flow models p 212 N92-15877 SEALS (STOPPERS)
- EXEAS (STOPPERS) Experiment of static and dynamic characteristics of spiral grooved seals p 223 N92-14361 Annular seals of high energy centrifugal pumps:
- Presentation of full scale measurement p 224 N92-14362 Industrial code development p 227 N92-15083
- Army research concerns in engine sealing p 228 N92-15089
- Programs at Wright-Patterson Air Force Base p 228 N92-15092 Areas of seal R/D at GE p 228 N92-15094
- Seal related development activities at EG/G p 228 N92-15095
- High-temperature combustor and seal for a water piston propulsor [AD-A242493] p 229 N92-15385
- SECONDARY FLOW
- Army research concerns in engine sealing p 228 N92-15089
- Areas of seal R/D at GE p 228 N92-15094 SENSITIVITY
- Aerodynamic sensitivity analysis methods for the compressible Euler equations p 233 A92-19619 SEPARATED FLOW
- Numerical prediction of subsonic turbulent flows over slender bodies at high incidence p 172 A92-18358 Flow separation patterns over an F-14A aircraft wing p 174 A92-20205

- Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736 Asymmetric separated flows at supersonic speeds
- p 176 A92-20742 A Navier-Stokes solution of Hull-ring wing-thruster interaction p 221 N92-14310 SFRVICE LIFF
- National research program for nondestructive inspection of aging aircraft p 169 A92-17294
- A probabilistic method for monitoring the remaining life of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292
- Multiaxial load spectra in a cooled gas turbine blade under in-service conditions p 201 A92-19696
- Monitoring load experience of individual aircraft [NLR-TP-90084-U] p 196 N92-15065 Flight operations for higher harmonic control research
- [AD-A242478] p 196 N92-15067 SERVOMECHANISMS
- Retrospective essay on nonlinearities in aircraft flight control p 204 A92-18601 Hydraulic actuator system for rotor control
- p 224 N92-14363
- Results of an Icing test on a NACA 0012 airfoil in the NASA Lewis Icing Research Tunnel [NASA-TM-105374] 0 185 N92-15051
- [NASA-TM-105374] p 185 N92-15051 SHEAR PROPERTIES
- Nondestructive testing developments in the aircraft industry p 214 A92-17288 SHOCK ABSORBERS
  - Nonlinear landing gear behavior at touchdowr
- p 192 A92-19606
- Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363 Viscous shock-layer equations for the calculation of reentry aerothermodynamics p 183 N92-15008 Hypersonic viscous shock layer in thermochemical
- nonequilibrium p 183 N92-15014 Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15016
- SHOCK TUBES Nonstationary gasdynamics p 220 N92-13985 SHOCK TUNNELS
- SHOCK TUNNELS Drag balance for hypervelocity impulse facilities
- p 207 A92-18375 High enthalpy testing in the Aachen (Fed. Republic of Germany) shock tunnel TH 2 p 208 N92-15021
- SHOCK WAVE INTERACTION Confined normal-shock/turbulent-boundary-layer interaction followed by an adverse pressure gradient
- p 172 A92-18365 Three-dimensional thermal structural analysis of a swept cowl leading edge subjected to skewed shock-shock
- interference heating p 174 A92-20306 Formation of shocks within axisymmetric nozzles p 176 A92-20760
- Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage (AD-A22656) p. 185 N92-15045
- [AD-A242656] p 185 N92-15045 SHOCK WAVE PROPAGATION
- Influences of wind tunnel parameters on airfoil characteristics at high subsonic speeds
- p 173 A92-18769
- Engineering method for calculating surface pressures and heating rates on vehicles with embedded shocks [AIAA PAPER 91-5060] \$p\$ 171 A92-17842 Effects of unsteady shock impingement on high-speed
- gaseous mixing [AIAA PAPER 91-5091] p 172 A92-17857 Similarity solutions for supersonic axisymmetric flows
- p 173 A92-18387 Broadband shock-associated noise from supersonic jets
- in flight p 235 A92-18683 Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique
- p 182 N92-14994 SHORT CRACKS
- Short fatigue crack growth from blunt notches in an aero-engine alloy p 212 A92-19760 Crack initiation and the short-to-long crack growth transition in a Ni-base superalloy p 213 A92-19767
- transition in a Ni-base superalloy p 213 A92-19767 SHROUDED PROPELLERS Analysis of an advanced ducted propeller subsonic
  - (NASA-TM-105393) p 179 N92-14002
- SIGNAL PROCESSING Simulation of radar clutter and jet engine modulation using digital quadrature modulator p 216 A92-19091 MIL-STD-1553 data bus/PCM multiplexer system
  - p 188 A92-19211 A state-of-the-art data acquisition system
    - p 217 A92-19231

enaine [NRC-TR-ENG-007] p 202 N92-14060 SILICON NITRIDES Ceramic regenerator program [NASA-CR-189053] p 225 N92-14374 SINGLE CRYSTALS High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796 SINGLE EVENT UPSETS Formulation of a strategy for monitoring control integrity in critical digital control systems p 206 N92-15075 [NASA-TM-104158] SINGLE STAGE TO ORBIT VEHICLES Solving the structures problem for hypersonic vehicles p 209 A92-17349 A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft [AIAA PAPER 91-5036] p 210 A92-17825 Operational design factors for NASP derived vehicles [AIAA PAPER 91-5081] p 210 A92-17851 Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076 SKID LANDINGS Aircraft landing-induced tire spinup p 193 A92-20209 SKIN (STRUCTURAL MEMBER) Methodology for assessment of skin repairs on Airbus aircraft p 226 N92-14428 SI ENDER CONES Hypersonic flows over slender circular cones at small andles of attack p 173 A92-19068 SLENDER WINGS Analysis of spiraling vortical flows around slender delta wings moving in an inviscid medium p 173 A92-18900 SLOTTED WIND TUNNELS Resonance prediction for slotted circular wind tunnel p 235 A92-18388 using finite element SMOKE TRAILS Simple method of supersonic flow visualization using p 219 A92-20764 smoke SOFTWARE ENGINEERING Case for real-time systems development - Quo vadis? [AIAA PAPER 91-3726] p 231 A92-17594 Advanced avionics system development environment [AIAA PAPER 91-3944] p 231 A92-17608 Applications of an automated programming system NAA PAPER 91-3767] p 231 A92-17629 [AIAA PAPER 91-3767] Designing through test [AIAA PAPER 91-3822] p 232 A92-17664 Verification of flight software by embedding software simulation in simulation of external environment p 232 A92-19084 A processor-in-the-loop simulation using an XANALOG omputer p 232 A92-19094 computer Cleanroom - An alternative software development p 233 A92-19386 process Aerospace software engineering in the United p 233 A92-19405 p 233 A92-19406 Kingdom Aerospace software in Sweden p 199 N92-14052 Avionics software evolution Avionics systems development: Technological trends, conflicts, and cost issues in a changing European environment p 199 N92-14054 Avionics technology beyond 2000 p 200 N92-14058 Architecture for Survivable System Processing (ASSP) p 220 N92-14210 SOFTWARE TOOLS Case for real-time systems development - Quo vadis? [AIAA PAPER 91-3726] p 231 A92-17594 Knowledge maintenance in an evolving system using deep structure representation [AIAA PAPER 91-3941] p 231 A92-17605 Advanced avionics system development environment [AIAA PAPER 91-3944] p 231 A92-17608

- Fault Tree Interpreter --- expert system shell for rule-based expert systems development for control of ATE [AIAA PAPER 91-3789] p 232 A92-17645
- Failure environment analysis tool (FEAT) development status [AIAA PAPER 91-3803] p 232 A92-17654
- Automated problem resolution prototype in automated en route air traffic control p 190 N92-14028 Mixed approach towards modular avionics conflicting requirements p 199 N92-14051
- Avionics software evolution p 199 N92-14052 Architecture for Survivable System Processing (ASSP) p 220 N92-14210
- Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype flight hardware p 220 N92-14217

SUBJECT INDEX
SORBENTS
Multicomponent gas sorption Joule-Thomson retrigeration
[NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
Multicomponent gas sorption Joule-Thomson
[NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
SOUND FIELDS Theoretical models for duct acoustic propagation and radiation p 236 N92-14782
The acoustic flashlight {MBB-Z-0359-90-PUB} p 239 N92-15938
SOUND GENERATORS
[MBB-Z-0359-90-PUB] p 239 N92-15938
Approximation methods for control of acoustic/structure
[NASA-CR-189578] p 234 N92-15658
SPACE SHUTTLE MAIN ENGINE Limit cycle vibrations in turbomachinery
[NASA-TP-3181] p 211 N92-14108
Engine turbopumps
[NASA-CH-184263] p 221 N92-14344 Test results for rotordynamic coefficients of the SSME
HPOTP turbine interstage seal with two swirl brakes
Dynamic characteristics and stability analysis of space
shuttle main engine oxygen pump p 224 N92-14366 Airfoil Vibration Dampers program
[NASA-CR-188929] p 225 N92-14391
seal area based on the thermal analysis and flow
models p 212 N92-15877 SPACE SHUTTLE ORBITERS
Testing of the high accuracy inertial navigation system
p 210 N92-14087
SPACE TRANSPORTATION Aerothermodynamics for United States advanced
programs p 184 N92-15039 SPACE TRANSPORTATION SYSTEM
'Spaceplanes' R&D status of Japan
[AIAA PAPER 91-5002] p 209 A92-17802 National Aeronautics and Space Administration
p 238 N92-14923 Aerothermodynamic challenges of the Saenger
space-transportation system p 184 N92-15042 SPACECRAFT COMPONENTS
Tribology needs for future space and aeronautical
[NASA-TM-104525] p 214 N92-15191
Solving the structures problem for hypersonic vehicles
p 209 A92-17349 The IBS plasma wind tunnels for the investigation of
thermal protection materials for reentry vehicles
SPACECRAFT CONTROL
Dynamics and control of hypersonic vehicles - The integration challenge for the 1990's
[AIAA PAPER 91-5057] p 203 A92-17840 Simulation requirements for BCS plume: Eleverad
interaction modelling on a winged reentry vehicle
SPACECRAFT DESIGN
The value of sub-scale flight tests in the development of NASP vehicles
[AIAA PAPER 91-5048] p 210 A92-17834 Dynamics and control of hypersonic vehicles - The
integration challenge for the 1990's
Aerothermodynamics for United States advanced
programs p 184 N92-15039 Evolution and development of hypersonic configurations
1958-1990
SPACECRAFT GUIDANCE
resting of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab
p 210 N92-14087 SPACECRAFT PROPULSION
Aerothermodynamics for Space Vehicles
Aerothermodynamic challenges of the Saenger
space-transportation system p 184 N92-15042

SPACECRAFT SHIELDING The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles

p 208 N92-15009 SPACECRAFT STRUCTURES

Enhancement of modal swept sine data by control of exciting forces p 215 A92-17562 SPACECRAFT TRAJECTORIES Automated trajectory synthesis for hypersonic vehicles

using energy management and variational calculus p 210 A92-19061 techniques The influence of a retarding rocket on parameter limits p 211 N92-15037 for reentry trajectories SPARK IGNITION

Current stabilizing of fastened composite joints to improve non-sparking lightning current performance

p 213 A92-20130 . SPATIAL MARCHING

Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary laver AIAA PAPER 91-5033] p 215 A92-17823

SPATIAL RESOLUTION Processing complexity of two approaches to object

p 234 N92-14677 detection and recognition SPECIFICATIONS

Common avionics baseline: The product of the joint p 199 N92-14053 integrated avionics working group SPHERICAL COORDINATES

Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction p 193 A92-20202

SPOILERS

Experimental investigation of transverse jet effects related to hypersonic space vehicles p 182 N92-14995

[NASA-CR-189044] p 195 N92-14037

The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies p 222 N92-14349

of a flexible rotor supported on squeeze film dampers

Stability of intershaft squeeze film dampers

STABILITY AUGMENTATION Roll-performance criteria for high augmented aircraft

p 204 A92-18623 STABILITY DERIVATIVES

Short time force measurement system p 208 N92-15001

STABILIZATION Aeroservoelastic stabilization techniques for hypersonic flight vehicles

(AIAA PAPER 91-50561 p 203 A92-17839 STABILIZERS (FLUID DYNAMICS)

F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation [AD-A242637] p 206 N92-15073

STAGNATION TEMPERATURE

High enthalpy testing in the Aachen (Fed. Republic of Germany) shock tunnel TH 2 p 208 N92-15021 p 208 N92-15021 STANDARDIZATION

Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 Historical perspective on the evolution of avionics

p 198 N92-14049 standards Avionics standardization in Europe

p 199 N92-14050 Common avionics baseline: The product of the joint p 199 N92-14053 integrated avionics working group STANDARDS

Historical perspective on the evolution of avionics p 198 N92-14049 standards Common avionics baseline: The product of the joint

integrated avionics working group p 199 N92-14053 Propeller-driven-small airplane noise certification (LR-650) p 237 N92-14798

STATE ESTIMATION An alternative derivation of the modified gain function of Song and Speyer p 232 A92-18464

STATIC CHARACTERISTICS Static aeroelastic analysis for generic configuration

wina p 174 A92-20201 Experiment of static and dynamic characteristics of spiral p 223 N92-14361 prooved seals

STATIC ELECTRICITY

Nonlinear triggered lightning models for use in finite difference calculations p 230 A92-20128 Analysis and modeling of lightning strikes to the F106B, p 186 A92-20129 CVF580, and C160 aircraft STATIC STABILITY

Regulation of relaxed static stability aircraft p 203 A92-18463

STATIC TESTS Methodology for assessment of skin repairs on Airbus aircraft p 226 N92-14428

STATISTICAL ANALYSIS Study of the engine bird ingestion experience of the

Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053 STATISTICS General aviation activity and avionics survey, calendar

ear 1989 PB91-1792341 p 169 N92-13926

FAA statistical handbook of aviation: Calendar year 1989

[PB91-202051] p 170 N92-13927 STATOPS

Rub induced rotor/stator vibration analysis on CF700 engine

p 202 N92-14060 [NRC-TR-ENG-007] Rotor-to-stator partial rubbing and its effects on rotor dvnamic response p 224 N92-14367

STEADY FLOW

Prediction of steady and unsteady asymmetric vortical flows around circular cones p 172 A92-18372 Numerical calculation of subsonic and supersonic aerodynamic loads around complex configuration vehicle p 175 A92-20488

Nonequilibrium hypersonic inviscid steady flows p 176 A92-20737

- STEADY STATE Scoping studies for small steady-state tokamaks for
- divertor testing [DE92-000740] p 238 N92-15761
- STEAM TURBINES Field telemetry of blade-rotor coupled torsional vibration

at Matuura Power Station Number 1 unit p 222 N92-14348

STEEPEST DESCENT METHOD Airfoil optimization with efficient gradient calculations

p 177 N92-13960 STEERABLE ANTENNAS

- Electronically steerable antenna for aircraft p 229 N92-15272 STIFFENING
- Representation of geometric stiffening in multibody p 217 A92-19463 system simulation STIFFNESS

Industrial code development p 227 N92-15083 STOCHASTIC PROCESSES

- Application of stochastic robustness to aircraft control systems p 204 A92-18620
- A stochastic regulator for integrated communication and control systems. I Formulation of control law. II Numerical analysis and simulation p 233 A92-19605

Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code

- DE92-0005971 p 229 N92-15392 STRAIN GAGES
- High temperature static strain gage development [NASA-CR-189044] p 195 N92-14037 STRAIN RATE

Limitations to the large strain theory p 219 A92-20356

STRATIFIED FLOW

Stratified flow around an axisymmetric body at small angle of attack STREAM FUNCTIONS (FLUIDS) p 172 A92-18385

Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363

STRESS INTENSITY FACTORS Fatigue crack initiation and small crack growth in several airframe alloys p 212 A92-19754

STRESS TENSORS Limitations to the large strain theory

p 219 A92-20356 STRESS-STRAIN RELATIONSHIPS

- Limitations to the large strain theory
- p 219 A92-20356 Review of investigations on aeronautical fatigue in the

Federal Republic of Germany [ETN-92-90317] p 225 N92-14397

STRINGERS

Fatigue of repaired composite structures p 214 N92-14411

STRUCTURAL ANALYSIS

- Static aeroelastic analysis for generic configuration p 174 A92-20201 wing aircraft payload considerations Structural for
- Modification: P-3C zero fuel weight increase [AD-A2426901 p 196 N92-15068

Industrial code development p 227 N92-15083 STRUCTURAL RELIABILITY

A concept for the revisions of structural inspection p 226 N92-14431 schedules STRUCTURAL STABILITY

Stability of intershaft squeeze film dampers

p 222 N92-14351 STRUCTURAL VIBRATION

Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions p 219 A92-20756

# STRUCTURAL VIBRATION

# SPUTTERING High temperature static strain gage development SQUEEZE FILMS

The stability of the steady state and bistable response

p 222 N92-14350

p 222 N92 14351

# STRUCTURAL WEIGHT

[NASA-CP-3122] p 222 N92-14346 Proceedings of Damping 1991, volume 3 [AD-A241313] p 225 N92-14386

STRUCTURAL WEIGHT Structural considerations for aircraft payload Modification: P-3C zero fuel weight increase

p 196 N92-15068 [AD-A2426901 SUBSONIC FLOW

Numerical prediction of subsonic turbulent flows over lender bodies at high incidence p 172 A92-18358 Numerical study on using sulfur hexafluoride as a wind slender bodies at high incidence tunnel test gas p 216 A92-18373

Influences of wind tunnel parameters on airfoil characteristics at high subsonic speeds p 173 A92-18769 Numerical calculation of subsonic and supersonic

aerodynamic loads around complex configuration vehicle p 175 A92-20488 Genuinely upwind algorithms for the multidimensional

p 175 A92-20733 Euler equations Research on inverse methods and optimization in Italy p 202 N92-13956

SUCTION Effect of suction on the stability of supersonic boundary

lavers, I - Second-mode waves, II - First-mode waves p 174 A92-19611

SULFUR FLUORIDES Numerical study on using sulfur hexafluoride as a wind p 216 A92-18373 tunnel test gas

SUPERCRITICAL FLOW Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 SUPERSONIC AIRCRAFT

Four decades of transonic fighter design

- p 193 A92-20203 SUPERSONIC BOUNDARY LAYERS Effect of suction on the stability of supersonic boundary
- layers. I Second-mode waves. II First-mode waves p 174 A92-19611 p 211 N92-14984 Supersonic combustion studies
- SUPERSONIC COMBUSTION
- An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861

Compressibility effects in thin channels with injection p 216 A92-18369 Supersonic combustion studies p 211 N9: SUPERSONIC COMBUSTION RAMJET ENGINES p 211 N92-14984

CFD application to 2D/3D flow fields in Scramjet enginø p 170 A92-17501 Scramjet research at the National Aerospace

Laboratory p 200 A92-17849 [AIAA PAPER 91-5076]

An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861 p 211 N92-14984 Supersonic combustion studies

SUPERSONIC FLIGHT

Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic needs

[AIAA PAPER 91-5038] p 171 A92-17826 Broadband shock-associated noise from supersonic jets p 235 A92-18683 in flight FALKE and COBRA technology development in

aerodynamics and aerothermodynamics p 183 N92-15017

SUPERSONIC FLOW

A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058] p 171 A92-17841 Prediction of steady and unsteady asymmetric vortical p 172 A92-18372 flows around circular cones Similarity solutions for supersonic axisymmetric flows p 173 A92-18387 p 173 A92-18680 Noise-driven flow Numerical calculation of subsonic and supersonic aerodynamic loads around complex configuration vehicle p 175 A92-20488 Genuinely upwind algorithms for the multidimensional Euler equations p 175 A92-20733 Newton's method solver for high-speed viscous p 176 A92-20736 separated flowfields Asymmetric separated flows at supersonic speeds p 176 A92-20742

Simple method of supersonic flow visualization using smoke p 219 A92-20764 The effects of winglets on low aspect ratio wings at supersonic Mach numbers [NASA-CR-4407] p 178 N92-13996

Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at p 181 N92-14987 super- and hypersonic speed

Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 Computation of aerodynamic coefficients on p 184 N92-15040 Hermes-Ariane5 configuration SUPERSONIC INLETS

Supersonic inlet flow computation p 171 A92-17502

SUPERSONIC JET FLOW Broadband shock-associated noise from supersonic jets

in flight p 235 A92-18683 Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence mode

[NASA-TM-105338] p 237 N92-14795 A survey of the broadband shock associated noise prediction methods

- [NASA-TM-105365] p 237 N92-14797 SUPERSONIC NOZZLES Formation of shocks within axisymmetric nozzles
- p 176 A92-20760 SUPERSONIC TURBINES
- The research progress on Hodograph Method of aerodynamic design at Tsinghua University
- p 177 N92-13974 SUPERSONIC WAKES

Sonic eddy - A model for compressible turbulence p 176 A92-20739 SUPERSONIC WIND TUNNELS

A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition [AIAA PAPER 91-5026]

- p 207 A92-17819 SURFACE DEFECTS Enhanced visual technique for rapid inspection of aircraft
- structures p 214 A92-17290 SURFACE ROUGHNESS

Wedge-induced turbulent boundary-layer separation on a roughened surface at Mach 6.0 p 175 A92-20379 SURFACE ROUGHNESS EFFECTS

Roughness effects on heat transfer from a NACA 0012 p 219 A92-20217 airfoil SURGES

- Whole aircraft lightning indirect effects evaluation using low level injection techniques p 192 A92-20134 SURVEYS
- General aviation activity and avionics survey, calendar ear 1989
- (PB91-179234) p 169 N92-13926 SWEEP EFFECT
- Enhancement of modal swept sine data by control of exciting forces p 215 A92-17562 SWEEP FREQUENCY

Whole aircraft lightning indirect effects evaluation using p 192 A92-20134 low level injection techniques SWEPT WINGS

Three-dimensional linear stability approach to transition on winds and bodies of revolution at incidence

p 172 A92-18361 Three-dimensional thermal structural analysis of a swept

cowl leading edge subjected to skewed shock-shock interference heating p 174 A92-20306 Numerical simulation of swept-wing flows

[NASA-CR-189457] p 180 N92-14969 SWIRLING

Experimental investigation of coannular jet flow with swirl along a centerbody p 172 A92-18367 SYSTEM FAILURES

Development of a calibrated software reliability model for flight and supporting ground software for avionic p 234 N92-15870 systems SYSTEM IDENTIFICATION

Identification of dynamic characteristics of flexible rotors p 220 N92-13962 as dynamic inverse problem SYSTEMS ENGINEERING

- Case for real-time syste [AIAA PAPER 91-3726] elopment - Quo vadis? p 231 A92-17594 Radar troubleshooting assistant expert system
- [AIAA PAPER 91-3764] p 231 A92-17626 Enhanced autopilot design through hardware-in-the-loop mulation p 204 A92-19103 simulation
- Some Aspects of uncertainty in computational fluid p 233 A92-19609 dynamics results
- Avionics systems development: Technological trends, conflicts, and cost issues in a changing European environment p 199 N92-14054
- Avionics reliability, durability, and integrity: Can they be p 200 N92-14056 independent of application? SYSTEMS INTEGRATION
- Performance improvements of an F-15 airplane with an integrated engine-flight control system p 205 A92-20204

Avionics technology beyond 2000

p 200 N92-14058

Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report [DOT/FAA/CT TN91/50] p 221 N92-14270

SUBJECT INDEX

Т

TABLES (DATA)

General aviation activity and avionics survey, calendar ear 1989

[PB91-1792341 p 169 N92-13926 FAA statistical handbook of aviation: Calendar year 1989

[PB91-202051] p 170 N92-13927 TAIL ASSEMBLIES

F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation (AD-A2426371

p 206 N92-15073 TECHNOLOGICAL FORECASTING International aviation (selected article)

p 170 N92-13991 [AD-A240986] TECHNOLOGY ASSESSMENT

International aviation (selected article)

- [AD-A240986] p 170 N92-13991 New Ways: Tiltrotor aircraft and magnetically levitated vehicles
- [OTA-SET-507] p 238 N92-14933 TECHNOLOGY UTILIZATION

Technology in the lives of an aircraft designer [AIAA PAPER 91-3069] p 192 A

NAA PAPER 91-3069] p 192 A92-20000 JPRS report: Science and technology. USSR: Space [JPRS-USP-91-007] p 211 N92-14101

TELEMETRY

Telemetry antenna patterns for single and multi-element p 188 A92-19216 arrays A new 1553 all-bus instrumentation monitor

p 198 A92-19252 Implementation and usage of the RJ program Data

Acquisition System Ground Station p 210 A92-19257 An integrated real-time turbine engine flight test svstem p 201 A92-19275 TELEOPERATORS

Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-18611

TEMPERATURE CONTROL

A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft [AIAA PAPER 91-5036]

p 210 A92-17825 A probabilistic method for monitoring the remaining life

of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 TEMPERATURE MEASUREMENT

Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 TEMPERATURE MEASURING INSTRUMENTS

Ablation and temperature sensors flight for measurements in reentry body heat shields

p 227 N92-15004

TERRAIN A multidimensional terrain model for low altitude tracking p 205 A92-19107 scenarios

**TERRAIN FOLLOWING AIRCRAFT** 

A low-altitude breakthrough system using optimal path arrain following p 205 A92-20483 terrain following

TEST FACILITIES 'Spaceplanes' R&D status of Japan

rotating composite rotor blades

landing systems

THERMAL ANALYSIS

models

aerothermodynamics

[AIAA PAPER 91-5035]

TAIAA PAPER 91-5063]

Image-supported navigation for

performance and simulation requirements

[AIAA PAPER 91-5002] p 209 A92-17802 Thrust nozzle test facility at DLR Cologne

- [AIAA PAPER 91-5024] p 206 A92-17818 program
- Conducting the NASP ground test [AIAA PAPER 91-5029] p 209 A92-17820 Heavy metal --- fighter aircraft test rigs p 207 A92-18100

Design and implementation of a total flight test system

Experimental investigation of periodically excited

Review of the European hypersonic wind tunnel

Application of the STAPAT II code to hypersonic vehicle

Analysis of cooling systems for hypersonic aircraft

Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow

p 189 A92-19278

p 218 A92-20213

testing instrument

p 189 N92-14012

p 209 N92-15043

p 209 A92-17824

p 216 A92-17843

p 212 N92-15877

THERMAL CONTROL COATINGS Protective coatings of thermal barrier type p 214 A92-20349 THERMAL CYCLING TESTS High temperature low cycle fatigue of single crystal nickel base superallovs p 213 A92-19796 THERMAL FATIGUE High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796 Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799 THERMAL PROTECTION The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009 Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020 Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise p 227 N92-15027 problems THERMODYNAMIC EQUILIBRIUM Linear acoustics in gas mixtures with rate processes p 238 N92-15013 Hypersonic viscous shock layer in thermochemical p 183 N92-15014 nonequilibrium THERMOELASTICITY Industrial code development p 227 N92-15083 THERMOGRAPHY Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique p 182 N92-14994 Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared p 208 N92-15003 thermography THIN AIRFOILS Numerical prediction of subsonic turbulent flows ove p 172 A92-18358 slender bodies at high incidence A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin winos p 178 N92-13997 [NASA-CR-4414] THIN FILMS High temperature static strain gage development [NASA-CR-189044] p 195 N92-1 p 195 N92-14037 THIN WINGS A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin wings [NASA-CR-4414] p 178 N92-13997 THREAT EVALUATION Optimal control problems with maximum functional p 232 A92-18616 THREE DIMENSIONAL BODIES Incompressible steady aerodynamics using a standard p 174 A92-20218 finite element code THREE DIMENSIONAL BOUNDARY LAYER Effect of nose shape on three-dimensional stagnation region streamlines and heating rates p 171 A92-17822 [AIAA PAPER 91-5032] Numerical solution of the boundary-layer equations for p 174 A92-20211 a general aviation fuselage THREE DIMENSIONAL FLOW CFD application to 2D/3D flow fields in Scramiet p 170 A92-17501 engine Three-dimensional solution-adaptive grid generation on p 172 A92-18352 of low-frequency composite configurations Three-dimensional calculation low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110 Three-dimensional thermal structural analysis of a swept cowl leading edge subjected to skewed shock-shock p 174 A92-20306 interference heating Engineering calculations of three-dimensional inviscid p 175 A92-20378 hypersonic flowfields Evaluation of a bounded high-resolution scheme for p 201 A92-20734 combustor flow computations Upwind scheme for solving the Euler equations on p 175 A92-20735 unstructured tetrahedral meshes Variational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953 Numerical investigations in three-dimensional internal flows [NASA-CR-189467] p 221 N92-14313 Transonic Navier-Stokes computations for a spinning body of revolution [AD-A241015] p 180 N92-14972 Grid impact on 3D hypersonic flows p 184 N92-15041 THREE DIMENSIONAL MODELS Three dimensional hypersonic inlets - Low speed performance [AIAA PAPER 91-5021] p 171 A92-17817

Three-dimensional linear stability approach to transition on wings and bodies of revolution at incidence p 172 A92-18361 A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin wings

- [NASA-CR-4414]
   p 178
   N92-13997

   Viscous shock-layer equations for the calculation of reentry aerothermodynamics
   p 183
   N92-15008

   Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection
   p 184
   N92-15025

   THRUST CONTROL
   Simulation requirements for RCS plume: Flowfield
   Simulation
   Flowfield
- interaction modelling on a winged reentry vehicle p 181 N92-14985 Experimental investigation of transverse jet effects
- related to hypersonic space vehicles p 182 N92-14995
- TILT ROTOR AIRCRAFT New Ways: Titrotor aircraft and magnetically levitated vehicles
- [OTA-SET-507] p 238 N92-14933 TIME DIVISION MULTIPLEXING
- Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report
- [D017/FAA/CT-TN91/50] p 221 N92-14270 TIME MARCHING
- Analysis of an advanced ducted propeller subsonic inlet [NASA-TM-105393] p 179 N92-14002
- TIME OPTIMAL CONTROL
- Time-periodic control of a multi-blade helicopter p 204 A92-18626 TITANIUM ALLOYS
- Inertia-friction welding of an advanced rapidly solidified titanium alloy p 212 A92-18898 Prediction of fatigue crack growth in a Ti-6AI-4V fan
- disk forging under spectrum loading p 213 A92-19817 TITANIUM COMPOUNDS Thermo-mechanical fatigue crack growth in aircraft
- engine materials p 213 A92-19799 TOKAMAK DEVICES
- Scoping studies for small steady-state tokamaks for divertor testing
- [DE92-000740] p 238 N92-15761 TOLERANCES (MECHANICS)
- Fatigue and damage tolerance verification of aircraft structures p 217 A92-19677 TOLLMIEN-SCHLICHTING WAVES
- Numerical simulation of swept-wing flows [NASA-CR-189457] p 180 N92-14969 TOROIDAL PLASMAS
- Scoping studies for small steady-state tokamaks for divertor testing
- [DE92-000740] p 238 N92-15761 TORSION
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348
- TORSIONAL VIBRATION
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit
- p 222 N92-14348
- Nonlinear landing gear behavior at touchdown p 192 A92-19606 TOUGHNESS
- Mechanical qualification tests for materials used in the fabrication of aircraft parts
- [CEAT-M5-5443/01] p 195 N92-14042 TRACKING PROBLEM
- A multidimensional terrain model for low altitude tracking scenarios p 205 A92-19107 TRAILING EDGE FLAPS
- Flow over a delta wing at hypersonic speeds p 181 N92-14993
- TRAILING EDGES
- Application of direct inverse analogy method (DIVA) and viscous design optimization techniques
- p 176 N92-13951 Navier-Stokes analysis of turbulent boundary layer and
- wake for two-dimensional lifting bodies p 221 N92-14309 TRAJECTORY CONTROL
- Optimal control problems with maximum functional
- p 232 A92-18616 Rapid near-optimal aerospace plane trajectory generation and guidance [NASA-CR-189469] p 205 N92-14066
- TRAJECTORY OPTIMIZATION Automated trajectory synthesis for hypersonic vehicles
- using energy management and variational calculus techniques p 210 A92-19061 A low-altitude breakthrough system using optimal path terrain following p 205 A92-20483 Rapid near-optimal aerospace plane trajectory
- generation and guidance [NASA-CR-189469] p 205 N92-14066

TRANSITION FLOW

- Three-dimensional linear stability approach to transition on wings and bodies of revolution at incidence p 172 A92-18361
- Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027 Applicability of bridging methods to hypersonic rarefied
- flow aerodynamics of reentry vehicles p 184 N92-15032
- Transitional flows around re-entry bodies p 184 N92-15035
- TRANSONIC COMPRESSORS
- Design of transonic compressor cascades using hodograph method p 202 N92-13973 The research progress on Hodograph Method of
- aerodynamic design at Tsinghua University p 177 N92-13974
- TRANSONIC FLIGHT
  - FALKE and COBRA technology development in aerodynamics and aerothermodynamics
- p 183 N92-15017
- Numerical study on using sulfur hexafluoride as a wind tunnel test gas p 216 A92-18373
- Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110
- Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction
- p 193 A92-20202 Inviscid drag prediction for transonic transport wings using a full-potential method p 174 A92-20212
- Evaluation of Euler solvers for transonic wing-fuselage geometries p 174 A92-20214
- Sonic eddy A model for compressible turbulence p 176 A92-20739
- Aerodynamic aircraft design methods and their notable applications: Survey of the activity in Japan p 193 N92-13930
  - A comparison of two closely-related approaches to
- aerodynamic design optimization \* p 193 N92-13933 Variational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953
- transonic flow with shocks in rotor p 176 N92-13953 Analysis and design of transonic airfoils using streamwise coordinates p 194 N92-13955
- streamwise coordinates p 194 N92-13955 Research on inverse methods and optimization in Italy
- p 202 N92-13956 Design optimization of transonic airfoils
- p 177 N92-13961 An inverse method with regularity condition for transonic
- airfoil design p 177 N92-13969 The research progress on Hodograph Method of
- aerodynamic design at Tsinghua University p 177 N92-13974 Transonic Navier-Stokes computations for a spinning
- body of revolution
  - [AD-A241015] p 180 N92-14972 Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage
  - [AD-A242656] p 185 N92-15045 TRANSONIC WIND TUNNELS Influences of wind tunnel parameters on airfoil
  - characteristics at high subsonic speeds p 173 A92-18769
  - The NASA Langley Research Center 0.3-meter transonic cryogenic tunnel microcomputer controller source code [NASA-CR-189556] p 209 N92-15077 TRANSPONDERS
  - The problem of multiple solutions in area navigation and computed centerline operations with the microwave landing system
  - [AD-A242757]
     p 191
     N92-15058

     TRANSPORT AIRCRAFT
     Cabin structural vibration and noise for transport aircraft
     p 192
     A92-17876

     Dornier 328 first flight
     p 192
     A92-19924
  - On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931 TRANSPORTATION NETWORKS Electronic systems in transportation [TP-9983] p 189 N92-14009 TRAVELING WAVES
- Noise-driven flow p 173 A92-18680 TRIBOLOGY
  - Seal related development activities at EG/G
  - p 228 N92-15095 Tribology needs for future space and aeronautical systems
- [NASA-TM-104525] p 214 N92-15191 TURBINE BLADES
  - PVD coatings for aircraft turbine blades
  - p 216 A92-17950 Large chord turbine cascade testing at engine Mach and Reynolds number p 173 A92-18771

p 215 A92-17414

p 169 N92-13926

p 184 N92-15039

p 172 A92-18372

modeling

TURBINE	ENGINES
---------	---------

Multiaxial load spectra in a cooled gas turbine blade under in-service conditions p 201 A92-19696 Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions p 219 A92-20756

Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391

TURBINE ENGINES An integrated real-time turbine engine flight test

- ystem p 201 A92-19275 LDV measurements and investigation of flow field system Technology needs for high speed rotorcraft (3) [NASA-CR-177592] p 195 Noo craft
- Universal weaving for turbine engine composite preforms [AD-A237667] p 202 N92-14059
- Turbine engine diagnostics system study p 202 [DOT/FAA/CT-91/16] N92-14064 TURBINE PUMPS
- Limit cycle vibrations in turbomachinery p 211 N92-14108 [NASA-TP-3181] Nonlinear rotordynamics analysis Space Shuttle Main
- Engine turbopumps [NASA-CR-184263] p 221 N92-14344 Test results for rotordynamic coefficients of the SSME
- HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357 Dynamic characteristics and stability analysis of space
- p 224 N92-14366 shuttle main engine oxygen pump Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391
- TURBINE WHEELS Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817
- Fatigue testing of a gas turbine fan disc p 217 A92-19818
- Test results for rotordynamic coefficients of the SSME HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357

# TURBOFAN ENGINES

- International aviation (selected article) [AD-A240987] p1 p 170 N92-13992 Theoretical models for duct acoustic propagation and p 236 N92-14782 radiation Design and performance of duct acoustic treatment
- p 236 N92-14783 TURBOFANS

Study of a new airfoil used in reversible axial fans p 177 N92-13970

TURBOGENERATORS

- The application of a cylindrical-spherical floating ring bearing device to control stability of p 224 N92-14371 as a turbogenerators TURBOMACHINE BLADES
- Aerodynamic damping of turbomachines --- Russian book in of blade vibrations p 200 A92-18198 TURBOMACHINERY
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances
- p 201 N92-13939 Research on inverse methods and optimization in Italy p 202 N92-13956
- Limit cycle vibrations in turbomachinery [NASA-TP-3181] p 211 N92-14108 Rotordynamic Instability Problems in High-Performance
- Turbomachinery, 1990 [NASA-CP-3122] p 222 N92-14346
- A simplified method for predicting the stability of aerodynamically excited turbomachinery p 224 N92-14364
- Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling p 224 N92-14370 machines
- TURBOPROP AIRCRAFT
- On-board data acquisition system for Embraer's BA123 p 198 A92-19251 CBA123 F27 aging aircraft programme emphasizes corrosion p 186 A92-20024 prevention TURBULENCE
- The application of experimental data to blade wake interaction noise prediction [NASA-CR-189461] p 237 N92-14789
- TURBULENCE EFFECTS Direct computation of turbulence and noise
- [NASA-CR-187616] p 236 N92-14788 TURBULENCE MODELS
- Algebraic turbulence modeling for unstructured and adaptive meshes p 216 A92-18362 Sonic eddy - A model for compressible turbulence
- p 176 A92-20739 Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies

p 221 N92-14309

Determination of rotordynamic coefficients for labyrinth rotordynamic seals and application to design calculations p 223 N92-14360 A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052

- TURBULENT BOUNDARY LAYER Confined normal-shock/turbulent-boundary-layer interaction followed by an adverse pressure gradient p 172 A92-18365
- Wedge-induced turbulent boundary-layer separation on a roughened surface at Mach 6.0 p 175 A92-20379 Turbulent boundary-layer characteristics over a
- flat-plate/wedge configuration at Mach 6 p 176 A92-20761
- Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies
  - p 221 N92-14309
- Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage [AD-A242656] p 185 N92-15045
- TURBULENT FLOW Numerical prediction of subsonic turbulent flows over
- slender bodies at high incidence p 172 A92-18358 Numerical study on using sulfur hexafluoride as a wind p 216 A92-18373 tunnel test gas
- A perspective on aerospace CFD p 169 A92-20145 CFD helps the Air Force fly right p 169 A92-20146 Navier-Stokes analysis of turbulent boundary laver and
- wake for two-dimensional lifting bodies p 221 N92-14309 Evaluation of rotordynamic coefficients of look-through
- labyrinths by means of a three volume bulk flow model p 223 N92-14356 Dynamic characteristics and stability analysis of space
- shuttle main engine oxygen pump p 224 N92-14366 Effect of eccentricity on the static and dynamic performance of a turbulent hybrid bearing p 225 N92-14373
- Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for space vehicles p 181 N92-14992 TURBULENT MIXING
- Compressibility effects in thin channels with injection
- p 216 A92-18369 p 236 N92-14784 Jet noise suppression Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model
- [NASA-TM-105338] p 237 N92-14795 p 211 N92-14984 Supersonic combustion studies
- TURBULENT WAKES
- Stratified flow around an axisymmetric body at small p 172 A92-18385 angle of attack TVD SCHEMES
- Hypersonic aerothermodynamic computations using a point-implicit TVD method p 183 N92-15006 p 183 N92-15006 TWO DIMENSIONAL BODIES
- Two-dimensional effects in a triangular convecting fin p 219 A92-20324 Navier-Stokes analysis of turbulent boundary layer and
- wake for two-dimensional lifting bodies p 221 N92-14309
- TWO DIMENSIONAL BOUNDARY LAYER Effect of suction on the stability of supersonic boundary
- layers. I Second-mode waves. II First-mode waves p 174 A92-19611 TWO DIMENSIONAL FLOW
- CFD application to 2D/3D flow fields in Scramjet engine p 170 A92-17501 Aerodynamic sensitivity analysis methods for the
- compressible Euler equations TWO DIMENSIONAL MODELS p 233 A92-19619 A multidimensional terrain model for low altitude tracking scenarios
- cenarios p 205 A92-19107 A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin wings INASA-CR-4414
- 178 N92-13997 TWO STAGE PLASMA ENGINES Aerothermodynamic challenges Saenger the of
- space-transportation system p 184 N92-15042

# U

U.S.S.R.

- Soviet CFD An international perspective
- p 233 A92-20150 JPRS report: Science and technology. USSR: Space [JPRS-USP-91-007] p 211 N92-14101
- Rapid ultrasonic scanning of aircraft structures p 215 A92-17292 ULTRASONIC TESTS

Rapid ultrasonic scanning of aircraft structures p 215 A92-17292

VACUUM CHAMBERS

ULTRASONICS

UNITED STATES

[PB91-1792341

UNSTEADY AERODYNAMICS

flows around circular cones

using finite element

dication of

year 1989

programs

U

UF

US

Ultrasonic motor utilizing elastic fin rotor

General aviation activity and avionics survey, calendar

Aerothermodynamics for United States advanced

Prediction of steady and unsteady asymmetric vortical

Resonance prediction for slotted circular wind tunnel sing finite element p 235 A92-18388

alactic

- Experimental investigation of periodically excited p 218 A92-20213 rotating composite rotor blades VACUUM DEPOSITION
- PVD coatings for aircraft turbine blades p 216 A92-17950
- VALVES Hydraulic actuator system for rotor control
- p 224 N92-14363 VANES High temperature static strain gage development
- p 195 N92-14037 [NASA-CR-189044] Ceramic regenerator program [NASA-CR-189053] p 225 N92-14374
- VARIABLE GEOMETRY STRUCTURES
- A geometric approach to regulator and tracker design for an aerospace plane [AIAA PAPER 91-5054] p 203 A92-17837
- VARIABLE SWEEP WINGS
  - History of EPOS air-launched spaceplane project p 211 N92-14103
- VARIATIONAL PRINCIPLES
- Variational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953 VELOCITY DISTRIBUTION
- Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 p 220 N92-13950 VENTILATION
- Study of a new airfoil used in reversible axial fans
- p 177 N92-13970 VERTICAL TAKEOFF AIRCRAFT
- Technology needs for high speed rotorcraft (3) [NASA-CR-177592] p 195 N92 p 195 N92-14039

SUBJECT INDEX

SUBJECT INDEX VIBRATION Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades [NASA-CR-189018] p 195 N92-14038 Limit cycle vibrations in turbomachinery NASA-TP-31811 p 211 N92-14108 [NASA-TP-3181] Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348 The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies p 222 N92-14349 VIBRATION DAMPING Cabin structural vibration and noise for transport p 192 A92-17876 aircraft blade vibrations in Aerodynamic damping of p 200 A92-18198 turbomachines --- Russian book Parameter insensitive control utilizing eigenspace methods --- for flutter suppression in aeroelastic vehicles p 204 A92-18615 Structure/control design synthesis of active flutter suppression system by goal programming p 204 A92-18621 Time-periodic control of a multi-blade helicopter p 204 A92-18626 Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990 [NASA-CP-3122] p 222 N92-14346 The stability of the steady state and bistable response of a flexible rotor supported on squeeze film dampers p 222 N92-14350 Stability of intershaft squeeze film dampers p 222 N92-14351 Proceedings of Damping 1991, volume 3 N92-14386 [AD-A241313] p 225 Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391 Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067 Flutter suppression via piezoelectric actuation p 197 N92-15070 [NASA-TM-104120] VIBRATION EFFECTS Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-18611 Numerical calculation of modulation transfer functions for low frequency mechanical vibrations p 235 A92-19982 p 182 N92-15000 High enthalpy nozzle flows VIBRATION ISOLATORS Nonlinear landing gear behavior at touchdown p 192 A92-19606 Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391 VIBRATION MEASUREMENT Rub induced rotor/stator vibration analysis on CF700 engine [NRC-TR-ENG-007] p 202 N92-14060 Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348 VIBRATION MODE Enhancement of modal swept sine data by control of xciting forces p 215 A92-17562 VIBRATION TESTS Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions p 219 A92-20756 Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpieces p 219 A92-20771 VIBRATIONAL SPECTRA Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and p 235 A92-20301 Herzfeld VIDEO COMMUNICATION Compression techniques for video telemetry p 188 A92-19214 VIDEO DATA

### Compression techniques for video telemetry p 188 A92-19214 VIDEO EQUIPMENT

- DARPA high resolution display technologies p 218 A92-19977 Image-supported navigation for testing instrument landing systems p 189 N92-14012 VISCOUS DAMPING
- Proceedings of Damping 1991, volume 3 [AD-A241313] p 225 N92-14386 VISCOUS FLOW
- Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736 Application of direct inverse anlogy method (DIVA) and viscous design optimization techniques
  - p 176 N92-13951

A unified viscous theory of lift and drag of 2-D thin airfoils and 3-D thin winos [NASA-CR-4414] p 178 N92-13997 SIMOUN and Scirocco wind tunnel nozzle viscous flow p 208 N92-14999 study Verification and application of the NSFLEX method for hypersonic flow conditions p 182 N92-15005 Viscous shock-layer equations for the calculation of p 183 N92-15008 reentry aerothermodynamics Hypersonic viscous shock layer in thermochemical nonequilibrium p 183 N92-15014

Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies p 227 N92-15029

Progress with multigrid schemes for hypersonic flow problems

- [NASA-CR-189579] p 185 N92-15047 A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 VISUAL FLIGHT RULES
- Operational survey: VFR heliport approaches and departures
- [SCT-91RR-26] p 190 N92-14033 VOICE COMMUNICATION
- Electronically steerable antenna for aircraft p 229 N92-15272
- VORTEX BREAKDOWN Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed
- [NASA-TP-3111] p 179 N92-14968 VORTEX FILAMENTS Analytical/numerical matching and periodic inversion:
- Two advances in free wake analysis

# VORTEX GENERATORS

Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959

- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics
- [NASA-TM-105321] p 179 N92-13998 Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage [AD-A242656] p 185 N92-15045

# VORTEX SHEDDING

Experimental investigation of coannular jet flow with swirf along a centerbody p 172 A92-18367 VORTICES

Analysis of spiraling vortical flows around slender delta wings moving in an inviscid medium p 173 A92-18900 A perspective on aerospace CFD p 169 A92-20145 Instabilities of flows over bodies at large incidence

p 176 A92-20738 Sonic eddy - A model for compressible turbulence p 176 A92-20739

Analytical/numerical matching and periodic inversion: Two advances in free wake analysis

p 178 N92-13994 Definition of the unsteady vortex flow over a wing/body configuration

[NASA-CR-180083] p 178 N92-13995

- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics
- [NASÁ-TM-105321] p 179 N92-13998 The application of experimental data to blade wake interaction noise prediction [NASA-CR-189461] p 237 N92-14789

[NASA-CR-189461] p 237 N92-14789 Wind tunnel investigation of vortex flows on F/A-18

configuration at subsonic through transonic speed [NASA-TP-3111] p 179 N92-14968 VORTICITY

Prediction of steady and unsteady asymmetric vortical flows around circular cones p 172 A92-18372 Analytical/numerical matching and periodic inversion: Two advances in free wake analysis

p 178 N92-13994 A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational

fluid dynamics [NASA-TM-105321] p 179 N92-13998

# W

### WAKES

Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies

	p 221	N92-14309
WALL FLOW		
Noise-driven flow	p 173	A92-18680
WAVE INTERACTION		
Numerical simulation of swept	wing flows	
[NASA-CR-189457]	p 180	N92-14969
WAVE PROPAGATION		
Noise-driven flow	p 173	A92-18680

### WAVE SCATTERING SATCOM antenna siting study on P-3C aircraft, volume 1

WING LOADING

[NASA-CR-189514] p 221 N92-14262 WEAPON SYSTEMS Evolution of avionic systems architecture, from the p 198 N92-14047 1950's to the present Avionics technology beyond 2000 p 200 N92-14058 WEAPONS DEVELOPMENT Avionics technology beyond 2000 p 200 N92-14058 WEAR Filter debris analysis: A concrete approach to wear diaonosis [DREP-TM-88-20] p 222 N92-14345 Tribology needs for future space and aeronautical emetere [NASA-TM-104525] p 214 N92-15191 WEAVING Universal weaving for turbine engine composite preforms [AD-A237667] p 202 N92-14059 WEDGE FLOW Wedge-induced turbulent boundary-layer separation on p 175 A92-20379 a roughened surface at Mach 6.0 Turbulent boundary-layer characteristics over a flat-plate/wedge configuration at Mach 6 p 176 A92-20761 Development of a CFD code for analysis of fluid dynamic p 228 N92-15084 forces in seals WIND MEASUREMENT Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and wind velocity, and wind measurements from aircraft inertial navigation systems p 188 A92-18172 WIND TUNNEL MODELS Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7 p 173 A92-18770 Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage [AD-A242656] p 185 N92-15045 Flutter suppression via piezoelectric actuation [NASA-TM-104120] p 197 NS p 197 N92-15070 WIND TUNNEL NOZZLES A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition [AIAA PAPER 91-5026] p 207 A92-17819 SIMOUN and Scirocco wind tunnel nozzle viscous flow study p 208 N92-14999 WIND TUNNEL TESTS Numerical study on using sulfur hexafluoride as a wind tunnel test das p 216 A92-18373 Broadband shock-associated noise from supersonic jets in flight p 235 A92-18683 Model oscillations at high angle of attack in a low speed wind tunnel test [IAF PAPER ST-91-001] p 175 A92-20649 Control system design for the free drop test of external wind tunnel stores in a [IAF PAPER ST-91-002] n 207 A92-20650 International aviation (selected articles) p 170 N92-13993 [AD-A241119] Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed [NASA-TP-3111] p 179 N92-14968 FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017 Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage AD-A242656] p 185 N92-15045 Results of an Icing test on a NACA 0012 airfoil in the [AD-A242656] NASA Lewis Icing Research Tunnel

[NASA-TM-105374] p 185 N92-15051 Flutter suppression via piezoelectric actuation

[NASA-TM-104120] p 197 N92-15070 WIND TUNNELS

The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009

### WIND TURBINES

Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code

[DE92-000597] p 229 N92-15392 WIND VELOCITY

Fair weather convection and light aircraft accidents [IAF PAPER ST-91-004] p 186 A92-20651 WING LOADING

A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058] p 171 A92-17841

Monitoring load experience of individual aircraft [NLR-TP-90084-U] p 196 N92-15065

# WING OSCILLATIONS

# WING OSCILLATIONS

Structure/control design synthesis of active flutter suppression system by goal programming

p 204 A92-18621 Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction

p 193 A92-20202 WING PANELS

Flow separation patterns over an F-14A aircraft wing p 174 A92-20205

WING PLANFORMS

Analysis and design of planar and non-planar wings for induced drag minimization [NASA-CR-189509] p 179 N92-13999

WING PROFILES Inviscid drag prediction for transonic transport wings using a full-potential method p 174 A92-20212 p 174 A92-20212 Upwind scheme for solving the Euler equations on unstructured tetrahedral meshes p 175 A92-20735 Research on inverse methods and optimization in Italy p 202 N92-13956

# WINGLETS

The effects of winglets on low aspect ratio wings at supersonic Mach numbers [NASA-CR-4407] p 178 N92-13996

WINGS

Review of aerodynamic design in the Netherlands p 193 N92-13929 Aerodynamic aircraft design methods and their notable

applications: Survey of the activity in Japan p 193 N92-13930

Application of direct inverse analogy method (DIVA) and viscous design optimization techniques p 176 N92-13951

An inverse method with regularity condition for transonic rfoil design p 177 N92-13969 airfoil design Definition of the unsteady vortex flow over a wing/body

configuration [NASA-CR-180083] p 178 N92-13995 The effects of winglets on low aspect ratio wings at supersonic Mach numbers

[NASA-CR-4407] p 178 N92-13996 Analysis and design of planar and non-planar wings for

induced drag minimization [NASA-CR-189509] p 179 N92-13999 Airbus Industrie A330/A340: Full scale fatigue test of

center fuselage and wing p 226 N92-14425 Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed [NASA-TP-3111] p 179 N92-14968

WORKSTATIONS DARPA high resolution display technologies p 218 A92-19977

### X-29 AIRCRAFT

Evaluations of X-29 high-AOA regime show promise for p 192 A92-19925 future fighters X-30 VEHICLE

Х

Conducting the NASP ground test program AIAA PAPER 91-5029] p 209 A92-17820 [AIAA PAPER 91-5029]

Dynamics and control of hypersonic vehicles - The integration challenge for the 1990's p 203 A92-17840 [AIAA PAPER 91-5057]

 [AIAA PAPEH 91-0007]
 p 200
 house

 Hydrogen exhaust gas disposition by afterburning

 [AIAA PAPER 91-5075]
 p 200
 A92-17848

 Hypersonic materials
 p 212
 A92-18002

A-28

# PERSONAL AUTHOR INDEX

AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

April 1992

# 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.

### ABGRALL, R.

Numerical simulations around models in hypersonic wind tunnels p 182 N92-14998 ABUMERI, G. H.

Α

- Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 ACHARYA. MUKUND
- Detection of flow state in an unsteady separating flow p 219 A92-20741
- ADAMS, J. D.
- Operational design factors for NASP derived vehicles [AIAA PAPER 91-5081] p 210 A92-17851 ADAMS, WILLIAM M., JR.
- Parameter insensitive control utilizing eigenspace methods p 204 A92-18615 ADAMSON, T. C., JR.
- Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363 ADVANI, S.
- Flight simulation p 207 N92-13982 AFFELT, E.
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424

# AGRAWAL, SHREEKANT

- Evaluation of Euler solvers for transonic wing-fuselage geometries p 174 A92-20214 AHUMADA, A.
- Sensor fusion for synthetic vision

[AIAA PAPER 91.3730] p 197 A92-17597 AL-MAAITAH, A. A.

- Effect of suction on the stability of supersonic boundary layers. I - Second-mode waves. II - First-mode waves p 174 A92-19611
- ALLEGRE, J. Experimental investigation of transverse jet effects
- related to hypersonic space vehicles p 182 N92-14995 ALPERINE, S.
- Protective coatings of thermal barrier type p 214 A92-20349
- ALTHAUS, JOSEF
  - Hydraulic actuator system for rotor control p 224 N92-14363

ALZIARYDEROQUEFORT, T.

- Infrared measurements of aerodynamic heating in hypersonic wind tunnel p 208 N92-15002 AN. C.-F.
- Analysis and design of transonic airfoils using streamwise coordinates p 194 N92-13955 AN. JINWEN
- A low-altitude breakthrough system using optimal path terrain following p 205 A92-20483 ANDERSON, BERNHARD H.
- Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959
- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics [NASA-TM-105321] p 179 N92-13998
- ANDERSON, MARK R.
- Three dimensional hypersonic inlets Low speed performance [AIAA PAPER 91-5021] p 171 A92-17817
- [AIAA PAPER 91-5021] p 1/1 A92-1/81/ ANDERSON, W. K.
- Numerical study on using sulfur hexafluoride as a wind tunnel test gas p 216 A92-18373 ANDERSON, W. L.
- High temperature static strain gage development [NASA-CR-189044] p 195 N92-14037
- ANDO, YASUNORI CFD application to 2D/3D flow fields in Scramjet engine p 170 A92-17501
- Numerical simulation for various flowfields of aero-engine components p 200 A92-17503 ANOLL, ROBERT K. Rotorcraft low altitude IFR benefit/cost analysis:
- Operations analysis [SCT-90RR-44] p 191 N92-15061
- ARMSTRONG, RICHARD Knowledge maintenance in an evolving system using
- a deep structure representation [AIAA PAPER 91-3941] p 231 A92-17605
- ARNAL, D. Three-dimensional linear stability approach to transition
- on wings and bodies of revolution at incidence p 172 A92-18361
- ATHAVALE, MAHESH M. Development of a CFD code for analysis of fluid dynamic forces in seals p 228 N92-15084 ATTISHA. M. R.
- A unique approach to aircraft conflict resolution using artificial intelligence techniques p 190 N92-14029 AUSTIN. MICHAEL E.
- Failure environment analysis tool (FEAT) development status
- [AIAA PAPER 91-3803] p 232 A92-17654 AUWETER-KURTZ, M.
- The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009
- AVNI, MICHA Electronic systems in transportation
- [TP-9963] p 189 N92-14009 AYMERDELACHEVALERIE, D.
- Infrared measurements of aerodynamic heating in hypersonic wind tunnel p 208 N92-15002 A717. A.
  - Two-dimensional effects in a triangular convecting fin p 219 A92-20324

# В

- BABINSKY, H.
- Flow over a delta wing at hypersonic speeds p 181 N92-14993 BABISH. CHARLES A., III
- Application of the STAPAT II code to hypersonic vehicle aerothermodynamics [AIAA PAPER 91-5035] p 209 A92-17824
- [AIAA PAPER 91-5035] p 209 A92-17824 BACKSTROM, M. G.
  - The use of finite difference electromagnetic analysis in the design and verification of modern aircraft p 192 A92-20136

BAESLACK, W. A., III

- Inertia-friction welding of an advanced rapidly solidified titanium alloy p 212 A92-18898 BAIK, KI-YOUNG
- Resonance prediction for slotted circular wind tunnel using finite element p 235 A92-18388 BAILEY, R. S.
- High temperature static strain gage development [NASA-CR-189044] p 195 N92-14037 BAKHLE, MILIND A.
- Time domain flutter analysis of cascades using a full-potential solver p 176 A92-20747
- BALAGEAS, D. L. Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 Ablation and temperature sensors for flight
- Ablation and temperature sensors for flight measurements in reentry body heat shields p 227 N92-15004

# BALAKRISHNA, S.

- The NASA Langley Research Center 0.3-meter transonic cryogenic tunnel microcomputer controller source code [NASA-CR-189556] p 209 N92-15077 BALAKRISHNAN, G.
- Compressibility effects in thin channels with injection p 216 A92-18369

# BANKS, H. T.

- Approximation methods for control of acoustic/structure models with piezoceramic actuators [NASA-CR-189578] p 234 N92-15658
- [NASA-CR-189578] p 234 N92-1565 BARBERO, J.
  - Electronically steerable antenna for aircraft p 229 N92-15272

### BARD, STEVEN

- Multicomponent gas sorption Joule-Thomson refrigeration [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
- BARILLOT, P. Analysis tools of ONERA and DLR for the
- aerothermodynamics of reentry vehicles p 211 N92-14977

# BARNERSSOI, HANS

- Development and evaluation of a finite element model for a fiber composite helicopter fuselage [MBB-UD-0584-90-PUB] p 196 N92-15066
- BARRIE, DOUGLAS Heavy metal p 207 A92-18100
- BARRON, R. M. Analysis and design of transonic airfoils using
- streamwise coordinates p 194 N92-13955 BARTLETT, C. S.
- Hydrogen exhaust gas disposition by afterburning [AIAA PAPER 91-5075] p 200 A92-17848 BASKHARONE, ERIAN
- Test results for rotordynamic coefficients of the SSME HPOTP turbine interstage seal with two swirt brakes p 223 N92-14357

# BATCHO, P.

- Direct computation of turbulence and noise [NASA-CR-187616] p 236 N92-14788
- BATINA, JOHN T. A fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes
- [NASA-TM-104186] p 185 N92-15050 BATTRICK. B.
- Aerothermodynamics for Space Vehicles [ESA-SP-318] p 180 N92-14973
- BAUM, J. Formation of shocks within axisymmetric nozzles
  - p 176 A92-20760

# BAYSAL, OKTAY

- Aerodynamic sensitivity analysis methods for the compressible Euler equations p 233 A92-19619 BECKER, A.
- DME growth elements and their use with MLS p 189 N92-14018

# BELCASTRO, CELESTE M.

Formulation of a strategy for monitoring control integrity in critical digital control systems [NASA-TM-104158] p 206 N92-15075

# BELCHER, P. J.

Automated trajectory synthesis for hypersonic vehicles using energy management and variational calculus p 210 A92-19061 techniques BELL R. A.

An inverse method for the aerodynamic design of three-dimensional aircraft engine nacelles p 194 N92-13958

### BELL. WAYNE E.

Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report

[DOT/FAA/CT-TN91/50] p 221 N92-14270 BENDER, THOMAS R.

Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 BENNETT, ROBERT M.

The benchmark aeroelastic models program: Description and highlights of initial results p 185 N92-15049 [NASA-TM-104180]

BENNETT, WILLIAM H. Regulation of relaxed static stability aircraft p 203 A92-18463

BENSEL, L. W.

Evaluation of triple simultaneous parallel II S approaches spaced 4300 feet apart, phase 4a

p 191 N92-14034 [ACD-340] BENSMAN, D. A.

SATCOM antenna siting study on P-3C aircraft, volume

p 221 N92-14262 [NASA-CR-189514] SATCOM antenna siting study on P-3C aircraft, volume 2

[NASA-CR-189515] p 221 N92-14263 BENTLY, DONALD E.

Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling p 224 N92-14370 machines

# BERDUGO, ALBERT

A new 1553 all-bus instrumentation monitor p 198 A92-19252 BERG, JORDAN

Regulation of relaxed static stability aircraft p 203 A92-18463

- BERG, M. Environmental fatigue tests with composite materials p 214 N92-14413
- BERGERON, D. p 177 N92-13979 Computational fluid dynamics
- BERGMAN, C. M. A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986
- BERGMANN, J. W.
- Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405 Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424

### BERMAN, C.

Direct computation of turbulence and noise [NASA-CR-187616] p 236 N92-14788 BERRY, W.

- Aerothermodynamic challenges for ESA programmes p 180 N92-14974
- Grid impact on 3D hypersonic flows p 184 N92-15041

BILL, ROBERT C. Army research concerns in engine sealing

p 228 N92-15089 BLAKE, CHRISTOPHER L

Common avionics baseline: The product of the joint integrated avionics working group p 199 N92-14053 BLISS, DONALD B.

- Eigenvalue calculation procedure for an Euler/Navier-Stokes solver with application to flows over airfoils p 170 A92-17429
- BLOM. ANDERS F. Fatigue and damage tolerance verification of aircraft tructures p 217 A92-19677 Damage tolerance of the fighter aircraft 37 Viggen, I structures
- Analytical assessment. II Experimental verification p 192 A92-19819
- BOETTCHER, ROLF-D. Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles
- p 184 N92-15032 BOGAR, T. J.
- normal-shock/turbulent-boundary-layer Confined interaction followed by an adverse pressure gradient p 172 A92-18365
- BOLDMAN, DONALD R.
- Analysis of an advanced ducted propeller subsonic intet [NASA-TM-105393] p 179 N92-14002
- **B-2**

### BOMAN, BRET L.

Application of the STAPAT II code to hypersonic vehicle aerothermodynamics p 209 A92-17824

[AIAA PAPER 91-5035] Engineering method for calculating surface pressures

- and heating rates on vehicles with embedded shocks [AIAA PAPER 91-5060] p 171 A92-17842 BOMAN. PER-OLOF
- Damage tolerance of the fighter aircraft 37 Viggen. I -Analytical assessment. II - Experimental verification p 192 A92-19819
- BOND, THOMAS H. Results of an Icing test on a NACA 0012 airfoil in the
- NASA Lewis Icing Research Tunnel [NASA-TM-105374] p 185 N92-15051
- BÒND. W. E. Model based reasoning in the aerospace domain [AIAA PAPER 91-3709] p 230 A92-17582
- BORRELLI, SALVATORE High enthalpy nozzle flows p 182 N92-15000 BORRIELLO, G.
- Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980

### BOSCHER, D.

- Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 BOUSLOG, S. A.
- Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020
- BOUSQUET, J. M.
- Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles p 211 N92-14977
- BOYD-LEE, A. D.
- Crack initiation and the short-to-long crack growth transition in a Ni-base superalloy p 213 A92-19767 BRAHNEY, JAMES H.
- Hydraulic pumps The key to power generation p 215 A92-17348 BRANAGAN, LYLE
- Dynamic characteristics and stability analysis of space shuttle main engine oxygen pump p 224 N92-14366 BRANDECKER, B.
- Methodology for assessment of skin repairs on Airbus p 226 N92-14428 aircraft BRAUSCH, J. F.
- p 236 N92-14784 Jet noise suppression BREEDLOVE, PHILLIP
- MIL-STD-1553 data bus/PCM multiplexer system p 188 A92-19211 BREIDENTHAL, ROBERT E.
- Sonic eddy A model for compressible turbulence p 176 A92-20739
- BRENNER, G. Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles p 211 N92-14977
- BRINGS, WOLF W.
- F27 aging aircraft programme emphasizes corrosion prevention p 186 A92-20024 BROKOF. U.
- Image-supported navigation for testing instrument p 189 N92-14012 landing systems BROZ, ALFRED L.
- National research program for nondestructive inspection p 169 A92-17294 of aging aircraft BRUCKART, JAMES E.
- Analysis of changes in the pilot population and general p 187 A92-20722 aviation accidents BRUECKNER-FOIT, A.
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424
- BRUEHL, STEPHAN
- The acoustic flashlight [MBB-Z-0359-90-PUB] p 239 N92-15938 BRUGNOLI, E.
- Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical p 217 A92-19812 invoctinations
- BRY, PIERRE-FRANCOIS Recent progress in inverse methods in France p 201 N92-13938
- BUALAT, MARIA G. Optical computing at NASA Ames Research Center
- [AIAA PAPER 91-3779] p 231 A92-17637 BUCCI, R. J. Methodology for the assessment of material quality
- effects on airframe fatigue durability p 213 A92-19820 BUFTFFISCH K
  - Review of the European hypersonic wind tunnel performance and simulation requirements p 209 N92-15043

BUXBAUM, O.

- Review of investigations on aeronautical fatigue in the Federal Republic of Germany [ETN-92-90317] p 225 N92-14397
- BYRNE, J.
- Short fatigue crack growth from blunt notches in an aero-engine alloy p 212 A92-19760

# С

CALICO, ROBERT A. Time-periodic control of a multi-blade helicopter p 204 A92-18626 CALISE. A. J. Rapid near-optimal aerospace plane trajectory generation and guidance p 205 N92-14066 [NASA-CR-1894691 CANDEL, S. Hypersonic viscous shock layer in thermochemical nonequilibrium p 183 N92-15014 CANEPA, FRANCO Knowledge based system applications for guidance and control [AGARD-AR-284] p 205 N92-14065 CANET, J. MIQUEL Flow and temperature computations for space vehicles using adaptive finite element techniques p 181 N92-14990 CAPLIN. J. Definition of the unsteady vortex flow over a wing/body configuration p 178 N92-13995 [NASA-CR-180083] CAPUANO, A. Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980

CARDONE. G. Infrared measurements of aerodynamic heating in p 208 N92-15002 hypersonic wind tunnel CARESSA, J. P.

- Experimental investigation of transverse jet effects related to hypersonic space vehicles
  - p 182 N92-14995
- CARLBERG, JAMES R. Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description
- [AD-A242598] p 170 N92-14966 CARLOMAGNO, G. M.
- Infrared measurements of aerodynamic heating in p 208 N92-15002 hypersonic wind tunnel CARLSON, LELAND A.
- Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction p 193 A92-20202

# CARLSSON, INGEMAR

CATENA, V.

e superalloys

CAVATORTA, ENRICO

[NASA-TM-105321]

[NASA-TM-105373]

fluid dynamics

CEBECI, TUNCER

CEDAR, R. D.

CELENLIGIL. M. C.

CHAMIS, CHRISTOS C.

Aerospace software in Sweden p 233 A92-19406 CARTER, J. M.

Current stabilizing of fastened composite joints to improve non-sparking lightning current performance p 213 A92-20130

- CASPER. PATRICIA A. An intelligent pilot vehicle interface for a day/night
- adverse weather pilotage system (D/NAPS) [AIAA PAPER 91-3729] p 197 A92-17596
- CÁSSAING, J. J. sensors Ablation and temperature for flight measurements in reentry body heat shields

High temperature low cycle fatigue of single crystal nickel

A study on vortex flow control on inlet distortion in the

e-engined 727-100 center inlet duct using computational

Three-dimensional linear stability approach to transition

A turbulence model for iced airfoils and its validation

An inverse method for the aerodynamic design of

Flat-ended circular cylinder in hypersonic rarefied flow

Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402

on wings and bodies of revolution at incidence

three-dimensional aircraft engine nacelles

p 227 N92-15004

p 213 A92-19796

p 179 N92-13998

p 172 A92-18361

p 186 N92-15052

p 194 N92-13958

p 174 A92-20304

p 229 N92-15402

# PERSONAL AUTHOR INDEX

CHAN, SAMUEL Y. Aeroservoelastic stabilization techr	niques fo	or hypersonic
flight vehicles [AIAA PAPER 91-5056]	p 203	A92-17839
CHAN, Y. S. Nonstationary gasdynamics	p 220	N92-13985
CHANDRA, RAMESH Experimental and theoretical ana	lysis of	composite
I-beams with elastic couplings CHANG, R.C.	p 216	A92-18377
Control system design for the free stores in a wind tunnel	drop tes	t of external
[IAF PAPER ST-91-002] CHAPMAN, DEAN R.	p 207	A92-20650
A perspective on aerospace CFD CHARGIN, MLADEN K.	p 169	A92-20145
Static aeroelastic analysis for g wing	p 174	configuration A92-20201
CHAVEZ, FRANK Dynamics and control of hyperso	nic veh	icles - The
integration challenge for the 1990's		
[AIAA PAPER 91-5057] CHEN D	p 203	A92-17840
Bulging of fatigue cracks in a	pressur	ized aircraft
fuselage		
CHEN, H. H.	b 190	N92-14045
Three-dimensional linear stability a	pproach	to transition
on wings and bodies of revolution at	n 172	A92-18361
CHEN, HSUN H.	P 112	10001
A turbulence model for iced airfoi	Is and	its validation
CHEN, JERRY M.	h 100	N92-13032
Model oscillations at high angle of a	attack in	a low speed
(IAF PAPER ST-91-001]	p 175	A92-20649
CHEN, ZUOYI Design of transpric compresso	v	onieu sehe
hodograph method	p 202	N92-13973
The research progress on Hod	ograph	Method of
aerodynamic design at Tsinghua Onin	p 177	N92-13974
CHENG, PETER Y. Aeroservoelastic stabilization techn	iques fo	r hypersonic
flight vehicles	- 000	A07 17920
CHENG, Y. M.	p 203	A92-17039
Limitations to the large strain theor	y n 210	492-20356
Сні, с. т.	P 210	NOE-20000
Control system design for the free	drop tes	t of external
[IAF PAPER ST-91-002]	p 207	A92-20650
Fair weather convection and light	ht aircra	aft accidents
[IAF PAPER ST-91-004] CHILDS, DARA W.	p 186	A92-20651
Test results for rotordynamic coeff	icients d	of the SSME
HPOTP turbine interstage seal with the	wo swirl n 223	brakes N92-14357
CHISHOLM, D. M.	P 220	1452-14557
Flight simulation CHOPRA, INDERJIT	p 207	N92-13982
Experimental and theoretical an I-beams with elastic couplings	alysis o p 216	f composite A92-18377
CHRISTHILF, DAVID M. Parameter insensitive control ut	lilizing	eigenspace
methods CLEMENTS NANCY (	p 204	A92-18615
Avionics standardization in the US	AF: 1980 p 198	0 to 1990 N92-14048
CLOUGH, BRUCE T.	,	
A review of digital flight control sy	stem up	sets caused

by electromagnetic interference [AIAA PAPER 91-3765] p 215 A92-17627

veoluii, sib /	<b>.</b>					
Mesoscale	dynamics	of	cold	fronts	•	Structures
described by	dropsoundir	ngs i	in Fror	nts 87		
				p 23	0	A92-18902

	 	-	<b></b>		-	-
COL	 :н.	H	СН	АΗ	U.	ъ.

- Analysis and modeling of lightning strikes to the F106B, CVF580, and C160 aircraft p 186 A92-20129 COLLINS, CHRISTOPHER C.
- Preliminary investigation of the shock-boundary layer interaction in a simulated fan passage [AD-A242656] p 185 N92-15045
- COLUCCI, FRANK Hypersonic materials p 212 A92-18002
- CONROY, CAROL Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720
- CONSTANTINESCU, V. N. A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058] p 171 A92-17841

CONWAY, SCOTT

- Technology needs for high speed rotorcraft (3) [NASA-CR-177592] p 195 N92-14039 COOK, ROBERT M.
- Airfoil Vibration Dampers program [NASA-CR-188929] p 225 N92-14391
- COONCE, KENNETH G. Design and implementation of a total flight test system
- p 189 A92-19278 COOPER, THOMAS D.
- ASNT and aerospace What about the next 50 years? p 215 A92-17293 COQUEL F.
- Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies
- p 227 N92-15029 CORBAN. J. E.
- Rapid near-optimal aerospace plane trajectory generation and guidance [NASA-CR-189469] p 205 N92-14066
- CRABB, C. A. A unique approach to aircraft conflict resolution using
- artificial intelligence techniques p 190 N92-14029 CRAIGHEAD, I. A.
- The application of a cylindrical-spherical floating ring bearing as a device to control stability of turbogenerators p 224 N92-14371 CRAVEN, B. K.
- Microwave landing system autoland system analysis [NASA-CR-189551] p 191 N92-15060 CREASMAN, SON F.

Evaluation of Euler solvers for transonic wing-fuselage geometries p 174 A92-20214 CROUSE WILLIAM F

- Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 CULPEPPER, STEVEN D.
- Structural considerations for aircraft payload Modification: P-3C zero fuel weight increase
- [AD-A242690] p 196 N92-15068 CURLETT, BRIAN P. The aerodynamic effect of fillet radius in a low speed
- [NASA-TM-105347] p 202 N92-14063
- CURRY, D. M. Aerodynamic heating on AFE due to nonequilibrium flow
- with variable entropy at boundary layer edge p 183 N92-15020 CYNAMON. LOUISA J.
- A processor-in-the-loop simulation using an XANALOG computer p 232 A92-19094

# D

### DACOSTA, J. L.

- Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles
- p 211 N92-14977 Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025
- vehicles with flap deflection p 184 N92-15025 DANSBERRY, BRYAN E. The benchmark aeroelastic models program:
- Description and highlights of initial results [NASA-TM-104180] p 185 N92-15049 DANZER, G.
- Fatigue of repaired composite structures p 214 N92-14411
- DARCY, SIMON C. F/A-18 stabilator: Equivalent set of point forces required
- for pneumatic bag load case simulation [AD-A242637] p 206 N92-15073 DAS. A.
- Analysis of spiraling vortical flows around slender delta wings moving in an inviscid medium p 173 A92-18900 DAVIS, LARRY P.
- CFD helps the Air Force fly right p\_169 A92-20146 DAWICKE, D. S.
- Proof test and fatigue crack growth modeling on 2024-T3 aluminum alloy p 213 A92-19828 DAYTON, RON
- Programs at Wright-Patterson Air Force Base p 228 N92-15092
- DE CARO, CHUCK Aerobureau - Strategic television airmobile reports via satellite p 218 A92-19988 DE MATTEIS, GUIDO
- Dynamics of hang-gliders p 204 A92-18608 DE MELO, DENISE A.
- Analysis of aircraft performance during lateral maneuvering for microburst avoidance p 205 A92-20207
- DE ROSA, S.
- Incompressible steady aerodynamics using a standard finite element code p 174 A92-20218

Heat transfer measurements from a		
airfoil	smooth	NACA 0012
Roughness effects on heat transfe	r from a	NACA 0012
airfoil	p 219	A92-20217
DEAR, ROGER G.		
2-Basic algorithm for collision avoid	n 188	/stem A92-18482
DEBRY, B.		
Definition of the unsteady vortex flo	w over a	a wing/body
[NASA-CR-180083]	n 178	N92-13995
DECHAUMPHAI, PRAMOTE	p	102 10000
Three-dimensional thermal structure	al analys	is of a swept
interference heating	n 174	A92-20306
DEGANI, DAVID		
Numerical prediction of subsonic t	urbulent	flows over
Instabilities of flows over bodies at	p 172 Jaroe in	A92-18358
	p 176	A92-20738
Surface flow patterns on an	ogive-	cylinder at
DEHOFF. RONALD L.	p 176	A92-20762
Turbine engine diagnostics system	study	
[DOT/FAA/CT-91/16]	p 202	N92-14064
Effect of nose shape on three-dim	ensiona	stagnation
region streamlines and heating rates	011010110	Sugnation
[AIAA PAPER 91-5032]	p 171	A92-17822
engineering method for calculating	surrace embed	e pressures
[AIAA PAPER 91-5060]	p 171	A92-17842
Engineering calculations of three-o	timensio	nal inviscid
hypersonic flowfields	p 175	A92-20378
Monitoring load experience of indiv	idual aire	craft
[NLR-TP-90084-U]	p 196	N92-15065
DELAURIER, J. D.		
Aerodynamics DELEEUW J. H	p 202	N92-13977
Flight research	p 194	N92-13981
DELUCA, L.		
hypersonic wind tunnel	n 208	N92-15002
DEOM, A. A.		
Heat transfer measurements in ONE	ERA sup	ersonic and
thermography	p 208	N92-15003
Ablation and temperature se	insors	for flight
measurements in reentry body heat s	hields p 227	N92-15004
DEPRIEST, MICHAEL S.		
Aviation Disgraphics And Maintone		functional
Aviation Diagnostics And Maintenar preliminary concept of operation	n and	
Aviation Diagnostics And Maintenar preliminary concept of operation description	n and	
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY M	p170	N92-14966
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies	p 170 p 211	N92-14966 N92-14984
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Tophology pages for high coord of	p 170 p 211	N92-14966 N92-14984
Aviation Diagnostics And Maintenau preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [MASA-CR-177592]	p 170 p 211 otorcraft p 195	N92-14966 N92-14984 (3) N92-14039
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [MASA-CR-177592] DEUTERMANN, ALAN	p 170 p 211 otorcraft p 195	N92-14966 N92-14984 (3) N92-14039
Aviation Diagnostics And Maintenau preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-177592] DEUTERMANN, ALAN Compression techniques for video for	p 170 p 211 otorcraft p 195 telemetry p 188	N92-14966 N92-14984 (3) N92-14039
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-177592] DEUTERMANN, ALAN Compression techniques for video for DEVENPORT, WILLIAM J.	p 170 p 211 otorcraft p 195 telemetry p 188	N92-14966 N92-14984 (3) N92-14039 A92-19214
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video to <b>DEVENPORT, WILLIAM J.</b> The application of experimental complexity of the system.	p 170 p 211 otorcraft p 195 telemetry p 188 data to I	N92-14966 N92-14984 (3) N92-14039 A92-19214 Diade wake
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video to <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461]	p 170 p 211 otorcraft p 195 telemetry p 188 data to l	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video for <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b>	p 170 p 211 otorcraft p 195 telemetry p 188 data to 1 p 237	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video for <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an	p 170 p 211 otorcraft p 195 telemetry p 188 data to l p 237 d DLF	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 I for the
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video for <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl	p 170 p 211 otorcraft p 195 telemetry p 188 data to I p 237 d DLP es p 211	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 I for the N92-14977
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video for <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b>	p 170 p 211 otorcraft ρ 195 telemetry p 188 data to I p 237 d DLP es p 211	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 I for the N92-14977
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [MASA-CR-177992] <b>DEUTERMANN, ALAN</b> Compression techniques for video f <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter	p 170 p 211 otorcraft p 195 telemetry p 188 data to I p 237 d DLF es p 211	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 I for the N92-14977
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-17592] DEUTERMANN, ALAN Compression techniques for video f DEVENPORT, WILLIAM J. The application of experimental of interaction noise prediction [NASA-CR-189461] DEVEZEAUX, D. Analysis tools of ONERA an aerothermodynamics of reentry vehicl DICKERSON, TERRY Fault Tree Interpreter [AIAA PAPER 91-3789] DIGIBOL AMO, BORERT D	p 170 p 211 otorcraft p 195 telemetry p 188 data to 1 p 237 d DLF es p 211 p 232	N92-14966 N92-14984 (3) N92-14039 A92-19214 Dlade wake N92-14789 for the N92-14977 A92-17645
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-17592] DEUTERMANN, ALAN Compression techniques for video f DEVENPORT, WILLIAM J. The application of experimental of interaction noise prediction [NASA-CR-189461] DEVEZEAUX, D. Analysis tools of ONERA an aerothermodynamics of reentry vehicl DICKERSON, TERRY Fault Tree Interpreter [AIAA PAPER 91-3789] DIGIROLAMO, ROBERT D. Neural network and fuzzy logic techr	p 170 p 211 otorcraft p 195 telemetry p 188 data to l p 237 d DLF es p 211 p 232 p 232	N92-14966 N92-14984 (3) N92-14039 A92-19214 Diade wake N92-14789 for the N92-14789 for the N92-14977 A92-17645
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-17592] DEUTERMANN, ALAN Compression techniques for video f DEVENPORT, WILLIAM J. The application of experimental of interaction noise prediction [NASA-CR-189461] DEVEZEAUX, D. Analysis tools of ONERA an aerothermodynamics of reentry vehicl DICKERSON, TERRY Fault Tree Interpreter [AIAA PAPER 91-3789] DIGIROLAMO, ROBERT D. Neural network and fuzzy logic technr control	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 dd DLF es p 211 p 232 eology fo	N92-14966 N92-14984 (3) N92-14039 A92-19214 Diade wake N92-14789 I for the N92-14789 I for the N92-14977 A92-17645 rnaval flight
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] DESAULTY, M. Supersonic combustion studies DETORE, JACK Technology needs for high speed r [NASA-CR-17592] DEUTERMANN, ALAN Compression techniques for video f DEVENPORT, WILLIAM J. The application of experimental of interaction noise prediction [NASA-CR-189461] DEVEZEAUX, D. Analysis tools of ONERA an aerothermodynamics of reentry vehicl DICKERSON, TERRY Fault Tree Interpreter [AIAA PAPER 91-3789] DIGIROLAMO, ROBERT D. Neural network and fuzzy logic techr control [AD-A242650] DISIMILE, P. J.	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 dd DLF es p 211 p 232 nology fo p 206	N92-14966 N92-14984 (3) N92-14039 A92-19214 Diade wake N92-14789 f for the N92-14977 A92-17645 rnaval flight N92-15074
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video for <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 d DLF es p 211 p 232 nology fo p 206 layer se	N92-14966 N92-14984 (3) N92-14039 A92-19214 Diade wake N92-14789 for the N92-14789 for the N92-14977 A92-17645 rnaval flight N92-15074 paration on
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video f <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary a roughened surface at Mach 6.0	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 d DLF es p 211 p 232 cology fo p 206 layer se p 175	N92-14966 N92-14984 (3) N92-14039 A92-19214 Dade wake N92-14789 for the N92-14789 for the N92-14977 A92-17645 rnaval flight N92-15074 paration on A92-20379
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video to <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary- a roughened surface at Mach 6.0 Turbulent boundary-layer chara	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 d DLP es p 211 p 232 hology fo p 206 layer se p 175 cteristics h 6	N92-14966 N92-14984 (3) N92-14039 A92-19214 Dlade wake N92-14789 It for the N92-14977 A92-17645 rnaval flight N92-15074 paration on A92-20379 s over a
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video to <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary: a roughened surface at Mach 6.0 Turbulent boundary-layer chara flat-plate/wedge configuration at Macc	p 170 p 211 otorcraft p 195 elemetry p 188 data to l p 237 d DLF es p 211 p 232 nology fo p 206 layer se p 175 cteristics h 6 p 776	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 I for the N92-14789 I for the N92-14977 A92-17645 rnaval flight N92-15074 paration on A92-20379 S over a A92-20761
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [NASA-CR-177592] <b>DEUTERMANN, ALAN</b> Compression techniques for video f <b>DEVENPORT, WILLIAM J.</b> The application of experimental c interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary a roughened surface at Mach 6.0 Turbulent boundary-layer chara flat-plate/wedge configuration at Mac	p 170 p 211 otorcraft p 195 telemetry p 188 data to l p 237 d DLF es p 211 p 232 tology fo p 206 layer se p 175 cteristics h 6 p 176	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 f for the N92-14789 f for the N92-14977 A92-17645 rnaval flight N92-15074 paration on A92-20379 s over a A92-20761
Aviation Diagnostics And Maintenar preliminary concept of operation description [AD-A242598] <b>DESAULTY, M.</b> Supersonic combustion studies <b>DETORE, JACK</b> Technology needs for high speed r [MASA-CR-177992] <b>DEUTERMANN, ALAN</b> Compression techniques for video f <b>DEVENPORT, WILLIAM J.</b> The application of experimental of interaction noise prediction [NASA-CR-189461] <b>DEVEZEAUX, D.</b> Analysis tools of ONERA an aerothermodynamics of reentry vehicl <b>DICKERSON, TERRY</b> Fault Tree Interpreter [AIAA PAPER 91-3789] <b>DIGIROLAMO, ROBERT D.</b> Neural network and fuzzy logic techr control [AD-A242650] <b>DISIMILE, P. J.</b> Wedge-induced turbulent boundary: a roughened surface at Mach 6.0 Turbulent boundary-layer chara flat-plate/wedge configuration at Macc <b>DOMINIQUE, H. P.</b> Filter debris analysis: A concrete diagnosis	p 170 p 211 otorcraft p 195 telemetry p 188 data to l p 237 d DLF es p 211 p 232 tology fo p 206 layer se p 175 cteristics h 6 p 176 approad	N92-14966 N92-14984 (3) N92-14039 A92-19214 blade wake N92-14789 f for the N92-14789 f for the N92-14977 A92-17645 rnaval flight N92-15074 paration on A92-20761 ch to wear

- DOMINY, R. G. Flat-ended circular cylinder in hypersonic rarefied flow
- p 174 A92-20304 DORRANCE, DANIEL R.
- Radar troubleshooting assistant expert system [AIAA PAPER 91-3764] p 231 A92-17626

# DORRANCE, DANIEL R.
### DOWELL, EARL H.

### DOWELL EARL H.

- calculation for Eigenvalue procedure an Euler/Navier-Stokes solver with application to flows over p 170 A92-17429 airfoils DOWNIE, JOHN D.
- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 DRAPER, ALFRED C.
- Evolution and development of hypersonic configurations 1958-1990
- [AD-A242768] p 197 N92-15069 DUGUNDJI, JOHN
- Nonlinear stall flutter and divergence analysis of cantilevered graphite/epoxy wings p 219 A92-20746 DULIKRAVICH, GEORGE S.
- Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3) [NASA-CR-188125] p 170 N92-13928
- Aerodynamic shape optimization of arbitrary hypersonic p 194 N92-13954 vehicles DUNN, PETER
- Nonlinear stall flutter and divergence analysis of p 219 A92-20746 cantilevered graphite/epoxy wings DURHAM, MICHAEL H.
- The benchmark aeroelastic models program: Description and highlights of initial results [NASA-TM-104180] p 185 N92-15049
- DZAMBA, LEN D. Rotorcraft low altitude IFR benefit/cost analysis:
- Operations analysis (SCT-90RR-44) p 191 N92-15061
- DZIEDZIC, WILLIAM M. Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17843
  - Ε
- EAST, R. A.
- ody junctions on p 182 N92-14996 Interference heating near fin/body hypersonic vehicles ECKSTROM, CLINTON V.
- The benchmark aeroelastic models program: Description and highlights of initial results [NASA-TM-104180] p 185 N92-15049
- EIKEL. HARVEY A. Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description
- [AD-A242598] p 170 N92-14966 EISSFELLER, B.
- Navsat A civil complement to GPS and Glonass [IAF PAPER 91-490] p 188 A92-18505 EL-SHAFEI, A.
- Stability of intershaft squeeze film dampers p 222 N92-14351 ELENEVSKII, D. S.
- Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpied p 219 A92-20771
- ELESHAKY, MOHAMED E. Aerodynamic sensitivity analysis methods for the
- compressible Euler equations p 233 A92-19619 ELIASSON. P. Hypersonic flow past delta wing flow simulated by
- p 180 N92-14981 Navier-Stokes solutions ENGLISH. C. Inertia-friction welding of an advanced rapidly solidified
- titanium allov p 212 A92-18898 ERB. DONA M.
- Case for real-time systems development Quo vadis? [AIAA PAPER 91-3726] p 231 A92-17594 ERICKSON, GARY E.
- Wind tunnel investigation of vortex flows on F/A-18 configuration at subsonic through transonic speed NASA-TP-3111] p 179 N92-14968
- ERIKSON, CAROL A. Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype flight hardware p 220 N92-14217 EROGLU, HASAN
- LDV measurements and investigation of flow field through radial turbine guide vanes p 217 A92-19618 EVANS, JAMES M.
- Testing of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab
- p 210 N92-14087 EVANS. R. H. Lightning protection requirements for aircraft: A
- proposed specification [RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92-14007
- EVERETT, R. A. Fatigue crack initiation and small crack growth in several
- airframe allovs p 212 A92-19754

EVERSMAN WALTER

- Theoretical models for duct acoustic propagation and radiation p 236 N92-14782 EWALD. J.
- FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017

### F

FANG. W.

- Approximation methods for control of acoustic/structure models with niezoceramic actuators.
- [NASA-CR-189578] p 234 N92-15658 FANKHAUSER, JAMES C. Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and wind
- measurements from aircraft inertial navigation systems p 188 A92-18172
- FARMER, MOSES G. The benchmark aeroelastic models
- program: Description and highlights of initial results [NASA-TM-104180] p 185 N92-15049 FAURE, J. C.
- Mechanical qualification tests for materials used in the fabrication of aircraft parts
- [CEAT-M5-5443/01] p 195 N92-14042 FÂVINI, B.
- Nonequilibrium hypersonic inviscid steady flow p 176 A92-20737 Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15016
- FFATHER J. B. Microwave landing system autoland system analysis
- [NASA-CR-189551] p 191 N92-15060 FEATHER TIMOTHY D Reducing environmental noise impacts: A USAREUR
- noise management program handbook [AD-A240797] p 237 N92-14791 FENNELL, P. J.
- Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-19 p 187 N92-15054
- FENNELL, ROBERT E. Parameter insensitive control utilizing eigenspace nethods p 204 A92-18615
- methods FIELDS, JAMES M.
- Human response to aircraft noise p 236 N92-14780 FISCHER, NORMAN H.
- Verification of flight software by embedding software simulation in simulation of external environment p 232 A92-19084
- FISCHER, TERENCE Evaluation of triple simultaneous parallel ILS approaches
- aced 4300 feet apart, phase 4a p 191 N92-14034 [ACD-340]
- FISCHERSWORRING-BUNK, A.
- Multiaxial load spectra in a cooled gas turbine blade p 201 A92-19696 under in-service conditions FISCHL ROBERT
- Formulation of a strategy for monitoring control integrity in critical digital control systems [NASA-TM-104158] p 206 N92-15075
- FISCHMEISTER, H. Probabilistic lifing approach for aero engine disks made
- of powder nickel base alloys containing ceramic defects p 226 N92-14424 FISHER, M.
- Numerical calculation of modulation transfer functions for low frequency mechanical vibrations
- p 235 A92-19982 FLAMENT, C.
- Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies
- p 227 N92-15029 FLORJANCIC, S.
- Annular seals of high energy centrifugal pumps: Presentation of full scale measurement p 224 N92-14362
- FOGARTY, P. J.
- Scoping studies for small steady-state tokamaks for divertor testing [DE92-000740] p 238 N92-15761
- FONG. C. VANESSA Automated problem resolution prototype in automated
- p 190 N92-14028 en route air traffic control FORBRICH, D.
- Application of direct inverse analogy method (DIVA) and viscous design optimization techniques p 176 N92-13951
- FOSS. G. C. Enhancement of modal swept sine data by control of exciting forces p 215 A92-17562
- FRANK, P. D. A comparison of two closely-related approaches to

FRANKLIN JERROLD F

Ceramic regenerator program [NASA-CR-189053] p 225 N92-14374 FRANKLIN, WESLEY D. Rotor-to-stator partial rubbing and its effects on rotor dynamic response p 224 N92-14367 FREY. M. O. Experimental investigation of coannular jet flow with swirl p 172 A92-18367 along a centerbody FRIEBEL, C. FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017 FRIEDMAN, PAUL J. An integrated real-time turbine engine flight test evetem p 201 A92-19275 FRIEDMANN, P. P. Helicopter air resonance modeling and suppression using active control p 204 A92-18625 FRINK, NEAL T. Upwind scheme for solving the Euler equations on unstructured tetrahedral meshes p 175 A92-20735 FUJII, KOZO Aerodynamic aircraft design methods and their notable

PERSONAL AUTHOR INDEX

- applications: Survey of the activity in Japan p 193 N92-13930
- FUJIMORI, TOSHIRO CFD application to 2D/3D flow fields in Scramjet p 170 A92-17501 enaine
- FUJIWARA, GENKICHI Cabin structural vibration and noise for transport aircraft
- p 192 A92-17876 FUSARO, ROBERT L. Tribology needs for future space and aeronautical
- systems [NASA-TM-104525] p 214 N92-15191
  - G

GALAMBOS, J. D.

GERHARZ, J. J.

GESSNER, F. B.

GILMORE, M. R.

GILREATH, H. E.

andle of attack

GLASS, CHRISTOPHER E.

interference heating GLEGG, STEWART A. L.

interaction noise prediction [NASA-CR-189461]

Jet noise suppression

GIORDANO, D.

study

along a centerbody

- Scoping studies for small steady-state tokamaks for divertor testino [DE92-000740] p 238 N92-15761
- GALANT, DAVID
- Optical computing at NASA Ames Research Center AIAA PAPER 91-3779] p 231 A92-17637 GALATOLO, R.
- Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817
- GALICA MA High-temperature combustor and seal for a water piston
- opulsor AD-A2424931 p 229 N92-15385
- GALKOWSKI, PEGGY J.
- An alternative derivation of the modified gain function p 232 A92-18464 of Song and Speyer GARDETTE, G.
- Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 GARRARD, G. D.
- Hydrogen exhaust gas disposition by afterburning
- AIAA PAPER 91-5075] p 200 A92-17848 GARY, CHARLES K.
- Optical computing at NASA Arres Research Center [AIAA PAPER 91-3779] p 231 A92-17637 GEDDES, NORMAN D.
- Knowledge maintenance in an evolving system using a deep structure representation TAIAA PAPER 91-3941]

Experimental investigation of coannular jet flow with swirl

Flat-ended circular cylinder in hypersonic rarefied flow

Stratified flow around an axisymmetric body at small

SIMOUN and Scirocco wind tunnel nozzle viscous flow

Three-dimensional thermal structural analysis of a swept

The application of experimental data to blade wake

cowl leading edge subjected to skewed shock-shock

Fatigue of repaired composite structures

n 231 A92-17605

p 214 N92-14411

p 172 A92-18367

p 174 A92-20304

p 172 Á92-18385

p 208 N92-14999

p 174 A92-20306

p 237 N92-14789

p 236 N92-14784

### PERSONAL AUTHOR INDEX

GLUDOWSKI, KANEN A.		
Real-time microfocus radiography	for elec	tronic failure
GORDON, G. Direct computation of turbulence a	nd noise	9
(NASA-CR-187616) GORSKI, J.	p 236	N92-14788
wake for two-dimensional lifting bodie	oounua	ary layer and
GOSWAMI. TARUN	p 221	N92-14309
Fatigue testing of a gas turbine fan	disc p 217	A92-19818
GOTTLIEB, J. J. Computational fluid dynamics Nonstationary gasdynamics	p 177 p 220	N92-13979 N92-13985
GOULD, RONALD W. Enhanced visual technique for rapid	inspecti	on of aircraft
structures GRAF, W. O. Flight simulation	р 214 р 207	A92-17290
GRAHAM, DUNSTAN Retrospective essay on nonlineari	ties in a	aircraft flight
control GRANDHI, R. V.	p 204	A92-18601
using energy management and y	ariation	nal calculus
techniques	p 210	A92-19061
GRANT, H. P.		
High temperature static strain gage [NASA-CR-189044]	develo p 195	pment N92-14037
GRANT, P. R. Flight simulation GRASSIN, CHRISTOPHE	p 207	N92-13982
Computation of aerodynamic	coeff	icients on
Hermes-Ariane5 configuration GRAWE, J.	p 184	N92-15040
Grid impact on 3D hypersonic flows	5 194	N02-15041
GREENWOOD, DAN	µ 104	1192-10041
The application of neural networks	to dron p 205	e control A92-19273
GREFF, E.		
Application of direct inverse analogy	metho	d (DIVA) and
viscous design optimization technique	יא 176 ס	N92-13951
GREGORY, IRENE M.	P P	
Trim drag reduction concepts for	horizor	ntal takeoff
single-stage-to-Orbit vehicles	- 000	100 45030
[NASA-IM-102687]	D 206	N92-15076
GREIN, HD.	F	
GREIN, HD. Supercritical blade design on s revolution with an inverse method	tream p 220	surfaces of N92-13950
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F.	tream p 220	surfaces of N92-13950
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities	tream p 220 at EG/ p 228	surfaces of N92-13950 G N92-15095
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2	tream p 220 at EG/ p 228 n (Fed. p 208	surfaces of N92-13950 G N92-15095 Republic of N92-15021
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp (tube DECD or Construction)	tream p 220 at EG/ p 228 n (Fed. p 208 pert sys	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROGMAN B	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 231	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Desion optimization of transonic air	tream : p 220 at EG/ p 228 n (Fed. p 208 p 208 p 231 foils	surfaces of N92-13950 G N92-15095 N92-15095 N92-15021 tem A92-17626
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T.	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 208 p 203 p 231 foils p 177	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 231 foils p 177 p 177 p 220	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in reven	tream ; p 220 at EG/ p 228 n (Fed. p 208 pert sys p 231 foils p 177 p 177 p 220 sible ax	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985 ial fans N92-13020
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 208 p 231 foils p 177 p 177 p 220 sible ax p 177	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985 ial fans N92-13970
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 208 p 208 p 208 p 231 foils p 177 p 177 p 220 sible ax p 177 p 277 p 270	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13970 N92-13985 ial fans N92-13970 bustion of a c air stream
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant ext [AIAA PAPER 91-3764] GROSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102]	tream p 220 at EG/ p 228 n (Fed. p 208 p 208 p 208 p 208 p 208 p 2177 p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 270 p 177 p 270 sible ax p 177 p 270 p 177 p 270 sible ax p 177 p 177	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13979 N92-13970 Surfans N92-13970 bustion of a c air stream A92-17861
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L.	tream p 220 at EG/ p 228 n (Fed. p 208 Dert sys p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tth hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe	ream p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 p 199	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUNTER, EDGAR J.	tream p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 p 177 p 212 p 199	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13970 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant ext [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of th hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUNTER, EDGAR J. Dynamic characteristics and stabiliti shuttle main engine oxygen pump GUIO	tream p 220 at EG/ p 228 n (Fed. p 208 Dert sys p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 p 199 y analy p 224	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUNTER, EDGAR J. Dynamic characteristics and stabilit shuttle main engine oxygen pump GUO, JINGRONG Design of transonic compresso brdonrab.	tream p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 p 177 p 222 p 199 y analy p 224 r c ascc	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13970 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366 ades using N92-13972
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant ext [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of th hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUO, JINGRONG Design of transonic compresso hodograph method	tream p 220 at EG/ p 228 n (Fed. p 208 cert sys p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 at EG/ p 212 p 199 y analy p 224 r casc p 202	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13970 N92-13970 N92-13970 N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366 ades using N92-13973
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUNTER, EDGAR J. Dynamic characteristics and stabilit shuttle main engine oxygen pump GUO, JINGRONG Design of transonic compresso hodograph method	tream p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 p 199 y analy p 224 r cascc p 202 p 202 p 202 p 202 p 202	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13970 N92-13970 bustion of a c air stream A92-17661 N92-14050 sis of space N92-14050 sis of space N92-14050 sis of space N92-13973 Method of
GREIN, HD. Supercritical blade design on s revolution with an inverse method GREINER, HAROLD F. Seal related development activities GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2 GROHMAN, KENNETH M. Radar troubleshooting assistant ext [AIAA PAPER 91-3764] GROSSMAN, B. Design optimization of transonic air GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics GU, CHUANGANG Study of a new airfoil used in rever GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102] GUIBERT, L. Avionics standardization in Europe GUNTER, EDGAR J. Dynamic characteristics and stabilit shuttle main engine oxygen pump GUO, JINGRONG Design of transonic compresso hodograph method The research progress on Hodor aerodynamic design at Tsinghua Univ	tream : p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 220 sible ax p 177 p 222 p 199 y analy p 224 r c ascc p 202 g graph ersity p 177	surfaces of N92-13950 G N92-15095 Republic of N92-15021 tem A92-17626 N92-13961 N92-13970 N92-13970 N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366 ades using N92-13973 Method of N92-13974
<ul> <li>GREIN, HD. Supercritical blade design on s revolution with an inverse method</li> <li>GREINER, HAROLD F. Seal related development activities</li> <li>GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2</li> <li>GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764]</li> <li>GROSMAN, B. Design optimization of transonic air</li> <li>GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics</li> <li>GU, CHUANGANG Study of a new airfoil used in rever</li> <li>GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102]</li> <li>GUIBERT, L. Avionics standardization in Europe</li> <li>GUO, JINGRONG Design of transonic compresso hodograph method</li> <li>The research progress on Hodd aerodynamic design at Tsinghua Univ</li> <li>GUPTA, K. K. Multidisciplinary modeling and simu hypersonic vehicle</li> </ul>	tream p 220 at EG/ p 228 n (Fed. p 208 Dert sys p 231 foils p 177 p 220 sible az p 177 p 220 sible az p 177 p 220 r 220 p 199 y analy p 224 r cascc p 202 graph r 177 p 199 y 204 r 109 p 177 p 199 y analy p 224 r cascc p 199 y analy p 177 p 199 y analy p 177 p 199 y analy p 177 p 199 y 201 r 109 r 107 r 109 r 109 r 109 r 107 r 109 r 109 r 109 r 107 r 109 r 109 r 107 r 109 r 107 r 109 r 109 r 109 r 107 r 109 r 109 r 107 r 109 r 109 r 109 r 107 r 109 r 107 r 109 r 109 r 107 r 109 r 109 r 109 r 109 r 107 r 109 r 109 r 109 r 107 r 109 r 1	surfaces of N92-13950 G N92-13950 Fepublic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13985 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366 ades using N92-13973 Method of N92-13974 of a generic
<ul> <li>GREIN, HD. Supercritical blade design on s revolution with an inverse method</li> <li>GREINER, HAROLD F. Seal related development activities</li> <li>GROENIG, H. High enthalpy testing in the Aache Germany) shock tunnel TH 2</li> <li>GROHMAN, KENNETH M. Radar troubleshooting assistant exp [AIAA PAPER 91-3764]</li> <li>GROSMAN, B. Design optimization of transonic air</li> <li>GROTH, C. P. T. Computational fluid dynamics Nonstationary gasdynamics</li> <li>GU, CHUANGANG</li> <li>GUERRA, ROSEMARIE An experimental investigation of tt hydrogen jet injected parallel in a su [AIAA PAPER 91-5102]</li> <li>GUIBERT, L. Avionics standardization in Europe</li> <li>GUNTER, EDGAR J. Dynamic characteristics and stabilit shuttle main engine oxygen pump</li> <li>GUO, JINGRONG Design of transonic compresso hodograph method The research progress on Hodd aerodynamic design at Tsinghua Univ</li> <li>GUPTA, K. K. Multidisciplinary modeling and simu hypersonic vehicle [AIAA PAPER 91-5015]</li> </ul>	rream : p 220 at EG/ p 228 n (Fed. p 208 p 231 foils p 177 p 220 p 177 p 220 sible ax p 177 p 220 p 177 p 220 sible ax p 177 p 220 p 199 p y analy p 177 p 177 p 220 p 199 p y analy p 177 p 220 p 199 p 177 p 220 p 224 r c ascc p 202 graph p 177 p 220 p 220 p 199 p 177 p 220 p 222 p 177 p 222 sible ax p 177 p 220 p 220 p 220 p 220 p 222 p 222	surfaces of N92-13950 G N92-13950 Fepublic of N92-15021 tem A92-17626 N92-13961 N92-13979 N92-13976 ial fans N92-13970 bustion of a c air stream A92-17861 N92-14050 sis of space N92-14366 ades using N92-13973 Method of N92-13974 of a generic A92-17813

HABIGER, H.

- The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009
- HADAR, O. Numerical calculation of modulation transfer functions for low frequency mechanical vibrations
- p 235 A92-19982 HAEUSER. J.
- Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with monoand multi-blocks including real gas effects, part 1
- p 227 N92-15030 Grid impact on 3D hypersonic flows p 184 N92-15041
- HAFTKA, R. T.
- Design optimization of transonic airfoils p 177 N92-13961
- HAGEMAIER, DONALD J. Nondestructive testing developments in the aircraft
- industry p 214 A92-17288 HANKEY, W. L.
- Automated trajectory synthesis for hypersonic vehicles using energy management and variational calculus p 210 A92-19061 techniques HANNEMANN, K.
- Review of the European hypersonic wind tunnel performance and simulation requirements
- p 209 N92-15043 HANSMAN, R. J., JR.
- Analysis of aircraft performance during lateral maneuvering for microburst avoidance p 205 A92-20207
- HANSON, A. W.
- Lightning protection requirements for aircraft: A proposed specification p 187 N92-14007 RAE-TM-FS(F)-632-REV-ISSUE]
- HÃO. Z. U. Interference heating near fin/body junctions on
- hypersonic vehicles p 182 N92-14996 HARDIN, JAY C. Removal of spurious reflections from computational fluid
- dynamic solutions with the complex cepstrum p 235 A92-20729
- HARRIS, J. R. Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-12
- p 187 N92-15054 HARRIS, JULIUS E.
- Numerical solution of the boundary-layer equations for p 174 A92-20211 a general aviation fuselage HARRISON, KENNETH R.
- Simulation of radar clutter and jet engine modulation using digital guadrature modulator p 216 A92-19091 HARTWICH. P.
- A Navier-Stokes solution of Hull-ring wing-thruster p 221 N92-14310 interaction HARVEY, J. K
- Flat-ended circular cylinder in hypersonic rarefied flow p 174 A92-20304
- HASSAN, BASIL
- Effect of nose shape on three-dimensional stagnation region streamlines and heating rates [AIAA PAPER 91-5032] p 171 A92-17822
- HAUNSCHILD, M. Navsat - A civil complement to GPS and Glonass
- [IAF PAPER 91-490] p 188 A92-18505 HAWBOLDT: R. J. p 220 N92-13985 Nonstationary gasdynamics HAWKEN, D. F. Computational fluid dynamics p 177 N92-13979
- p 220 N92-13985 Nonstationary gasdynamics HAYASHIDA, ROBERT D. Rotor-to-stator partial rubbing and its effects on rotor
- p 224 N92-14367 dynamic response HAYBALL, C. p 202 N92-13977 Aerodynamics
- HECHT-NIELSEN, ROBERT Processing complexity of two approaches to object detection and recognition p 234 N92-14677
- HEDGE, B. Electronically steerable antenna for aircraft p 229 N92-15272
- HEEG, JENNIFER Flutter suppression via piezoelectric actuation
- [NASA-TM-104120] p 197 N92-15070 HEIDENREICH. R.
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424 HEIDLEBAUGH, D. L.
- Current stabilizing of fastened composite joints to improve non-sparking lightning current performance p 213 A92-20130

HEMDAN, HAMDI T.

- Similarity solutions for supersonic axisymmetric flows p 173 A92-18387
- Hypersonic flows over slender circular cones at small p 173 A92-19068 angles of attack HENCKELS A
  - Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique p 182 N92-14994
- HERNANZ, M. Electronically steerable antenna for aircraft
- p 229 N92-15272 HERNANZ M. L
  - Electronically steerable antenna for aircraft p 229 N92-15272
  - HERZOG, P. Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique
  - p 182 N92-14994 HEWITT, K. L.
  - On the accuracy of an aircraft-borne ambient electric-field measuring system p 186 A92-20127
  - Operational design factors for NASP derived vehicles [AIAA PAPER 91-5081]
  - Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637
  - HINKLE, A. J.
  - HIRD, GEOFFREY R.
  - p 230 A92-17585 HIRSCH, CH.
  - Genuinely upwind algorithms for the multidimensional p 175 A92-20733 Euler equations HIRSCHEL, E. H.
  - Aerothermodynamic challenges of the Saenger pace-transportation system p 184 N92-15042 space-transportation system
  - HIRSHMAN, S. P. Scoping studies for small steady-state tokamaks for divertor testina
  - [DE92-000740] p 238 N92-15761 HITCHCOCK, LLOYD
  - Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a
  - [ACD-340] p 191 N92-14034 HOADLEY, SHERWOOD T.
  - Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations , p 204 A92-18622
  - HODGE, CHARLES G. Quiet aircraft design and operational characteristics
  - p 236 N92-14787
- HOELD, ROLAND K.
  - Viscous shock-layer equations for the calculation of p 183 N92-15008 reentry aerothermodynamics HOLDEN, S. J.
  - Whole aircraft lightning indirect effects evaluation using low level injection techniques p 192 A92-20134 HOLL. JUDITH A.
  - Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 HOLMES, R.
  - The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies
  - p 222 N92-14349 HOMICZ, G. F.
  - Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code
- [DE92-000597] p 229 N92-15392 HOPPE, A.
- Flight simulation p 207 N92-13982 HOVEY. PETER W.
- Study of the engine bird ingestion experience of the Boeing 737 aircraft [DOT/FAA/CT-89/16] p 187 N92-15053
- HOWARD, R. M. Flight test of a half-scale unmanned air vehicle
- p 193 A92-20208
- HSIAO, C. Y. Control system design for the free drop test of external stores in a wind tunnel [IAF PAPER ST-91-002] p 207 A92-20650
- HSU C F Control system design for the free drop test of external tores in a wind tunne [IAF PAPER ST-91-002] p 207 A92-20650
  - HUANG, L Noise-driven flow p 173 A92-18680

- - HICKMAN, R. A.
  - p 210 A92-17851 HINE, BUTLER P.
  - - Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820
  - Formal specification and verification of Ada software [AIAA PAPER 91-3713] p 230 A92-17585

### HUANG, PAO S.

### HUANG, PAO S.

- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics p 179 N92-13998 [NASA-TM-105321]
- HUANG. T. T.
- Three-dimensional linear stability approach to transition on wings and bodies of revolution at incidence p 172 A92-18361
- HUANG, TSAIR G.
- Model oscillations at high angle of attack in a low speed wind tunnel test [IAE PAPER ST-91-001] p 175 A92-20649
- HUBBARD. HARVEY H. Aeroacoustics of flight vehicles: Theory and practice.
- Volume 2: Noise control [NASA-BP-1258-VOL-2] p 235 N92-14779
- HULSE, C. O. High temperature static strain gage development
- [NASA-CR-189044] p 195 N92-14037 HULSHOFF. S.
- p 202 N92-13977 Aerodynamics HUNGENBERG, H. G.
- Thrust nozzle test facility at DLR Cologne [AIAA PAPER 91-5024] p 206 A92-17818 HUO, WINIFRED M.
- Rate parameters for coupled vibration-dissociation in a ceneralized SSH approximation p 235 A92-20301 HUSSEY, I. W.
- Short fatigue crack growth from blunt notches in an p 212 A92-19760 aero-engine alloy HUTH. H.
- Environmental fatigue tests with composite materials p 214 N92-14413

### 1

- IBRAHIM, MOUNIR
- Analysis of an advanced ducted propeller subsonic inle
- [NASA-TM-105393] p 179 N92-14002 IEK, CHANTHY
- Analysis of an advanced ducted propeller subsonic inlet p 179 N92-14002
- [NASA-TM-105393] INNOCENTI, MARIO
- Roll-performance criteria for high augmented aircraft p 204 A92-18623 IRANI. E.
- Simple method of supersonic flow visualization using p 219 A92-20764 smoke ISIL KUNIYOSHI
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348
- ISLAM, MOHAMMED A. An alternative derivation of the modified gain function
- p 232 A92-18464 of Song and Speyer IVANOV, M. IA. Soviet CFD - An international perspective
- p 233 A92-20150 IWATSUBO, T.
- Experiment of static and dynamic characteristics of spiral arooved seals p 223 N92-14361 J

- JACKSON, E.
- Direct computation of turbulence and noise p 236 N92-14788 [NASA-CR-187616]
- JACQUOTTE, OLIVIER-PIERRE Recent progress in inverse methods in France p 201 N92-13938
- JADIC, I A lifting line theory for supersonic flow applications
- [AIAA PAPER 91-5058] p 171 A92-17841 JAECKELS, H.
- Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424
- JENNINGS, NICHOLAS Aerospace software engineering in the United Kingdom p 233 A92-19405 JOH, C.-Y.
- Design optimization of transonic airfoils
- p 177 N92-13961 JOHANNSMEIER, DIETER Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031 JOHNSTON, G. W. Aerodynamics n 202 N92-13977 Computational fluid dynamics p 177 N92-13979

### JOLY, V.

- Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies
  - p 227 N92-15029 JONES, JACK A.
- Joule-Thomson Multicomponent gas sorption refrigeration
- [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203 JONES, RICKIE
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034
- JONES, STUART C. A comparison of cooling methods for the airframe nozzle
- of a single-stage-to-orbit aircraft [AIAA PAPER 91-5036] p 210 A92-17825
- Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17843 JORDAN, D. T.
- Whole aircraft lightning indirect effects evaluation using p 192 A92-20134 low level injection techniques

### K

### KAM. MOSHE

- Formulation of a strategy for monitoring control integrity in critical digital control systems [NASA-TM-104158] p 206 N92-15075
- KAMINER, ARKADII A.
- Aerodynamic damping of blade vibrations p 200 A92-18198 turbomachines KANDIL OSAMA A
- Prediction of steady and unsteady asymmetric vortical p 172 A92-18372 flows around circular cones KARNIADAKIS, G.
- Direct computation of turbulence and noise [NASA-CR-187616] p 236 N92-14788
- KARPEL, MORDECHAY Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations p 204 A92-18622
- KAWAI, MASAFUMI CFD application to 2D/3D flow fields in Scramjet p 170 A92-17501 ngin KAZEMPOUR, AMIR
- Aircraft landing-induced tire spinup p 193 A92-20209
- KAZMIN, VYACHESLAV
- History of EPOS air-launched spaceplane project p 211 N92-14103 KEENAN, JAMES A.
- The effects of winglets on low aspect ratio wings at supersonic Mach numbers
- [NASA-CR-4407] p 178 N92-13996 KEENER, EARL R.
- Experimental research of the aerodynamics of nozzles and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048
- KEITH, THEO G., JR.
- Time domain flutter analysis of cascades using a full-potential solver p 176 A92-20747 KELLY, R. J.
- MLS system error model identification and synthesis p 189 N92-14015
- KHAVARAN, ABBAS
- Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence mode
- [NASA-TM-105338] p 237 N92-14795 A survey of the broadband shock associated noise prediction methods
- [NASA-TM-105365] p 237 N92-14797 KHRAMOV. A. G.
- Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpi p 219 A92-20771
- **KIENEL, GERHARD** PVD coatings for aircraft turbine blades p 216 A92-17950
- KILGORE, W. ALLEN The NASA Langley Research Center 0.3-meter transonic cryogenic tunnel microcomputer controller source code [NAŠA-CR-189556] p 209 N92-15077
- KIM, CHAN M. Computation of supersonic jet mixing noise for an
- axisymmetric CD nozzle using k-epsilon turbulence mod [NASA-TM-105338] p 237 N92-14795
- A survey of the broadband shock associated noise prediction methods p 237 N92-14797 (NASA-TM-1053651
- KIM, YONG H.

Aircraft landing-induced tire spinup p 193 A92-20209 PERSONAL AUTHOR INDEX

KING. C. H.

- Analysis technique for lightning attachment zoning of aircraft p 186 A92-20126 KING, J. E. Crack initiation and the short-to-long crack growth
- transition in a Ni-base superalloy p 213 A92-19767 KIRDEIKIS, J.
- Flight simulation p 207 N92-13982 KLYDE, DAVID H.
- Aeroservoelastic stabilization techniques for hypersonic flight vehicles
- [AIAA PAPER 91-5056] p 203 A92-17839 KNABE, F.
- Image-supported navigation for testing instrument p 189 N92-14012 landing systems
- KOENIG. G. Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects
  - p 226 N92-14424

### KOENIG. KLAUS Short time force measurement system

p 208 N92-15001 KOIFMAN. M.

- Autonomously aided strapdown attitude reference system p 204 A92-18610
- KOMERATH, N. M. Definition of the unsteady vortex flow over a wing/body configuration
- [NASA-CR-180083] p 178 N92-13995 KOMOROWSKI, JERZY P.
- Enhanced visual technique for rapid inspection of aircraft p 214 A92-17290 structures
- KOPEIKA, N. S. Numerical calculation of modulation transfer functions
- for low frequency mechanical vibrations p 235 A92-19982
- KOPPENWALLNER, GEORG FALKE and COBRA technology development in

performance and simulation requirements

electric-field measuring system

KOSITSKY, J.

KRAFT, R. E.

KRAINIUKOV, N. I.

KRAMER, MARK T.

description

oreforms

model

control

KROLL, N.

KROUTIL J. C.

KUCHER, A. G.

Confined

[AD-A2425981

AD-A2376671

KREJSA, EUGENE A.

[NASA-TM-105338]

prediction methods

[NASA-TM-105365]

super- and hypersonic speed

KUBRYNSKI, KRZYSZTOF

temperature limit criterion

KROGMANN, UWE K.

KRAULAND, KONRAD L.

aerodynamics and aerothermodynamics p 183 N92-15017 Behaviour and modelling of the aerothermodynamics of

ballistic entry vehicles in the high altitude flow regimes

Review of the European hypersonic wind tunnel

On the accuracy of an aircraft-borne ambient

Holographic-interferometry methods employed for

Aviation Diagnostics And Maintenance (ADAM) system

Universal weaving for turbine engine composite

Computation of supersonic jet mixing noise for an

A survey of the broadband shock associated noise

Introduction to neural computing and categories of

Steps towards an efficient and accurate method solving

Design of 3-dimensional complex airplane configurations

A probabilistic method for monitoring the remaining life

of aircraft gas turbine engine components using the

normal-shock/turbulent-boundary-layer

the Euler equations around a re-entry configuration at

interaction followed by an adverse pressure gradient

with specified pressure distribution via optimization

neural network applications to guidance, navigation and

axisymmetric CD nozzle using k-epsilon turbulence

preliminary concept of operation and functional

vibration-strength testing of aviation-engine workpieces

Design and performance of duct acoustic treatment

p 184 N92-15031

p 209 N92-15043

p 186 A92-20127

p 236 N92-14783

p 219 A92-20771

p 170 N92-14966

p 202 N92-14059

p 237 N92-14795

p 237 N92-14797

p 234 N92-14674

p 181 N92-14987

p 172 A92-18365

p 194 N92-13948

p 201 A92-18292

### PERSONAL AUTHOR INDEX

KUHLMAN, JOHN M.		
The effects of winglets on low	aspect ra	tio wings a
supersonic Mach numbers		
[NASA-CR-4407]	p 178	N92-13996
KUNZ, ROBERT F.		
Explicit Navier-Stokes computati	on of ca	scade flows
using the k-epsilon turbulence mode	el 🛛	
•	p 175	A92-20727
KURODA, SHIN-ICHI	•	
Supersonic inlet flow computation	•	
	o 171	A92-17502

KUROSAWA, MINORU Ultrasonic motor utilizing elastic fin rotor

p 215 A92-17414 KWATNY, HARRY G. Regulation of relaxed static stability aircraft

p 203 A92-18463

### L

LA BARBERA, A.

- Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerical investigations p 217 A92-19812 LABELLE, LINDA J.
- Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- [SCT-90RR-44] p 191 N92-15061 LABRUJERE, TH. E.
- Review of aerodynamic design in the Netherlands p 193 N92-13929

### LACOR, C.

- Genuinely upwind algorithms for the multidimensional Euler equations p 175 A92-20733 LACROIX. J. P.
- Mixed approach towards modular avionics conflicting requirements p 199 N92-14051

### LAEMMERMANN, HELMUT

PVD coatings for aircraft turbine blades p 216 A92-17950

### LAIBLE, CHRISTOPH

- An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861
- LAKSHMINARAYANA, BUDUGUR Explicit Navier-Stokes computation of cascade flows using the k-epsilon turbulence model

p 175 A92-20727

- Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838 LAMONICA, GARY L.
- Reconfigurable Mobile System Ground, sea and air applications p 218 A92-19986
- LANDRUM, D. B.
- Engineering method for calculating surface pressures and heating rates on vehicles with embedded shocks [AIAA PAPER 91-5060] p 171 A92-17842 LARIMER\_J.

Sensor fusion for synthetic vision

- [AIAA PAPER 91-3730] p 197 A92-17597 LAROCCA, FRANCESCO
- Research on inverse methods and optimization in Italy p 202 N92-13956

LARUELLE, GERARD

Potential hypersonic vehicles applications [AIAA PAPER 91-5086] p 169 A92-17854 LAURE, S.

The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles

p 208 N92-15009

LAVIRON M.

Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program and test implantation

[CEAT-S8-6551-PARTIEL-1-PT-] p 195 N92-14043 LAWRENCE, STELLA

- Development of a calibrated software reliability model for flight and supporting ground software for avionic systems p 234 N92-15870
- systems LAWSON, C. L.
- Multidisciplinary modeling and simulation of a generic hypersonic vehicle
- [AIAA PAPER 91-5015] p 232 A92-17813 LEBEAU, RAYMOND P.
- Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description [AD-A242598] p 170 N92-14966
- LECREN, R. T. High-temperature combustor and seal for a water piston
- propulsor [AD-A242493] p 229 N92-15385

- LEDERER, R.
- Hypersonic airbreathing propulsion activities for Saenger
- [AIAA PAPER 91-5040] p 200 A92-17828 LEE, IN
- Resonance prediction for slotted circular wind tunnel using finite element p 235 A92-18388 Static aeroelastic analysis for generic configuration wing p 174 A92-20201 LEE. R.
- Jet noise suppression p 236 N92-14784 LENAKOS, J.
- Definition of the unsteady vortex flow over a wing/body configuration [NASA-CR-180083] p 178 N92-13995
- LEONARD, DESIREE M.
- Analysis of objects in binary images [NASA-CR-4420] p 234 N92-14598 LEONDES, CORNELIUS T.
- Preumatic distortion compensation for aircraft surface pressure sensing devices p 218 A92-20206
- LEONE, G. High enthalpy nozzle flows p 182 N92-15000
- LEPAPE, MARIE-CLAIRE Recent progress in inverse methods in France p 201 N92-13938
- LESCHIUTTA, S.
- Navsat A civil complement to GPS and Glonass [IAF PAPER 91-490] p 188 A92-18505 LESTEL, J. C.
- Ablation and temperature sensors for flight measurements in reentry body heat shields p 227 N92-15004
- LEUNG, P. S.
- The application of a cylindrical-spherical floating ring bearing as a device to control stability of turbogenerators p 224 N92-14371 LEVY. RALPH
- Vortex generator design for aircraft inlet distortion as a numerical optimization problem p 194 N92-13959 LEVY, YUVAL
- Numerical prediction of subsonic turbulent flows over slender bodies at high incidence p 172 A92-18358 LI. CHAOJUN
- Study of a new airfoil used in reversible axial fans p 177 N92-13970
- LIANN, W. C. Fair weather convection and light aircraft accidents [IAF PAPER ST-91-004] p 186 A92-20651
- LIEBE, DETLEF Application of MSC/DYNA to shock and impact problems in aircraft industry
- problems in aircraft industry [MBB-UD-0593-91-PUB] p 225 N92-14382 LIFSHITZ S.
- Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation p 197 A92-19611
- Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216 LINAN, A.
- Compressibility effects in thin channels with injection p 216 A92-18369
- LINDEMANN, ULRICH Project of an adaptive multiaxial autopilot with learning pilot control
- [ETN-92-90592] p 205 N92-15072 LINDGREN, RANDAHL N.
- Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- [SCT-90RR-44] p 191 N92-15061 LIOU, LUEN-WOEI
- A stochastic regulator for integrated communication and control systems. I - Formulation of control law. II - Numerical analysis and simulation p 233 A92-19605 LIOU, S. G.
- Definition of the unsteady vortex flow over a wing/body configuration
- [NASA-CR-180083] p 178 N92-13995 LIU, C. H.
- Prediction of steady and unsteady asymmetric vortical flows around circular cones p 172 A92-18372 LIU, GAO-LIAN
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances
- p 201 N92-13939 Variational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953 LOCK, G. D.
- Nonstationary gasdynamics p 220 N92-13985 LOHNER, R.

Formation of shocks within axisymmetric nozzles p 176 A92-20760

	p 176	A92-20760
LOURME, D.		
Review of the European h	woersonic v	wind tunnel
performance and simulation requ	irements	
perior name and annual and requ	n 200	N02-15043
OWELD	p 203	1132-13043
LOWE, J. D.		
Aerodynamics	p 202	N92-13977
LOWRIE, ROBERT B.		
Evaluation of Euler solvers for	transonic wi	ing-fuselage
geometries	n 174	A92-20214
LI PING	P	
Optimal control and large with		
Opumal control problems with	maximum iu	ncuonal
	p 232	A92-18616
LU, PONG-JEU		
Flutter analysis of anisotropic	c panels wi	th patched
cracks	n 219	A92-20216
LICAS JEFFERY C	<b>P</b> 2.0	
LOOND, VEITENT C.		
Enhanced autopilot design throi	ugh hardware	-in-the-loop
simulation	p 204	A92-19103
LUDWIG, GARY L.		
Evolution of avionic system	s architectur	e, from the

Formation of shocks within axisymmetric nozzles

MARMIGNON, C.

1950's to the present p 198 N92-14047 LUKSAK, D. A.

- Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820 LUONGO, RENEE
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a (ACD-340) p 191 N92-14034
- [ACD-340] p 191 N92-14034 LYONS, D. F.
  - Flight test of a half-scale unmanned air vehicle p 193 A92-20208

### M

MA, PAUL W.

analysis

MARCHETTI, M.

investigations

MARCHIONNI, M

base superalloys

[NASA-CR-189514]

[NASA-CR-189515]

[NASA-CR-189469]

viscous flows around reentry bodies

MARKOPOULOS, N.

MARMIGNON, C.

MARHEFKA, R. J.

LOTH. E.

- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 MAFFIONE, R. A.
- On the accuracy of an aircraft-borne ambient electric-field measuring system p 186 A92-20127 MAGNUSEN, P. E.
- Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820 MAHAJAN, APARAJIT J.
- Eigenvalue calculation procedure for an Euler/Navier-Stokes solver with application to flows over airfoils p 170 A92-17429
- MAIER, A. Fatigue of repaired composite structures
- p 214 N92-14411 MAILLETTE, J.
- Nonstationary gasdynamics p 220 N92-13985 MAJJIGI, R. K.
- Jet noise suppression p 236 N92-14784
- Thermo-mechanical fatigue crack growth in aircraft engine materials p 213 A92-19799 MALONE, ERLE W.
- MIL-STD-1553 data bus/PCM multiplexer system
- p 188 A92-19211 MALONE, J. B.
- Inverse airfoil design procedure using a multigrid Navier-Stokes method p 193 N92-13932 MAMICH, HARVEY
- Dynamics and control of hypersonic vehicles The integration challenge for the 1990's
- [AIAA PAPER 91-5057] p 203 A92-17840 MARCHESE, MICHAEL Real-time microfocus radiography for electronic failure

Fracture analysis and crack propagation in pressurized

High temperature low cycle fatigue of single crystal nickel

SATCOM antenna siting study on P-3C aircraft, volume

SATCOM antenna siting study on P-3C aircraft, volume

Rapid near-optimal aerospace plane trajectory generation and guidance

Numerical simulation of thermochemical non-equilibrium

fuselage structures - Experimental and numerical

p 214 A92-17289

p 217 A92-19812

p 213 A92-19796

p 221 N92-14262

p 221 N92-14263

p 205 N92-14066

p 227 N92-15029

**B-7** 

### MARRAFFA, L

- SIMOUN and Scirocco wind tunnel nozzle viscous flow p 208 N92-14999 study MARTIN. C.
- Electronically steerable antenna for aircraft p 229 N92-15272
- MARZANO, A. Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980
- MASAD, J. A. Effect of suction on the stability of supersonic boundary layers. I - Second-mode waves. II - First-mode waves p 174 A92-19611
- MASOTTO, THOMAS K.
- Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 MATARRESE, M. D.
- Control of hypersonic aerodynamic forces with surface p 172 A92-18363 blowing MATSUDA, SEIJI
- Structure/control design synthesis of active flutter suppression system by goal programming p 204 A92-18621
- MATSUNAGA, KOJI
- Numerical simulation for various flowfields of aero-engine components p 200 A92-17503 MAUGHMER, MARK D.
- Analysis and design of planar and non-planar wings for induced drag minimization [NASA-CR-189509] p 179 N92-13999
- MAURER, F. Experimental study of hypersonic shock wave boundary
- layer interactions by means of infrared technique p 182 N92-14994 MAVRIPLIS, DIMITRI J.
- Algebraic turbulence modeling for unstructured and adaptive meshes p 216 A92-18362 MAYER, JUERGEN F.
- Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110
- MCCLOSKEY, T. Annular seals of high energy centrifugal pumps: Presentation of full scale measurement
- p 224 N92-14362 MCDONALD, GARY H. Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow p 212 N92-15877 models
- MCFARLAND, R. H. New siting techniques for the ILS glide slope p 188 A92-17422
- MCFAWN, LESTER Avionics technology beyond 2000
- p 200 N92-14058 MCGOVERN, JAMES J.
- Flight operations for higher harmonic control research [AD-A242478] p 196 N92-15067 p 196 N92-15067 MCKENNA, P. M.
- The use of finite difference electromagnetic analysis in the design and verification of modern aircraft p 192 A92-20136
- MCKENZIE, A. J. Filter debris analysis: A concrete approach to wear diagnosis [DREP-TM-88-20] p 222 N92-14345
- MCKINNEY, BARRY T. Designing through test [AIAA PAPER 91-3822] p 232 A92-17664 MČKINNEY, W. D. Aerodynamics o 202 N92-13977
- MCQUISTON, BARBARA K. Turbine engine diagnostics system study [DOT/FAA/CT-91/16] p 20 p 202 N92-14064
- MCRAE, D. S. Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736
- MCRUE, DUANE T. Aeroservoelastic stabilization techniques for hypersonic flight vehicles
- [AIAA PAPER 91-5056] p 203 A92-17839 MCRUER, DUANE
- Retrospective essay on nonlinearities in aircraft flight p 204 A92-18601 MEADOWS, KRISTINE R.
- Removal of spurious reflections from computational fluid dynamic solutions with the complex cepstrum p 235 A92-20729
- MEASE, KENNETH D.
- A geometric approach to regulator and tracker design for an aerospace plane [AIAA PAPER 91-5054] p 203 A92-17837 MECHAM, MICHAEL Domier 328 first flight p 192 A92-19924
- **B-8**

- Evaluations of X-29 high-AOA regime show promise for future fighters p 192 A92-19925 MEE. D. J.
- Large chord turbine cascade testing at engine Mach p 173 A92-18771 and Reynolds number MEHTA, U. B.
- Some Aspects of uncertainty in computational fluid dynamics results p 233 A92-19609 MENG. GUANG
- The stability of the steady state and bistable response of a flexible rotor supported on squeeze film dampers p 222 N92-14350
- MENON, P. K. A. Nonlinear control of a twin-lift helicopter configuration p 204 A92-18624
- Image-based ranging and guidance for rotorcraft [NASA-CR-184829] p 191 N92-14036 MÈRHAV, S. J.
- Autonomously aided strapdown attitude reference p 204 A92-18610 system Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation
- p 197 A92-18611 MERKEL, J. Navsat - A civil complement to GPS and Glonass
- p 188 A92-18505 [IAF PAPER 91-490] MÈRLO, A.
- Numerical simulations around models in hypersonic wind tunnels p 182 N92-14998 MERTENS. JOSEF
- Short time force measurement system p 208 N92-15001
- MESSERSCHMID, E. W. The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles
- p 208 N92-15009 MESSITER, A. F.
- Control of hypersonic aerodynamic forces with surface blowing p 172 A92-18363 MEYER, H.-J.
- A concept for the revisions of structural inspection p 226 N92-14431 chedules MILLER, JAMES G.
- Failure environment analysis tool (FEAT) development status
- [AIAA PAPER 91-3803] p 232 A92-17654 MILLER, L. S.
- Simple method of supersonic flow visualization using smoke p 219 A92-20764
- MILLER, WAYNE OWEN Analytical/numerical matching and periodic inversion: Two advances in free wake analysis p 178 N92-13994
- MILLS. HARLAN D.
- Cleanroom An alternative software development p 233 A92-19386 process MITCHELL, RICK
- Implementation and usage of the RJ program Data Acquisition System Ground Station p 210 A92-19257 MIURA, HIROKAZU
- Static aeroelastic analysis for generic configuration wing p 174 A92-20201 MIXSON, JOHN S.
- p 236 N92-14785 Interior noise MIYAJIMA, HIROSHI Scramjet research at the National Aerospace
- Laboratory (AIAA PAPER 91-5076) p 200 A92-17849 MOKRY. M.
- Complex variable boundary element method for externa potential flows p 172 A92-18353
- MONTANO, WILLIAM G. High rate PCM data receiving, recording and relying p 189 A92-19279
- MORGAN, D. R. Avionics technology beyond 2000
- p 200 N92-14058 MORO, MIKE
- An integrated real-time turbine engine flight test system p 201 A92-19275 MORRIS, M. J.
- Confined normal-shock/turbulent-boundary-layer interaction followed by an adverse pressure gradient p 172 A92-18365
- MORTARA, K. Analysis and design of planar and non-planar wings for induced drag minimization
- p 179 N92-13999 [NASA-CR-189509] MOTSINGER, R. E. Design and performance of duct acoustic treatment
- p 236 N92-14783 MUIR. H. C.
- Passenger knowledge of airline safety information (CRANFIELD-AERO-9111) p 187 N92-15054

- MUNSON, JOHN
- Seal development activities at Allison Turbine Division p 228 N92-15093 MURAKAMI, HIDEAKI
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348
- MURTHY, P. L. N. Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92 15402 MURTY, H.
- p 202 N92-13977 Aerodynamics Computational fluid dynamics p 177 N92-13979
- MUSZYNSKA, AGNES Rotor-to-stator partial rubbing and its effects on rotor
- dynamic response p 224 N92-14367 Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling p 224 N92-14370 machines
- MUYLAERT, J.
- Review of the European hypersonic wind tunnel performance and simulation requirements p 209 N92-15043
- MYERS, LAWRENCE P.
- Performance improvements of an F-15 airplane with an integrated engine-flight control system
- p 205 A92-20204 MYERS, THOMAS T.
- Aeroservoelastic stabilization techniques for hypersonic flight vehicles
- [AIAA PAPER 91-5056] p 203 A92-17839

### Ν

- NAKAMURA, KENTARO Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414 NAKAZAWA, TORU Ultrasonic motor utilizing elastic fin rotor
- p 215 A92-17414 NAPOLITANO, LUIGI G.
- Linear acoustics in gas mixtures with rate processes p 238 N92-15013 NAYFEH, A. H.
- Effect of suction on the stability of supersonic boundary layers. I - Second-mode waves. II - First-mode waves
  - p 174 A92-19611
- NEILAND, V. YA. Aerothermodynamic configuration of first generation aerospace planes (of Buran-type) and first flight results
- p 211 N92-14975 NELSON, B. E. Scoping studies for small steady-state tokamaks for divertor testing [DE92-000740] p 238 N92-15761 NELSON, T. Computational fluid dynamics p 177 N92-13979 NETTERFIELD. M. P. Hypersonic aerothermodynamic computations using a point-implicit TVD method p 183 N92-15006 NEUMANN, RICHARD D.
- The value of sub-scale flight tests in the development of NASP vehicles
- [AIAA PAPER 91-5048] p 210 A92-17834 NEWMAN, J. C., JR.
- Fatigue crack initiation and small crack growth in several p 212 A92-19754 airframe allovs Proof test and fatigue crack growth modeling on 2024-T3
- aluminum alloy p 213 A92-19828 NEWMAN, ROBERT B. Rotorcraft low altitude IFR benefit/cost analysis:
- Operations analysis [SCT-90RR-44] p 191 N92-15061

Heat transfer measurements from a smooth NACA 0012

Nonlinear triggered lightning models for use in finite

Two-dimensional effects in a triangular convecting fin

Navier-Stokes analysis of turbulent boundary layer and

Thermo-mechanical fatigue crack growth in aircraft

Analysis tools of ONERA and DLR for the

wake for two-dimensional lifting bodies

aerothermodynamics of reentry vehicles

p 218 A92-20215

p 230 A92-20128

p 219 A92-20324

p 221 N92-14309

p 213 A92-19799

p 211 N92-14977

NEWTON, JAMES E.

difference calculations

airfoil

NG, POH H.

NGUYEN, H.

NGUYEN, PHUC

NICHOLAS, T.

engine materials

NIEDERDRENK, P.

### PERSONAL AUTHOR INDEX

### NIELSEN, T.

### Airbus Industrie A330/A340: Full scale fatigue test of p 226 N92-14425 center fuselage and wing NIKLASCH, N.

- Navsat A civil complement to GPS and Glonass
- p 188 A92-18505 [IAF PAPER 91-490] NITSOPOULOS, IOANNIS Application of MSC/DYNA to shock and impact problems in aircraft industry
- [MBB-UD-0593-91-PUB] p 225 N92-14382 NOAH, SHERIF T.

Nonlinear rotordynamics analysis [NASA-CR-184263]

- p 221 N92-14344 NOLL. BERTHOLD
- Evaluation of a bounded high-resolution scheme for combustor flow computations p 201 A92-20734 NORDMANN, R.
- Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356
- Determination of rotordynamic coefficients for labyrinth and application to rotordynamic desian seals p 223 N92-14360 calculations
- NOREN, GEORGE
- Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft

0

- O'RENDY, JOSEPH E.
- Retrofit provides navigation enhancement for older p 198 A92-20025 aircraft
- ODAM, G. A. M. Lightning protection requirements for aircraft: A proposed specification
- p 187 N92-14007 [RAE-TM-FS(F)-632-REV-ISSUE] OGDEN, T. P.
- Analysis technique for lightning attachment zoning of p 186 A92-20126 aircraft
- OHMORI, YASUNORI
- CFD application to 2D/3D flow fields in Scramjet p 170 A92-17501 engine OKABE. AKIRA
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit
- p 222 N92-14348 OLIVIER, H.
- High enthalpy testing in the Aachen (Fed. Republic of Germany) shock tunnel TH 2 p 208 N92-15021 OLSON, RICHARD F.
- Simulation of radar clutter and jet engine modulation p 216 A92-19091 using digital quadrature modulator OLSSON, MATS-OLOF
- Damage tolerance of the fighter aircraft 37 Viggen. I -Analytical assessment. II - Experimental verification p 192 A92-19819
- ONATE, E.
- Flow and temperature computations for space vehicles using adaptive finite element techniques p 181 N92-14990
- ONG. C. L.
- Some results on metal and composite patch reinforcement of aluminum honeycomb panel p 216 A92-18830
- ONO. M.
- Experiment of static and dynamic characteristics of spiral p 223 N92-14361 arooved seals ONOFRI, M.
- Nonequilibrium hypersonic inviscid steady flows
- p 176 A92-20737 Influence of chemical modeling on the solution of p 183 N92-15016 hypersonic shock layers
- OREN. N. The influence of a retarding rocket on parameter limits p 211 N92-15037 for reentry trajectories
- ORKWIS, PAUL D. Newton's method solver for high-speed viscous separated flowfields p 176 A92-20736
- ORSZAG. S. Direct computation of turbulence and noise
- [NASA-CR-187616] p 236 N92-14788 ORTWERTH, PAUL J.
- Three dimensional hypersonic inlets Low speed nerformance
- [AIAA PAPER 91-5021] p 171 A92-17817 OTAWARA, YASUHIKO
- Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit
  - p 222 N92-14348

### Ρ

- PADOVAN, JOE
- Aircraft landing-induced tire spinup p 193 A92-20209
- PALLEGOIX, JEAN-FRANCOIS Transitional flows around re-entry bodies p 184 N92-15035
- PALMBERG, BJORN Damage tolerance of the fighter aircraft 37 Viggen, 1
- Analytical assessment. II Experimental verification p 192 A92-19819
- PANDEY, AJAY K.
- Three-dimensional thermal structural analysis of a swept cowl leading edge subjected to skewed shock-shock interference heating p 174 A92-20306 PAPIRNYK. O.
- Review of the European hypersonic wind tunnel performance and simulation requirements p 209 N92-15043
- PARK, CHUL
- Rate parameters for coupled vibration-dissociation in a p 235 A92-20301 generalized SSH approximation PASCHAL, WILLIAM A.
- A study on vortex flow control on inlet distortion in the e-engined 727-100 center inlet duct using computational fluid dynamics
- [NASA-TM-105321] p 179 N92-13998 PAVEL M.
- Sensor fusion for synthetic vision p 197 A92-17597 [AIAA PAPER 91-3730] PEART, NOEL A.
- Flyover-noise measurement and prediction
- p 236 N92-14786 PEGAH. M.
- Model based reasoning in the aerospace domain [AIAA PAPER 91-3709] . p 230 A92 17582 PEISEN, DEBORAH J.
- Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- ISCT-90RR-441 p 191 N92-15061 PELLAZAR, MILES B.
- Advanced avionics system development environment p 231 A92-17608 [AIAA PAPER 91-3944] PENG, Y. K. M.
- Scoping studies for small steady-state tokamaks for divertor testing
- [DE92-000740] p 238 N92-15761 PENNA, SERGIÓ D.
- On-board data acquisition system for Embraer's p 198 A92-19251 **CBA123** PERALA, R. A.
- The use of finite difference electromagnetic analysis in the design and verification of modern aircraft
- p 192 A92-20136 PERALA, RODNEY A.
- Nonlinear triggered lightning models for use in finite p 230 A92-20128 difference calculations Analysis and modeling of lightning strikes to the F106B,
- CVF580, and C160 aircraft p 186 A92-20129 PERRIN, M. Y. Hypersonic viscous shock layer in thermochemical
- p 183 N92-15014 nonequilibrium PERRY, DOUGLAS
- Verification of flight software by embedding software simulation in simulation of external environment
- p 232 A92-19084 PETERS, C.
- Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin p 226 N92-14414
- PETERS, DAVID A.
- Integration of dynamic, aerodynamic, and structural optimization of helicopter rotor blades [NASA-CR-189018] p 195 N92-14038
- PETERSEN, K. L. Multidisciplinary modeling and simulation of a generic
- hypersonic vehicle p 232 A92-17813 AIAA PAPER 91-50151
- PETLEY, DENNIS H. A comparison of cooling methods for the airframe nozzle
- of a single-stage-to-orbit aircraft [AIAA PAPER 91-5036] p 210 A92-17825
- Analysis of cooling systems for hypersonic aircraft p 216 A92-17843 [AIAA PAPER 91-5063] PETRICK, S. WALTER
- Multicomponent gas sorption Joule-Thomson refrigeration [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203
- PETRINI, G. L. p 220 N92-13985 Nonstationary gasdynamics
- PEZZULLO, G. Incompressible steady aerodynamics using a standard
- p 174 A92-20218 finite element code

PHILLIPS, D.

Inertia-friction welding of an advanced rapidly solidified p 212 A92-18898 titanium allov PHILLIPS, E. P.

RADESPIEL, R.

p 179 N92-14001

p 191 N92-15058

p 204 A92-18624

p 227 N92-15033

p 231 A92-17637

p 228 N92-15084

p 195 N92-14037

p 194 N92-13949

p 194 N92-13981

p 181 N92-14990

p 211 N92-14977

p 185 N92-15047

B-9

- Fatigue crack initiation and small crack growth in several p 212 A92-19754 airframe alloys PICCO, E.
- High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796
- PICKET, J. S. Nonstationary gasdynamics PILAND, WILLIAM M. p 220 N92-13985
- Aerothermodynamics for United States advanced programs p 184 N92-15039
- PINCKNEY, S. Z. A configuration development strategy for the NASP [AIAA PAPER 91-5044] p 210 A92-17830
- p 210 A92-17830 PISARENKO, GEORGII S.
- Aerodynamic damping of blade vibrations in p 200 A92-18198 turbomachines POE. C. C., JR.
- Proof test and fatigue crack growth modeling on 2024-T3 p 213 A92-19828 aluminum alloy POERTNER, T.
- Simulation requirements for RCS plume: Flowfield interaction modelling on a winged reentry vehicle p 181 N92-14985
- POINSATTE, PHILIP E. Heat transfer measurements from a smooth NACA 0012 airfoil p 218 A92-20215
- Roughness effects on heat transfer from a NACA 0012 airfoil p 219 A92-20217 POLESKY, SANDRA P.
- Three-dimensional thermal structural analysis of a swept

[NASA-TM-105389]

POWELL, CLEMANS A.

landing system

[AD-A242757]

PRASAD, J. V. R.

PRISCO, GIULIO

PRYOR, ANNA H.

forces in seals

QIAN. Y. J.

QUACH. TAI

QUADFASEL U.

QUART, BARRY

OUINTANA, F.

RADESPIEL, R.

[NASA-CR-189579]

POWELL, FREDERICK D.

(DSMC) code for fluid dynamics

[AIAA PAPER 91-3779]

PRZEKWAS, ANDRZEJ J.

PRZYBYSZEWSKI, J. S.

[NASA-CR-189044]

Flight research

inverse aerodynamic design

- cowl leading edge subjected to skewed shock-shock interference heating p 174 A92-20306 POPE A NELSON
- Areas of seal R/D at GE p 228 N92-15094 POTAPCZUK, MARK G. LEWICE/E: An Euler based ice accretion code

Human response to aircraft noise p 236 N92-14780

The problem of multiple solutions in area navigation and

computed centerline operations with the microwave

Nonlinear control of a twin-lift helicopter configuration

Parallelization of a Direct Simulation Monte Carlo

Optical computing at NASA Ames Research Center

Development of a CFD code for analysis of fluid dynamic

High temperature static strain gage development

Q

Extended mapping and characteristics techniques for

Probabilistic lifing approach for aero engine disks made

Implementation and usage of the RJ program Data

Flow and temperature computations for space vehicles

Acquisition System Ground Station p 210 A92-19257

R

Analysis tools of ONERA and DLR for the

Progress with multigrid schemes for hypersonic flow

using adaptive finite element techniques

aerothermodynamics of reentry vehicles

of powder nickel base alloys containing ceramic defects p 226 N92-14424

### RADMAND, MANSOUR

### RADMAND, MANSOUR

- A state-of-the-art data acquisition system p 217 A92-19231
- RAFFIN, M.
- Experimental investigation of transverse jet effects related to hypersonic space vehicles p 182 N92-14995
- RAM, G. R.
- A unique approach to aircraft conflict resolution using artificial intelligence techniques p 190 N92-14029 RAMAMOORTHY, R. P.
- Nonlinear landing gear behavior at touchdown p 192 A92-19606 RAMETTE, PHILIPPE
- Potential hypersonic vehicles applications
- [AIAA PAPER 91-5086] p 169 A92-17854 RAMIZ, M. A.
- Detection of flow state in an unsteady separating flow p 219 A92-20741 RAMSEY, CHRISTOPHER
- Test results for rotordynamic coefficients of the SSME HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357
- RAND, O.
- Experimental investigation of periodically excited rotating composite rotor blades p 218 A92-20213 RANEY, DAVID L
- Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838 RANUCCI, D.
- High temperature low cycle fatigue of single crystal nickel base superalloys p 213 A92-19796 RAPP. HELMUT
- Avionics systems development: Technological trends, conflicts, and cost issues in a changing European environment p 199 N92-14054 RATCLIFF, ROBERT R.
- Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction p 193 A92-20202
- RAY, ASOK
- A stochastic regulator for integrated communication and control systems. I - Formulation of control Iaw. II - Numerical analysis and simulation p 233 A92-19605 RAY LAURA R
- Application of stochastic robustness to aircraft control systems p 204 A92-18620 BFABDON, KIMBERLY
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a
- [ACD-340] p 191 N92-14034 REDDY, E. S.
- Analysis of aircraft engine blade subject to ice impact [NASA-TM-105336] p 229 N92-15402 REDDY, T. S. R.
- Time domain flutter analysis of cascades using a full-potential solver p 176 A92-20747 REED. HELEN L.
- Numerical simulation of swept-wing flows [NASA-CR-189457] p 180 N92-14969 REID, L. D.
- Flight simulation p 207 N92-13982 REID, MAX B.
- Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637 REIGHARD, M. K.
- Rapid ultrasonic scanning of aircraft structures p 215 A92-17292
- RICE, WILLIAM A. High rate PCM data receiving, recording and relying p 189 A92-19279
- RICKER, WILLIAM G. A new 1553 all-bus instrumentation monitor
- p 198 A92-19252 RIEGER, H. Computational aerothermodynamic methods for
- industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027 RIEGER, JAMES L
- Telemetry antenna patterns for single and multi-element arrays p 188 A92-19216 RILEY, CHRISTOPHER J.
- Engineering calculations of three-dimensional inviscid hypersonic flowfields p 175 A92-20378 RIVERA, JOSE A., JR.
- The benchmark aeroelastic models program: Description and highlights of initial results [NASA-TM-104180] p 185 N92-15049
- RIZZI, A. Hypersonic flow past delta wing flow simulated by
- Navier-Stokes solutions p 180 N92-14981 **ROBERTS, G. T.** Interference beating near fin/body junctions on

interior of one from any	 min boody jo	
hypersonic vehicles	p 182	N92-14996
ROBINSON, P. A.		
Flight simulation	p 207	N92-13982

Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020

- RODI, ALFRED R. Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and wind measurements from aircraft inertial navigation systems
  - p 188 A92-18172 DECK, W. The IRS plasma wind tunnels for the investigation of
- thermal protection materials for reentry vehicles p 208 N92-15009 ROISMAN. W. P.
- Identification of dynamic characteristics of flexible rotors as dynamic inverse problem p 220 N92-13962 ROLF, R. L.
- Methodology for the assessment of material quality effects on airframe fatigue durability p 213 A92-19820 ROMANO, R. A.
- Flight simulation p 207 N92-13982 ROSE, WILLIAM C.
- Numerical investigations in three-dimensional internal flows
- [NASA-CR-189467] p 221 N92-14313 ROTT, D.
- Environmental fatigue tests with composite materials p 214 N92-14413
- RUDOLPH, TERENCE Nonlinear triggered lightning models for use in finite difference calculations p 230 A92-20128 Analysis and modeling of lightning strikes to the F106B,
- CVF580, and C160 aircraft p 186 A92-20129 RUIJGROK, G. J. J. Propeller-driven-small airplane noise certification
- [LR-650] p 237 N92-14798 RUSSELL, JULIE C.
- Fatal occupational injury related to helicopters in the United States 1980-1985 p 186 A92-20720 RUSSO, G.
- SIMOUN and Scirocco wind tunnel nozzle viscous flow study p 208 N92-14999 High enthalpy nozzle flows p 182 N92-15000
- RUTH, JOHN C. Historical perspective on the evolution of avionics
- standards p 198 N92-14049 RYAN, S. G.
- Limit cycle vibrations in turbomachinery
- [NASA-TP-3181] p 211 N92-14108

### S

- SAARENVIRTA, G.
- Aerodynamics p 202 N92-13977 SABETTA, F.
- Nonequilibrium hypersonic inviscid steady flows p 176 A92-20737 Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15016
- SABUNCU, M. Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions
- p 219 A92-20756 SAFFOLD, J. A.
- A multidimensional terrain model for low altitude tracking scenarios p 205 A92-19107 SAGNIER, P.
- Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles
- p 211 N92-14977 Review of the European hypersonic wind tunnel performance and simulation requirements
- p 209 N92-15043
- Transonic Navier-Stokes computations for a spinning body of revolution [AD-A241015] p 180 N92-14972
- [AD-A241015] p 180 N92-14972 SAJBEN, M.
- Confined normal-shock/turbulent-boundary-layer interaction followed by an adverse pressure gradient p 172 A92-18365
- SALLEY, THOMAS An alternative method for acquiring avionic bus data in a class I PCM telemetry system p 217 A92-19202
- SANANDRES, LUIS A. Effect of eccentricity on the static and dynamic
- performance of a turbulent hybrid bearing p 225 N92-14373 SANDERSON, S. R.
- Drag balance for hypervelocity impulse facilities p 207 A92-18375
- SANSONE, A. Aerothermodynamic development of the CARINA
- re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980

- SAUCEREAU, D.
- Supersonic combustion studies p 211 N92-14984 SAVU, G.
- On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931
- SCAGGS, N. E.
- Wedge-induced turbulent boundary-layer separation on a roughened surface at Mach 6.0 p 175 A92-20379 Turbulent boundary-layer characteristics over a flat-plate/wedge configuration at Mach 6
  - p 176 A92-20761

SCHABER, VEIT

Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110

SCHAEFER, W.

Navsat - A civil complement to GPS and Gionass [IAF PAPER 91-490] p 188 A92-18505 SCHAPHORST, RICHARD

Compression techniques for video telemetry p 188 A92-19214

SCHEITLE, H.

SCHMAELZLE, U

SCHMATZ M.A.

SCHMIDT, DAVID K

hypersonic flow conditions

[AIAA PAPER 91-5057]

SCHNEIDER, STEVEN P.

AIAA PAPER 91-5026]

integration challenge for the 1990's

speed boundary laver transition

super- and hypersonic speed

Federal Republic of Germany

aerothermodynamics of reentry vehicles

aircraft

SCHMIDT. E.

SCHOENE, J.

SCHOEPFEL, A.

SCHRAGE, D. P.

SCHWAB, R. R.

SCHWARMANN, L.

Saenger

schedules

SCOTT, C. D.

SCHWARTEN, H.

[ETN-92-90317]

SCHUMACHER, GARY A.

[AIAA PAPER 91-5040]

SCHWERTASSEK, RICHARD

system simulation

SCOTT, WILLIAM B.

future fighters

viscous design optimization techniques

with variable entropy at boundary layer edge

- Influences of wind tunnel parameters on airfoil characteristics at high subsonic speeds p 173 A92-18769
- SCHELL, ALLAN C. CFD helps the Air Force fly right p 169 A92-20146
- SCHETTINO, ANTONIO High enthalpy nozzle flows p 182 N92-15000
- SCHETZ, J. A. Effects of unsteady shock impingement on high-speed
- gaseous mixing [AIAA PAPER 91-5091] p 172 A92-17857
- SCHIFF, LEWIS B. Numerical prediction of subsonic turbulent flows over
- slender bodies at high incidence p 172 A92-18358 SCHIJVE, J.
  - Bulging of fatigue cracks in a pressurized aircraft fuselage [LR-655] p 196 N92-14045

Methodology for assessment of skin repairs on Airbus

Verification and application of the NSFLEX method for

Dynamics and control of hypersonic vehicles - The

Supercritical blade design on stream surfaces of

A quiet-flow Ludwieg tube for experimental study of high

Analysis tools of ONERA and DLR for the

Steps towards an efficient and accurate method solving

Review of investigations on aeronautical fatigue in the

Nonlinear control of a twin-lift helicopter configuration

Design and implementation of a total flight test system

Hypersonic airbreathing propulsion activities for

A concept for the revisions of structural inspection

Application of direct inverse analogy method (DIVA) and

Representation of geometric stiffening in multibody

Aerodynamic heating on AFE due to nonequilibrium flow

Evaluations of X-29 high-AOA regime show promise for

the Euler equations around a re-entry configuration at

revolution with an inverse method p 220 N92-13950

p 226 N92-14428

p 182 N92-15005

p 203 A92-17840

p 207 A92-17819

p 211 N92-14977

p 181 N92-14987

p 225 N92-14397

p 204 A92-18624

p 189 A92-19278

p 200 A92-17828

p 226 N92-14431

p 176 N92-13951

p 217 A92-19463

p 183 N92-15020

p 192 A92-19925

### PERSONAL AUTHOR INDEX

### SEALS, J. D. Putting ten pounds of avionics in a one pound package (Can we do it again?) AIAA PAPER 91-37661 p 197 A92-17628 SEHER. CHRIS National research program for nondestructive inspection of aging aircraft p 169 A92-17294 SHAPIRO, WILBUR Industrial code development p 227 N92-15083 SHAPOSHNIKOV. IU. N. Holographic-interferometry methods employed for vibration-strength testing of aviation-engine workpieces p 219 A92-20771 SHARMA, SURENDRA P. Rate parameters for coupled vibration-dissociation in a generalized SSH approximation p 235 A92-20301 SHAUGHNESSY, JOHN D. Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles [NASA-TM-102687] p 206 N92-15076 SHEEN, OUEN Y Model oscillations at high angle of attack in a low speed wind tunnel test [IAF PAPER ST-91-001] p 175 A92-20649 SHEFFER, SCOTT G. Aerodynamic shape optimization of arbitrary hypersonic p 194 N92-13954 vehicles SHEKELL, TED K. Reducing environmental noise impacts: A USAREUR noise management program handbook [AD-A240797] p 237 N92-14791 SHEN, S. B. Some results on metal and composite patch reinforcement of aluminum honeycomb panel p 216 A92-18830 SHENG, B. C. Experiment of static and dynamic characteristics of spiral p 223 N92-14361 arooved seals SHERIF. YOSEF S. Z-Basic algorithm for collision avoidance system p 188 A92-18482 SHIH. PETER K. The value of sub-scale flight tests in the development of NASP vehicles [AIAA PAPER 91-5048] p 210 A92-17834 SHIN. JAIWON Results of an Icing test on a NACA 0012 airfoil in the NASA Lewis Icing Research Tunnel [NASA-TM-105374] p 185 N92-15051 A turbulence model for iced airfoils and its validation [NASA-TM-105373] p 186 N92-15052 SHOPE, FREDERICK L. Conjugate conduction/convection/nucleate-boiling heat transfer with a high-speed boundary layer p 215 A92-17823 [AIAA PAPER 91-5033] SHUBIN, G. R.

A comparison of two closely-related approaches to p 193 N92-13933 aerodynamic design optimization SICLARI, M. J.

Asymmetric separated flows at supersonic speeds p 176 A92-20742 SIERON, THOMAS B.

Evolution and development of hypersonic configurations

1958-1990		
[AD-A242768]	p 197	N92-15069

SILCOX. R. J. Approximation methods for control of acoustic/structure models with piezoceramic actuators

[NASA-CR-189578] p 234 N92-15658 SIMMONS. J. M.

Drag balance for hypervelocity impulse facilities p 207 A92-18375 SIMPSON, DAVID L.

Enhanced visual technique for rapid inspection of aircraft structures p 214 A92-17290 SINGH. K. ROMI

- A strategy for exploiting the full potential of MLS based terminal procedures in Canada p 190 N92-14025 p 190 N92-14025 SINGHAL, ASHOK K.
- Development of a CFD code for analysis of fluid dynamic p 228 N92-15084 forces in seals

SKINN, DONALD A. Study of the engine bird ingestion experience of the Boeing 737 aircraft

p 187 N92-15053 [DOT/FAA/CT-89/16] SLUSARCZUK, MARKO

DARPA high resolution display technologies p 218 A92-19977

SMITH. HOWARD R.

An intelligent pilot vehicle interface for a day/night adverse weather pilotage system (D/NAPS) [AIAA PAPER 91-3729] p 197 A92-17596

SMITH. I. G. A unique approach to aircraft conflict resolution using p 190 N92-14029 artificial intelligence techniques

SMITH R C

Approximation methods for control of acoustic/structure nodels with piezoceramic actuators [NASA-CR-189578] p 234 N92-15658

SNEGIREV N A

A probabilistic method for monitoring the remaining life of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 SNYDER, CURTIS D.

A configuration development strategy for the NASP [AIAA PAPER 91-5044] p 210 A92-17830 SOBIECZKY, H.

Extended mapping and characteristics techniques for inverse aerodynamic design p 194 N92-13949 SOLAZZO, M.

- Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980
- SONSINO, C. M. Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405
- SOOSAAR, R. J. Flight simulation p 207 N92-13982 SORENSEN, THOMAS
- Airfoil optimization with efficient gradient calculations p 177 N92-13960

SOSUNOV, V. A. Soviet CFD - An international perspective p 233 A92-20150

- SPEED. F. M., JR.
- Designing through test [AIAA PAPER 91-3822] p 232 A92-17664
- SPIRKOVSKA, LILLY Optical computing at NASA Arnes Research Center
- [AIAA PAPER 91-3779] p 231 A92-17637 SRINIVASAN S
- Hypersonic flow past delta wing flow simulated by Navi er-Stokes solutions p 180 N92-14981 STARZEL-DEHEL, BARBARA
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a [ACD-340] p 191 N92-14034
- STECKEMETZ, B.

FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017

STEINBERG, MARC L. Neural network and fuzzy logic technology for naval flight

control [AD-A242650] p 206 N92-15074

- STENGEL, ROBERT F.
- Application of stochastic robustness to aircraft control p 204 A92-18620 systems STEPHAN, AMY
- Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype p 220 N92-14217 flight hardware STETTER. H.
- Experimental investigations of exciting forces caused p 223 N92-14354 by flow in labyrinth seals
- STETTER, HEINZ Three-dimensional calculation of low-frequency unsteady transonic flow in axial turbine stages p 174 A92-19110

STEVENS, E. G. Whole aircraft lightning indirect effects evaluation using

low level injection techniques p 192 A92-20134 STEVENSON, ROBERT W.

Failure environment analysis tool (FEAT) development status

- p 232 A92-17654 [AIAA PAPER 91-3803] STICKLEN, JON
- Model based reasoning in the aerospace domain p 230 A92-17582 [AIAA PAPER 91-3709] STOCK. H.
- Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise p 227 N92-15027 problems STOLLERY, J. L.

Flow over a delta wing at hypersonic speeds p 181 N92 14993

STORACE, ALBERT F. A simplified method for predicting the stability of aerodynamically excited turbomachinery p 224 N92-14364

STRACHAN, RUSSELL L.

Testing of the high accuracy inertial navigation system the Shuttle Avionics Integration Lab p 210 N92-14087

STRAUSSFOGEL, DENNIS M. Analysis and design of planar and non-planar wings for

induced drag minimization p 179 N92-13999 [NASA-CR-189509]

**TARN, JIANN-QUO** 

STREIT. T.

e

S

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s

s

s

s

S

S

S

S

Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at p 181 N92-14987 super- and hypersonic speed STUERCHLER, R.

Annular seals of high energy centrifugal pumps:

resentation of fail scale measurement
p 224 N92-14362
TURGES, JAMES W.
Reconfigurable Mobile System - Ground, sea and air
applications p 218 A92-19986
TURSBERG, K. H.
Thrust nozzle test facility at DLR Cologne
[AIAA PAPER 91-5024] p 206 A92-17818
ULLIVAN, P. A.
Computational fluid dynamics p 177 N92-13979
ULLIVAN, WILLIAM
Conducting the NASP ground test program
[AIAA PAPER 91-5029] p 209 A92-17820
UNDARAM, P.
A Navier-Stokes solution of Hull-ring wing-thruster
interaction p 221 N92-14310
USKI, HARALD
Application of MSC/DYNA to shock and impact
problems in aircraft industry
[MBB-UD-0593-91-PUB] p 225 N92-14382
UZUKI, SHINJI
Structure/control design synthesis of active flutter
suppression system by goal programming
p 204 A92-18621
UZUKI, TAKAKO
CFD application to 2D/3D flow fields in Scramjet
engine p 170 A92-17501
WAIN, M. H.
Fatigue crack initiation and small crack growth in several
airframe alloys p 212 A92-19754
WANSON, H. C.
Inverse airfoil design procedure using a multigrid
Navier-Stokes method p 193 N92-13932
Progress with multigrid schemes for hypersonic flow
problems(
[NASA-CH-1895/9] p 185 N92-15047
WEETMAN, BILL
Infra-red offers new landing aid competition
p 198 A92-18937
TRES, J. E. H.
The effects of manufacturing tolerances on the vibration
of aero-engine rotor-damper assemblies
p 222 N92-14349
TMS, HATMUND A.
I INDIANANAN AUDIOUS VILL BALANT AND THE STREET

Operational survey: VFR heliport approaches and denartures [SCT-9188-26] p 190 N92-14033

Т

TABAKOFF. WIDEN

LDV measurements and investigation of flow field through radial turbine guide vanes p 217 A92-19618 TAL TSZE C.

Flow separation patterns over an F-14A aircraft wing p 174 A92-20205 TAKAHASHI, M. D.

Helicopter air resonance modeling and suppression using active control p 204 A92-18625

TAKANASHI, SUSUMU Aerodynamic aircraft design methods and their notable applications: Survey of the activity in Japan

- p 193 N92-13930 TALMADGE, RICHARD D.
- A state-of-the-art data acquisition system p 217 A92-19231
- TAM. C. K. W. Broadband shock-associated noise from supersonic jets in flight p 235 A92-18683
- TAM. L. T. Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020
- TANAKA, ATSUSHIGE

Numerical simulation for various flowfields of p 200 A92-17503 aero-engine components TANNER, J. C.

Flight test of a half-scale unmanned air vehicle

p 193 A92-20208 TANNER. M.

Base pressure measurements on a cone at Mach numbers from M sub infinity = 5 to 7

p 173 A92-18770 Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for space vehicles p 181 N92-14992

TARN, JIANN-QUO Flutter analysis of anisotropic panels with patched p 219 A92-20216 cracks

- TEGTMEIER, A. FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017
- THAYER, J. S. On the accuracy of an aircraft-borne ambient electric-field measuring system p 186 A92-20127
- THIELEKE, G. Experimental investigations of exciting forces caused by flow in labyrinth seals p 223 N92-14354
- THIVET, F. Hypersonic viscous shock layer in thermochemical
- nonequilibrium p 183 N92-15014 THOMAS, J. Vibration characteristics of pretwisted aerofoil
- cross-section blade packets under rotating conditions p 219 A92-20756 THOMPSON, JOE F.
- Three-dimensional solution-adaptive grid generation on composite configurations p 172 A92-18352 THORPE, ALAN J.
- Mesoscale dynamics of cold fronts Structures described by dropsoundings in Fronts 87 p 230 A92-18902
- THORSSELL, STEVEN E. An alternative method for acquiring avionic bus data in a class I PCM telemetry system p 217 A92-19202 THUKRAL AJAY
- Roll-performance criteria for high augmented aircraft p 204 A92-18623
- TING, P. C. Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge p 183 N92-15020
- TOBAK, MURRAY Surface flow patterns on an ogive-cylinder at
- incidence p 176 A92-20762
- Numerical simulation for various flowfields of aero-engine components p 200 A92-17503 TRIFU, Ø.
- On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931 TSUI, Y.
- Limitations to the large strain theory p 219 A92-20356
- TU, YEN Three-dimensional solution-adaptive grid generation on
- composite configurations p 172 A92-18352 TUBANOS, N.
- The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009
- TUDES, BULENT Rub induced rotor/stator vibration analysis on CF700
- engine [NRC-TR-ENG-007] p 202 N92-14060 TULEY. M. T.
- A multidimensional terrain model for low altitude tracking scenarios p 205 A92-19107
- TURKOVICH, JOHN J. Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 TURTON. JOHN A.
- Avionics software evolution p 199 N92-14052

### U

- UCHIKI, TATSUYA
- Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414 UEHA. SADAYUKI
- Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414 ULBRICH, HEINZ
- Hydraulic actuator system for rotor control p 224 N92-14363
- UNDERWOOD, HAROLD W. Avionics reliability, durability, and integrity: Can they be independent of application? p 200 N92-14056
  - v
- VAJINGORTIN, L. D.
- Identification of dynamic characteristics of flexible rotors as dynamic inverse problem p 220 N92-13962 VALORANI, M.
- Nonequilibrium hypersonic inviscid steady flows p 176 A92-20737
- VAN BUREN, MARK A. A geometric approach to regulator and tracker design

for an aerospace plane [AIAA PAPER 91-5054]	p 203	A92-17837

- VAN DER VOOREN, J.
- Inviscid drag prediction for transonic transport wings using a full-potential method p 174 A92-20212 VAN DER WEES. A. J.
- Inviscid drag prediction for transport wings using a full-potential method p 174 A92-20212 VAN FOSSEN, G. J.
- Heat transfer measurements from a smooth NACA 0012 airfoil p 218 A92-20215
- Roughness effects on heat transfer from a NACA 0012 airfoil p 219 A92-20217 VAN OORDT, T. W.
- Rapid ultrasonic scanning of aircraft structures p 215 A92-17292 VANPAASSEN, D. M.
- Propeller-driven-small airplane noise certification
- [LR-650] p 237 N92-14798 VASSALLO, J.
- Electronically steerable antenna for aircraft p 229 N92-15272 VAUGHAN, ROBIN L.
- Use of distance-measuring equipment (DME) for correcting errors in position, velocity, and wind measurements from aircraft inertial navigation systems n 188 A92-18172
- VENUGOPAL. N.
- Automated trajectory synthesis for hypersonic vehicles using energy management and variational calculus techniques p 210 A92-19061 VETROV, A. N.
- A probabilistic method for monitoring the remaining life of aircraft gas turbine engine components using the temperature limit criterion p 201 A92-18292 VETTER. M.
- High enthalpy testing in the Aachen (Fed. Republic of Germany) shock tunnel TH 2 p 208 N92-15021 VINH, NGUYEN X.
- Optimal control problems with maximum functional p 232 A92-18616
- VOELCKERS, U. A Taxi And Ramp Management And Control system (TARMAC) p 207 N92-14027 VOIRON. T.
- Review of the European hypersonic wind tunnel performance and simulation requirements p 209 N92-15043
- VOKITS, RONALD S. Avionics modernization/upgrades in the late 1990s p 199 N92-14055
- VOS, JAN B. A multiblock flow solver for inviscid hypersonic flows
- p 181 N92-14986
- Hypersonic airbreathing propulsion activities for Saenger
- [AIAA PAPER 91-5040] p 200 A92 17828

### W

WAALAND, I. T.

- Technology in the lives of an aircraft designer [AIAA PAPER 91-3069] p 192 A92-20000 WAGNER. B.
- Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise problems p 227 N92-15027 WAGNER, S.
- Influences of wind tunnel parameters on airfoil characteristics at high subsonic speeds p 173 A92-18769
- WAHLGREN, B. I.
- The use of finite difference electromagnetic analysis in the design and verification of modern aircraft p 192 A92-20136
- WAIDMANN, WINFRIED An experimental investigation of the combustion of a
- hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861 WALDER, RAY
- Aging aircraft programme entails major effort and expense p 169 A92-20023 WALKER CARRIE K.
- Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629 WALLRAPP, OSKAR
- Representation of geometric stiffening in multibody system simulation p 217 A92-19463 WALSH. C.
- Computational fluid dynamics p 177 N92-13979 WALSH, KEVIN R.
- Performance improvements of an F-15 airplane with an integrated engine-flight control system
  - p 205 A92-20204

WANG C Y

Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic speeds

PERSONAL AUTHOR INDEX

- [AIAA PAPER 91-5038] p 171 A92-17826 WANG. Z. H.
- Numerical and experimental study of jet impingement or interaction effects at hypersonic and supersonic speeds
- [AIAA PAPER 91-5038] p 171 A92-17826
- WANIE, K. M. Verification and application of the NSFLEX method for hypersonic flow conditions p 182 N92-15005 WEBB. STEVEN G.
- Time-periodic control of a multi-blade helicopter p 204 A92-18626
- WEI, BAOSUO Study of a new airfoil used in reversible axial fans
- p 177 N92-13970 WEISER, P.
- Evaluation of rotordynamic coefficients of look-through labyrinths by means of a three volume bulk flow model p 223 N92-14356 Determination of rotordynamic coefficients for labyrinth
- seals and application to rotordynamic design calculations p 223 N92-14360 WESTPHAL R. V.
- Measurements of the flow around a lifting-wing/body junction p 175 A92-20726 WEYER, H. B.
- Thrust nozzle test facility at DLR Cologne [AIAA PAPER 91-5024] p 206 A92-17818
- WHITFORD, RAY Four decades of transonic fighter design
- p 193 A92-20203 WHITMORE, STEPHEN A.
- Pneumatic distortion compensation for aircraft surface pressure sensing devices p 218 A92-20206 WIE. YONG-SUN
- Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211 WIEDEMANN, RANDAL A.
- Operational survey: VFR heliport approaches and departures
- [SCT-91RR-26] p 190 N92-14033 WIENSS, W. FALKE and COBRA technology development in
- FALKE and COBRA technology development in aerodynamics and aerothermodynamics
- p 183 N92-15017 WIESEL, WILLIAM E.
- Time-periodic control of a multi-blade helicopter p 204 A92-18626
- WILBY, JOHN F. Interior noise p 236 N92-14785 WILKINSON, T. S.
- The application of a cylindrical-spherical floating ring bearing as a device to control stability of turbogenerators p 224 N92-14371 WILLIAMS, F. A.

WILSON, JOSEPH J.

WOLF. KLAUS

WONG. C. H.

WONG, TIN-CHEE

gaseous mixing

WOOD, RICHARD J.

Aerodynamics

WOODCOCK, B.

WOOD, C. W.

WOOD, D. H.

iunction

WOOD, N. L.

WONG, H.

[DOT/FAA/CT-89/16]

problems in aircraft industry [MBB-UD-0593-91-PUB]

flows around circular cones

[AIAA PAPER 91-5091]

Nonstationary gasdynamics

Compressibility effects in thin channels with injection

Study of the engine bird ingestion experience of the Boeing 737 aircraft

Application of MSC/DYNA to shock and impact

Equilibrium solution of the Euler and Navier-Stokes

Prediction of steady and unsteady asymmetric vortical

Effects of unsteady shock impingement on high-speed

Measurements of the flow around a lifting-wing/body

Architecture for Survivable System Processing (ASSP)

Rapid ultrasonic scanning of aircraft structures

equations around a double ellipsoidal shape with mono-

and multi-blocks including real gas effects, part 1

Grid impact on 3D hypersonic flows

p 216 A92-18369

p 187 N92-15053

p 225 N92-14382

p 220 N92-13985

p 227 N92-15030

p 184 N92-15041

p 172 A92-18372

p 172 A92-17857

p 175 A92-20726

p 215 A92-17292

p 220 N92-14210

p 202 N92-13977

## CORPORATE SOURCE INDEX

### AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

April 1992

### **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.

### Δ

- Adsystech, Inc., Silver Spring, MD. General aviation activity and avionics survey, calendar
- ear 1989 p 169 N92-13926 [PB91-1792341
- Advisory Group for Aerospace Research and Development, Neulily-Sur-Seine (France).
- Knowledge based system applications for guidance and control [AGARD-AR-284] p 205 N92-14065
- Artificial Neural Network Approaches in Guidance and Control [AGARD-LS-179] p 234 N92-14673
- AeroChem Research Labs., Inc., Princeton, NJ. Direct computation of turbulence and noise
- p 236 N92-14788 [NASA-CR-187616] Aerojet-General Corp., Sacramento, CA. Ceramic regenerator program
- [NASA-CR-189053] p 225 N92-14374 Aeronautical Research Inst. of Sweden, Bromma.
- Hypersonic flow past delta wing flow simulated by p 180 N92-14981 Navier-Stokes solutions
- Aeronautical Research Labs., Melbourne (Australia). F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation [AD-A242637] p 206 N92-15073
- Aeronautical Systems Div., Wright-Patterson AFB, OH. Evolution of avionic systems architecture, from the 950's to the present p 198 N92-14047
- 1950's to the present Avionics standardization in the USAF: 1980 to 1990 p 198 N92-14048 Common avionics baseline: The product of the joint
- p 199 N92-14053 integrated avionics working group Avionics modernization/upgrades in the late 1990s p 199 N92-14055
- Avionics reliability, durability, and integrity: Can they be dependent of application? p 200 N92-14056 independent of application? Aerospace Corp., El Segundo, CA.
- Operational design factors for NASP derived vehicles p 210 A92-17851 [AIAA PAPER 91-5081]

Aerospatiale, Les Mureaux (France). Transitional flows around re-entry bodies

- p 184 N92-15035 Computation of aerodynamic coefficients p 184 N92-15040 Hermes-Ariane5 configuration Air Force Academy, CO.
- Effects of unsteady shock impingement on high-speed gaseous mixing
- [AIAA PAPER 91-5091] p 172 A92-17857 Air Force Systems Command, Wright-Patterson AFB, OH
- International aviation (selected article)
- p 170 N92-13991 [AD-A2409861 International aviation (selected article)
- p 170 [AD-A240987] N92-13992 International aviation (selected articles)
- [AD-A241119] p 170 N92-13993 Programs at Wright-Patterson Air Force Base
- p 228 N92-15092 Ferrundi Company supplies 4500 model head up display
- devices to India's MIG-21 aircraft [AD-A241044] p 229 N92-15367
- Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
- Avionics technology beyond 2000
- p 200 N92-14058 Alenia Spazio S.p.A., Naples (Italy).
- Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests p 211 N92-14980 Allied-Signal Aerospace Co., Baltimore, MD.
- MLS system error model identification and synthesis
- p 189 N92-14015 Analytical Services and Materials, Inc., Hampton, VA. Proof test and fatigue crack growth modeling on 2024-T3
- p 213 A92-19828 aluminum alloy Arizona State Univ., Tempe.
- Dynamics and control of hypersonic vehicles The integration challenge for the 1990's p 203 A92-17840 [AIAA PAPER 91-5057]
- Numerical simulation of swept-wing flows p 180 N92-14969
- [NASA-CR-189457] p 180 N92 Army Aerostructures Directorate, Hampton, VA. Fatigue crack initiation and small crack growth in several
- airframe alloys airframe alloys p 212 A92-19754 Army Avlation Systems Command, Moffett Field, CA.
- Helicopter air resonance modeling and suppression p 204 A92-18625 using active control Army Propulsion Lab., Cleveland, OH.
- Army research concerns in engine sealing p 228 N92-15089
- Aviation Inst., Bucharest (Romania). On a global aerodynamic optimization of a civil transport aircraft p 193 N92-13931 Montreal (Quebec). Aviation Planning Services Ltd.,
- A strategy for exploiting the full potential of MLS based terminal procedures in Canada p 190 N92-14025 p 190 N92-14025

### B

- Ballistic Research Labs., Aberdeen Proving Ground, MD.
- Transonic Navier-Stokes computations for a spinning body of revolution p 180 N92-14972
- [AD-A241015] Beijing Univ. (China).
- An inverse method with regularity condition for transonic airfoil design p 177 N92-13969 Bently Rotor Dynamics Research Corp., Minden, NV. Rotor-to-stator partial rubbing and its effects on rotor
- p 224 N92-14367 dynamic response Comments on frequency swept rotating input perturbation techniques and identification of the fluid force models in rotor/bearing/seal systems and fluid handling machines p 224 N92-14370
- Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (Germany, F.R.),
- Introduction to neural computing and categories of neural network applications to guidance, navigation and p 234 N92-14674 control

Boeing Co., Seattle, WA.

- Flyover-noise measurement and prediction
- p 236 N92-14786 Quiet aircraft design and operational characteristics p 236 N92-14787
- Boeing Computer Services Co., Seattle, WA. A comparison of two closely-related approaches to
- aerodynamic design optimization p 193 N92-13933 Boeing Military Airplane Development, Seattle, WA. Historical perspective on the evolution of avionics standards p 198 N92-14049

### С

- California State Univ., Fullerton.
- Z-Basic algorithm for collision avoidance system p 188 A92-18482
- California Univ., Los Angeles. Helicopter air resonance modeling and suppression
- p 204 A92-18625 using active control California Univ., San Diego, La Jolla.
- Processing complexity of two approaches to object detection and recognition p 234 N92-14677
- Centre d'Essais Aeronautique Toulouse (France). Mechanical gualification tests for materials used in the fabrication of aircraft parts
- [CEAT-M5-5443/01] p 195 N92-14042 Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program and test implantation
- [CEAT-S8-6551-PARTIEL-1-PT-] p 195 N92-14043 Centre National de la Recherche Scientifique, Chatenay-Malabry (France).
- Hypersonic viscous shock layer in thermochemical p 183 N92-15014 nonequilibrium Centre National de la Recherche Scientifique,
- Marseilles (France). Numerical simulations around models in hypersonic wind nnels p 182 N92-14998 tunnels
- Centro Italiano Ricerche Aerospaziali, Naples. High enthalpy nozzle flows p 182 N92-15000 CFD Research Corp., Huntsville, AL. Development of a CFD code for analysis of fluid dynamic p 182 N92-15000
- forces in seals p 228 N92-15084
- City Univ. of New York, Bronx. Development of a calibrated software reliability model for flight and supporting ground software for avionic systems p 234 N92-15870
- Clemson Univ., SC. Parameter insensitive control utilizing eigenspace
- methods p 204 A92-18615 Committee of Conference (U.S. Congress).
- National Aeronautics and Space Administration research and development p 238 N92-15937 Committee on Appropriations (U.S. Senate).
  - National Aeronautics and Space Administration
  - p 238 N92-14925 National Aeronautics and Space Administration
- p 238 N92-14927 Communications Gillies, Inc., Sainte Lambert (Quebec). Electronic systems in transportation
- p 189 N92-14009 [TP-9983] CompEngServ Ltd., Ottawa (Ontario).
- A unique approach to aircraft conflict resolution using artificial intelligence techniques p 190 N92-14029
- Computer Sciences Corp., Hampton, VA. Analysis of objects in binary images [NASA-CR-4420] p 234 N92-14598
- Computer Technology Associates, Inc., McKee City, NJ.
- Evaluation of triple simultaneous parallel ILS approaches spaced 4300 feet apart, phase 4a p 191 N92-14034 (ACD-340)
- Congress of the United States, Washington, DC. National Aeronautics and Space Administration
- p 238 N92-14923 Cranfield Inst. of Tech., Bedford (England).

Flow over a delta wing at hypersonic speeds p 181 N92-14993

Passenger knowledge of airline safety information [CRANFIELD-AERO-9111] p 187 N92-15054

### D

David Taylor Research Center, Bethesda, MD. Navier-Stokes analysis of turbulent boundary layer and wake for two-dimensional lifting bodies

p 221 N92-14309 Aviation Diagnostics And Maintenance (ADAM) system preliminary concept of operation and functional description

[AD-A242598] p 170 N92-14966 Dayton Univ. Research Inst., OH.

Study of the engine bird ingestion experience of the Boeing 737 aircraft

[DOT/FAA/CT-89/16] p 187 N92-15053 Defence Research Establishment Pacific, Victoria (British Columbia).

Filter debris analysis: A concrete approach to wear diagnosis

[DREP-TM-88-20] p 222 N92-14345 Detroit Diesel Allison, MI.

Seal development activities at Allison Turbine Division p 228 N92-15093

- Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.) Application of direct inverse analogy method (DIVA) and viscous design optimization techniques p 176 N92-13951
- A concept for the revisions of structural inspection p 226 N92-14431 schedules Short time force measurement system

p 208 N92-15001 Deutsche Airbus G.m.b.H., Hamburg (Germany, F.R.).

Airbus Industrie A330/A340: Full scale fatigue test of center fuselage and wing p 226 N92-14425 Methodology for assessment of skin repairs on Airbus p 226 N92-14428 aircraft

Deutsche Forschungs- und Versuchsanstalt fuer Luftund Raumfahrt, Brunswick (Germany, F.R.).

Image-supported navigation for testing instrument p 189 N92-14012 landing systems DME growth elements and their use with MLS

p 189 N92-14018 A Taxi And Ramp Management And Control system p 207 N92-14027 (TARMAC)

Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).

Steps towards an efficient and accurate method solving the Euler equations around a re-entry configuration at super- and hypersonic speed p 181 N92-14987 super- and hypersonic speed p 181 Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).

Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique p 182 N92-14994

- Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
- Extended mapping and characteristics techniques for verse aerodynamic design p 194 N92-13949 Simulation requirements for RCS plume: Flowfield inverse aerodynamic design interaction modelling on a winged reentry vehicle p 181 N92-14985

Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for p 181 N92-14992 space vehicles Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles

p 184 N92-15032 Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).

Computational aerothermodynamic methods for industrial applications to re-entry and hypersonic cruise p 227 N92-15027 problems

Douglas Aircraft Co., Inc., Long Beach, CA. Microwave landing system autoland system analysis p 191 N92-15060 [NASA-CR-189551]

Draper (Charles Stark) Lab., Inc., Cambridge, MA. Applications of an automated programming system [AIAA PAPER 91-3767] p 231 A92-17629

Duke Univ., Durham, NC. procedure Eigenvalue calculation for an

Euler/Navier-Stokes solver with application to flows over p 170 A92-17429 airfoils Analytical/numerical matching and periodic inversion: Two advances in free wake analysis

p 178 N92-13994

Ε

Ecole Polytechnique Federale de Lausanne (Switzerland).

A multiblock flow solver for inviscid hypersonic flows p 181 N92-14986 Edgerton, Germeshausen and Grier, Inc., Wellesley,

Seal related development activities at EG/G

p 228 N92-15095

Electro Magnetic Applications, Inc., Lakewood, CO. Nonlinear triggered lightning models for use in finite p 230 A92-20128 difference calculations Eloret Corp., Sunnyvale, CA.

Experimental research of the aerodynamics of nozzles and plumes at hypersonic speeds [NASA-CR-187316] p 185 N92-15048

Embraer S.A., Sao Jose dos Campos (Brazil). Analysis of aircraft performance during lateral

maneuvering for microburst avoidance p 205 A92-20207

- European Space Agency, Paris (France). Aerothermodynamics for Space Vehicles
- [ESA-SP-318] p 180 N92-14973
- European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
  - Aerothermodynamic challenges for ESA programmes p 180 Ň92-14974 SIMOUN and Scirocco wind tunnel nozzle viscous flow
- p 208 N92-14999 study Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with mono-

and multi-blocks including real gas effects, part 1 p 227 N92-15030 Parallelization of a Direct Simulation Monte Carlo

- p 227 N92-15033 (DSMC) code for fluid dynamics Grid impact on 3D hypersonic flows p 184 N92-15041
- Review of the European hypersonic wind tunnel performance and simulation requirements
- p 209 N92-15043 Executive Resource Associates, Inc., Arlington, VA. General aviation activity and avionics survey, calendar ear 1989

[PB91-179234] p 169 N92-13926

### F

- Federal Aviation Administration, Atlantic City, NJ. Data Multiplexing Network (DMN) phase 3 equipment Operational Test and Evaluation (OT and E)/integration test report [DOT/FAA/CT-TN91/50] p 221 N92-14270
- Federal Aviation Administration, Washington, DC. FAA statistical handbook of aviation: Calendar year 1989
- p 170 N92-13927 [PB91-202051] Flat Aviazione S.p.A., Turin (Italy).
- Research on inverse methods and optimization in Italy p 202 N92-13956
- Florida Atlantic Univ., Boca Raton, The application of experimental data to blade wake
- interaction noise prediction [NASA-CR-189461] p 237 N92-14789 Florida State Univ., Tallahassee
- Broadband shock-associated noise from supersonic jets p 235 A92-18683 in flight Fluid Gravity Engineering Ltd., Witley (England).
- Hypersonic aerothermodynamic computations using a point-implicit TVD method p 183 N92-15006
- Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).
  - Review of investigations on aeronautical fatigue in the Federal Republic of Germany
  - p 225 N92-14397 [ETN-92-90317] Fatigue of repaired composite structures

p 214 N92-14411

Environmental fatigue tests with composite materials p 214 N92-14413

### G

- General Electric Co., Cincinnati, OH. An inverse method for the aerodynamic design of
- three-dimensional aircraft engine nacelles p 194 N92-13958 A simplified method for predicting the stability of
- aerodynamically excited turbomachinery p 224 N92-14364
  - Design and performance of duct acoustic treatment p 236 N92-14783
- p 236 N92-14784 Jet noise suppression Areas of seal R/D at GE p 228 N92-15094
- Georgia Inst. of Tech., Atlanta. Definition of the unsteady vortex flow over a wing/body configuration
- [NASA-CR-180083] p 178 N92-13995 Image-based ranging and guidance for rotorcraft
- [NASA-CR-184829] p 191 N92-14036 Integration of dynamic, aerodynamic, and structural
- optimization of helicopter rotor blades [NASA-CR-189018] p 195 N92-14038

Rapid near-optimal aerospace plane trajectory generation and guidance

p 205 N92-14066

CORPORATE SOURCE

н

[NASA-CR-189469]

Hecht-Nielsen Neurocomputer Corp., Inc., San Diego, CA.

Processing complexity of two approaches to object detection and recognition p 234 N92-14677 High Technology Corp., Hampton, VA.

Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211 Hyperschall-Technologie-Goettingen (Germany, F.R.). Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes p 184 N92-15031

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### Industrieanlagen-Betriebsgesellschaft m.b.H.,

Ottobrunn (Germany, F.R.).

Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405 Comparison between hot/wet test and RT/dry test on

the Seastar horizontal stabilizer and fin p 226 N92-14414

Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424

Innovative Textile Applications Co., Grand Junction, CO.

Universal weaving for turbine engine composite preforms

AD-A2376671 p 202 N92-14059 Institut National de Recherche d'Informatique et d'Automatique, Valbonne (France).

Numerical simulations around models in hypersonic wind tunnels p 182 N92-14998

Institute for Computer Applications in Science and Engineering, Hampton, VA.

Progress with multigrid schemes for hypersonic flow problems

[NASA-CR-189579] p 185 N92-15047 Approximation methods for control of acoustic/structure models with piezoceramic actuators

[NASA-CR-189578] p 234 N92-15658 Institute for Water Resources, Fort Belvoir, VA.

Reducing environmental noise impacts: A USAREUR noise management program handbook p 237 N92-14791 [AD-A240797]

Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).

The influence of a retarding rocket on parameter limits for reentry trajectories p 211 N92-15037 International Centre for Numerical Methods in

Engineering, Barcelona (Spain).

Jet Propulsion Lab., California Inst. of Tech.,

Multicomponent gas sorption

[NAŠA-CASE-NPO-17569-1-CU]

Kaiserslautern Univ. (Germany, F.R.).

Khmelnitsky Technological Inst. (USSR).

as dynamic inverse problem

Pasadena

refrigeration

calculations

Kobe Univ. (Japan).

arooved seals

[JPRS-USP-91-007]

Flow and temperature computations for space vehicles using adaptive finite element techniques p 181 N92-14990

J

Z-Basic algorithm for collision avoidance system

Joint Publications Research Service, Arlington, VA.

Κ

labyrinths by means of a three volume bulk flow mode

seals and application to rotordynamic

JPRS report: Science and technology. USSR: Space

History of EPOS air-launched spaceplane project p 211 N92-14103

Evaluation of rotordynamic coefficients of look-through

p 223 N92-14356 Determination of rotordynamic coefficients for labyrinth

Identification of dynamic characteristics of flexible rotors

Experiment of static and dynamic characteristics of spiral

p 188 A92-18482

p 228 N92-15203

p 211 N92-14101

design

p 223 N92-14360

p 220 N92-13962

p 223 N92-14361

Joule-Thomson

### CORPORATE SOURCE

Kyushu Electric Power Co., Inc., Fukuoka (Japan). ield telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit

p 222 N92-14348

Lockheed Engineering and Sciences Co., Hampton, VA.

A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft

- [AIAA PAPER 91-5036] p 210 A92-17825 Analysis of cooling systems for hypersonic aircraft [AIAA PAPER 91-5063] p 216 A92-17
- p 216 A92-17843 Parameter insensitive control utilizing eigenspace p 204 A92-18615 methods Fatigue crack initiation and small crack growth in several
- p 212 A92-19754 airframe alloys Three-dimensional thermal structural analysis of a swept

cowl leading edge subjected to skewed shock-shock p 174 A92-20306 interference heating

### Μ

Massachusetts Inst. of Tech., Cambridge,

- Analysis of aircraft performance during lateral maneuvering for microburst avoidance
- p 205 A92-20207 Airfoil optimization with efficient gradient calculations p 177 N92-13960
- McDonnell Aircraft Co., Saint Louis, MO. Aeroservoelastic stabilization techniques for hypersonic
- flight vehicles [AIAA PAPER 91-5056] p 203 A92-17839
- Mechanical Technology, Inc., Latham, NY.
- Industrial Code development p 227 N92-15083 Messerschmitt-Boelkow-Biohm G.m.b.H., Munich (Germany, F.R.).
- Avionics' systems development: Technological trends, conflicts, and cost issues in a changing European environment p 199 N92-14054 Application of MSC/DYNA to shock and impact lems in aircraft industry [MBB-UD-0593-91-PUB] p 225 N92-14382 Verification and application of the NSFLEX method for p 182 N92-15005 hypersonic flow conditions Viscous shock-layer equations for the calculation of p 183 N92-15008 reentry aerothermodynamics Aerothermodynamic challenges of the Saenge p 184 N92-15042 space-transportation system Development and evaluation of a finite element model
- for a fiber composite helicopter fuselage p 196 N92-15066 [MBB-UD-0584-90-PUB] The acoustic flashlight
- [MBB-Z-0359-90-PUB] p 239 N92-15938 Ministry of Defence, London (England). Avionics software evolution p 199 N92-14052 Ministry of Defence, Paris (France).

Avionics standardization in Europe p 199 N92-14050

- Missouri Univ., Rolla. Theoretical models for duct acoustic propagation and radiation
- p 236 N92-14782 Mitre Corp., Bedford, MA. The problem of multiple solutions in area navigation and
- computed centerline operations with the microwave landing system [AD-A242757] p 191 N92-15058
- Mitre Corp., Houston, TX. Case for real-time systems development - Quo vadis? [AIAA PAPER 91-3726] p 231 A92-17594 Mitre Corp., McLean, VA.
- Automated problem resolution prototype in automated en route air traffic control p 190 N92-14028

### Ν

Naples Univ. (Italy).

- Infrared measurements of aerodynamic heating in p 208 N92-15002 hypersonic wind tunnel Linear acoustics in gas mixtures with rate processes p 238 N92-15013
- NASP Joint Program Office, Wright-Patterson AFB, OH. Conducting the NASP ground test program
- p 209 A92-17820 [AIAA PAPER 91-5029] A configuration development strategy for the NASP [AIAA PAPER 91-5044] p 210 A92-17830
- National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
- Sensor fusion for synthetic vision [AIAA PAPER 91-3730]
- p 197 A92-17597 Optical computing at NASA Ames Research Center [AIAA PAPER 91-3779] p 231 A92-17637

Numerical prediction of subsonic turbulent flows over slender bodies at high incidence p 172 A92-18358 computational fluid Some Aspects of uncertainty in dynamics results p 233 A92-19609 Static aeroelastic analysis for generic configuration p 174 A92-20201 wing Rate parameters for coupled vibration-dissociation in a p 235 A92-20301 generalized SSH approximation Measurements of the flow around a lifting-wing/body p 175 A92-20726 junction Instabilities of flows over bodies at large incidence p 176 A92-20738

Surface flow patterns on an ogive-cylinder at incidence p 176 A92-20762

- National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA. Multidisciplinary modeling and simulation of a generic
  - hypersonic vehicle p 232 A92-17813 [AIAA PAPER 91-5015] Performance improvements of an F-15 airplane with an
  - integrated engine-flight control system p 205 A92-20204 Pneumatic distortion compensation for aircraft surface
- p 218 A92-20206 pressure sensing devices p 218 A93 National Aeronautics and Space Administration.
- Lyndon B. Johnson Space Center, Houston, TX. Aerodynamic heating on AFE due to nonequilibrium flow with variable entropy at boundary layer edge
- p 183 N92-15020 National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
- Applications of an automated programming system
- p 231 A92-17629 [AIAA PAPER 91-3767] Effect of nose shape on three-dimensional stagnation region streamlines and heating rates
- p 171 A92-17822 [AIAA PAPER 91-5032] A comparison of cooling methods for the airframe nozzle of a single-stage-to-orbit aircraft
- p 210 A92-17825 [AIAA PAPER 91-5036] Control concept for maneuvering in hypersonic flight [AIAA PAPER 91-5055] p 203 A92-17838
- Analysis of cooling systems for hypersonic aircraft (AIAA PAPER 91-5063) p 216 A92-17 p 216 A92-17843 Algebraic turbulence modeling for unstructured and
- adaptive meshes p 216 A92-18362 Prediction of steady and unsteady asymmetric vortical flows around circular cones p 172 A92-18372
- Numerical study on using sulfur hexafluoride as a wind tunnel test gas p 216 A92-18373 Parameter insensitive control utilizing eigenspace
- p 204 A92-18615 methods of aeroservoelastic modeling using Application minimum-state unsteady aerodynamic approximations
- p 204 A92-18622 Fatigue crack initiation and small crack growth in several p 212 A92-19754 airframe alloys
- Proof test and fatigue crack growth modeling on 2024-T3 aluminum alloy p 213 A92-19828
- Numerical solution of the boundary-layer equations for a general aviation fuselage p 174 A92-20211 Three-dimensional thermal structural analysis of a swept p 174 A92-20211
- cowl leading edge subjected to skewed shock-shock p 174 A92-20306 interference heating Engineering calculations of three-dimensional inviscid p 175 A92-20378 hypersonic flowfields Removal of spurious reflections from computational fluid
- dynamic solutions with the complex cepstrum p 235 A92-20729
- Upwind scheme for solving the Euler equations on p 175 A92-20735 unstructured tetrahedral meshes Inverse airfoil design procedure using a multigrid p 193 N92-13932 Navier-Stokes method
- A Navier-Stokes solution of Hull-ring wing-thruster teraction p 221 N92-14310 interaction Aeroacoustics of flight vehicles: Theory and practice. Volume 2: Noise control
- [NASA-RP-1258-VOL-2] p 235 N92-14779 p 236 N92-14780 Human response to aircraft noise Interior noise p 236 N92-14785 Aerothermodynamics for United States advanced
- p 184 N92-15039 rograms p aeroelastic models program: The benchmark Description and highlights of initial results
- p 185 N92-15049 [NASA-TM-104180] A fast implicit upwind solution algorithm for three-dimensional unstructured dynamic meshes
- p 185 N92-15050 [NASA-TM-104186] Flutter suppression via piezoelectric actuation
- p 197 N92-15070 [NASA-TM-104120] Formulation of a strategy for monitoring control integrity in critical digital control systems
- p 206 N92-15075 [NASA-TM-104158] Trim drag reduction concepts for horizontal takeoff single-stage-to-Orbit vehicles
- [NASA-TM-102687] p 206 N92-15076

### **Naval Postgraduate School**

- National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH. Eigenvalue calculation procedure for an Euler/Navier-Stokes solver with application to flows over irfoils p 170 A92-17429 Heat transfer measurements from a smooth NACA 0012 airfoils airfoil p 218 A92-20215 Roughness effects on heat transfer from a NACA 0012
- airfoil p 219 A92-20217 Vortex generator design for aircraft inlet distortion as p 194 N92-13959 a numerical optimization problem
- A study on vortex flow control on inlet distortion in the re-engined 727-100 center inlet duct using computational fluid dynamics
- [NASA-TM-105321] p 179 N92-13998 LEWICE/E: An Euler based ice accretion code (NASA-TM-105389) p 179 N92-14001
- Analysis of an advanced ducted propeller subsonic
- p 179 N92-14002 [NASA-TM-105393] The aerodynamic effect of fillet radius in a low speed
- compressor cascade [NASA-TM-105347] p 202 N92-14063
- Rotordynamic Instability Problems in High-Performance Turbomachinery, 1990
- [NASA-CP-3122] p 222 N92-14346 Computation of supersonic jet mixing noise for an axisymmetric CD nozzle using k-epsilon turbulence model
- [NASA-TM-105338] p 237 N92-14795 A survey of the broadband shock associated noise rediction methods
- [NASA-TM-105365] p 237 N92-14797 Wind tunnel investigation of vortex flows on F/A-18
- configuration at subsonic through transonic speed [NASA-TP-3111] p 179 N92-14968
- Results of an Icing test on a NACA 0012 airfoil in the NASA Lewis Icing Research Tunnel [NASA-TM-105374] p 185 N92-15051
- A turbulence model for iced airfoils and its validation p 186 N92-15052 [NASA-TM-105373]
- Tribology needs for future space and aeronautical eveteme
- p 214 N92-15191 [NASA-TM-104525] Analysis of aircraft engine blade subject to ice impact p 229 N92-15402 [NASA-TM-105336]
- Structural Dynamics Branch research and accomplishments for FY 1990 p 230 N92-15406 [NASA-TM-103747]
- National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
- Limit cycle vibrations in turbomachinery
- [NASA-TP-3181] p 211 N92-14108 National Aeronautics and Space Administration.
- Pasadena Office, CA.

[AD-A242478]

[AD-A242690]

- Multicomponent gas Joule-Thomson sorption refrigeration
- [NASA-CASE-NPO-17569-1-CU] p 228 N92-15203 National Aerospace Lab., Amsterdam (Netherlands). Review of aerodynamic design in the Netherlands p 193 N92-13929
  - Monitoring load experience of individual aircraft p 196 N92-15065 [NLR-TP-90084-U]
- National Research Council of Canada, Ottawa (Ontario).
- Rub induced rotor/stator vibration analysis on CF700
- engine {NRC-TR-ENG-007} p 202 N92-14060
- National Transportation Safety Board, Washington, DC
- Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990
- [PB91-910405] p 187 N92-14006 Aircraft accident/incident summary report: Midair collision involving Lycoming Air Services Piper Aerostar PA-60 and Sun Company Aviation Department Bell 412, Merion, Pennsylvania, April 4, 1991
- [PB91-910407] p 187 N92-15055 Naval Air Development Center, Warminster, PA. Neural network and fuzzy logic technology for naval flight control
- p 206 N92-15074 [AD-A242650]
- Naval Postgraduate School, Monterey, CA. Preliminary investigation of the shock-boundary layer
- interaction in a simulated fan passage [AD-A242656] p 185 N92-15045 Flight operations for higher harmonic control research

Structural considerations for

Modification: P-3C zero fuel weight increase

p 196 N92-15067

aircraft payload

p 196 N92-15068

C-3

### Nevada Univ.

Nevada Univ., Reno.

Numerical investigations in three-dimensional internal flows

p 221 N92-14313 [NASA-CR-189467] Newcastle Polytechnic, Newcastle-upon-Tyne

(England). The application of a cylindrical-spherical floating ring bearing as a device to control stability of turbogenerators p 224 N92-14371

turbogenerators North Carolina State Univ., Raleigh. Effect of nose shape on three-dimensional stagnation

region streamlines and heating rates p 171 A92-17822 [AIAA PAPER 91-5032] Engineering calculations of three-dimensional inviscid

p 175 A92-20378 hypersonic flowfields Northwestern Polytechnical Univ., Xian (China). The stability of the steady state and bistable response

of a flexible rotor supported on squeeze film dampers p 222 N92-14350

### 0

Oak Ridge National Lab., TN.

Scoping studies for small steady-state tokamaks for divertor testing [DE92-000740] p 238 N92-15761

Office National d'Etudes et de Recherches

Aerospatiales, Paris (France). Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles

p 211 N92-14977 Heat transfer measurements in ONERA supersonic and hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003

Ablation and temperature sensors for flight measurements in reentry body heat shields p 227 N92-15004

Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025 Numerical simulation of thermochemical non-equilibrium

viscous flows around reentry bodies p 227 N92-15029

Office of Technology Assessment, Washington, DC. New Ways: Tiltrotor aircraft and magnetically levitated vehicles

p 238 N92-14933 [OTA-SET-507] OHB-System G.m.b.H., Bremen (Germany, F.R.).

FALKE and COBRA technology development in aerodynamics and aerothermodynamics p 183 N92-15017

Ohio State Univ., Columbus. SATCOM antenna siting study on P-3C aircraft, volume

[NASA-CR-189514] p 221 N92-14262 SATCOM antenna siting study on P-3C aircraft, volume

p 221 N92-14263 [NASA-CR-189515] Old Dominion Univ., Norfolk, VA.

Prediction of steady and unsteady asymmetric vortical p 172 A92-18372 flows around circular cones Aerodynamic sensitivity analysis methods for the p 233 A92-19619 compressible Euler equations

ORA Corp., Ithaca, NY. Formal specification and verification of Ada software p 230 A92-17585 [AIAA PAPER 91-3713]

### P

### Pennsylvania State Univ., University Park.

A stochastic regulator for integrated communication and control systems. I - Formulation of control law. II - Numerical analysis and simulation p 233 A92-19605 Third International Conference on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES-3)

[NASA-CR-188125] p 170 N92-13928 Aerodynamic shape optimization of arbitrary hypersonic chicles p 194 N92-13954 vehicles

Analysis and design of planar and non-planar wings for induced drag minimization [NASA-CR-189509] p 179 N92-13999

Planning and Management Consultants Ltd., Carbondale, IL.

Reducing environmental noise impacts: A USAREUR noise management program handbook [AD-A240797] p

p 237 N92-14791 Princeton Univ., NJ.

A geometric approach to regulator and tracker design for an aerospace plane

[AIAA PAPER 91-5054] p 203 A92-17837 Application of stochastic robustness to aircraft control p 204 A92-18620 systems

Purdue Univ., West Lafayette, IN.

A quiet-flow Ludwieg tube for experimental study of high speed boundary layer transition [AIAA PAPER 91-5026] p 207 A92-17819

### R

- Rockwell International Corp., Canoga Park, CA.
- Airfoil Vibration Dampers program [NASA-CR-188929] n 225 N92-14391 Rockwell Space Operations Co., Houston, TX.
- Testing of the high accuracy inertial navigation system in the Shuttle Avionics Integration Lab p 210 N92-14087
- Rome Air Development Center, Griffiss AFB, NY, Architecture for Survivable System Processing (ASSP)
- p 220 N92-14210 Rome Univ. (Italy),
- Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15016 Royal Aerospace Establishment, Farnborough
- (England). Lightning protection requirements for aircraft: A
- proposed specification [RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92-14007

### S

- Sandia National Labs., Albuquerque, NM.
- Numerical simulation of VAWT stochastic aerodynamic loads produced by atmospheric turbulence: VAWT-SAL code [DE92-000597]
- p 229 N92-15392 Shanghai Inst. of Mechanical Engineering (China).
- Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics. Review of Chinese advances p 201 N92-13939
- Variational formulation of hybrid problems for fully 3-D transonic flow with shocks in rotor p 176 N92-13953 Societe d'Etudes et de Services pour Souffieries et
- Installations Aerothermodynamiques, Paris (France). Experimental investigation of transverse jet effects related to hypersonic space vehicles
  - p 182 N92-14995
- Societe Europeenne de Propulsion, Vernon (France). Supersonic combustion studies p 211 N92-14984 Societe Nationale d'Etude et de Construction de
- Moteurs d'Aviation, Cincinnati, OH.
- Recent progress in inverse methods in France
- p 201 N92-13938 Solar Turbines, Inc. San Diego, CA.
- High-temperature combustor and seal for a water piston propulsor
- [AD-A242493] p 229 N92-15385 Southampton Univ. (England).
- The effects of manufacturing tolerances on the vibration of aero-engine rotor-damper assemblies
- p 222 N92-14349 Interference heating near fin/body junctions on ypersonic vehicles p 182 N92-14996 hypersonic vehicles Stuttgart Univ. (Germany, F.R.).
- Supercritical blade design on stream surfaces of revolution with an inverse method p 220 N92-13950 Experimental investigations of exciting forces caused
- by flow in labyrinth seals p 223 N92-14354 The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles
- p 208 N92-15009 Sulzer Bros. Ltd., Winterthur (Switzerland).
- Annular seals of high energy centrifugal pumps: Presentation of full scale measurement
  - p 224 N92-14362
- Syms (Raymond A.) and Associates, Bridge Water, NJ. Operational survey: VFR heliport approaches and departures
- [SCT-91RR-26] p 190 N92-14033 Systems Control Technology, Inc., Arlington, VA.
- Operational survey: VFR heliport approaches and departures [SCT-91RR-26] p 190 N92-14033
- Rotorcraft low altitude IFR benefit/cost analysis: Operations analysis
- [SCT-90RR-44] p 191 N92-15061 Systems Control Technology, Inc., Palo Alto, CA. Turbine engine diagnostics system study
- [DOT/FAA/CT-91/16] p 202 N92-14064 Systems Technology, Inc., Hawthorne, CA
- Aeroservoelastic stabilization techniques for hypersonic flight vehicles
- [AIAA PAPER 91-5056] p 203 A92-17839

### т

Technion - Israel Inst. of Tech., Haifa.

Numerical prediction of subsonic turbulent flows over slender bodies at high incidence p 172 A92-18358 Adaptive suppression of biodynamic interference in helmet-mounted displays and head teleoperation

p 197 A92-18611

- Application of aeroservoelastic modeling using minimum-state unsteady aerodynamic approximations p 204 A92-18622
- Technische Hochschule, Aachen (Germany, F.R.). High enthalpy testing in the Aachen (Fed. Republic of p 208 N92-15021 Germany) shock tunnel TH 2
- Technische Univ., Brunswick (Germany, F.R.). Project of an adaptive multiaxial autopilot with learning pilot control
- [ETN-92-90592] p 205 N92-15072 Technische Univ., Delft (Netherlands).
- The two-bay crack problem in fuselages built in GLARE and ARALL [LR-653] p 196 N92-14044
- Bulging of fatigue cracks in a pressurized aircraft fuselage
- [LR-655] p 196 N92-14045 Propeller-driven-small airplane noise certification [LR-650] p 237 N92-14798
- Technische Univ., Munich (Germany, F.R.). Hydraulic actuator system for rotor control

p 224 N92-14363

Technology Development Corp., Madrid (Spain). Electronically steerable antenna for aircraft p 229 N92-15272

Tennessee Univ., Chattanooga Redesign of flight space shuttle main engine nozzle G-15 seal area based on the thermal analysis and flow models p 212 N92-15877

Texas A&M Univ., College Station.

- Direct-inverse transonic wing-design method in curvilinear coordinates including viscous interaction p 193 A92-20202 Nonlinear rotordynamics analysis
- [NASA-CR-184263] p 221 N92-14344 Test results for rotordynamic coefficients of the SSME
- HPOTP turbine interstage seal with two swirl brakes p 223 N92-14357 Effect of eccentricity on the static and dynamic performance of a turbulent hybrid bearing

p 225 N92-14373

Textron Bell Helicopter, Fort Worth, TX.

applications: Survey of the activity in Japan

calculation

Titan Systems, Inc., Princeton, NJ.

Tokyo Univ., Sagamihara (Japan).

requirements

and 3-D thin wings

[NASA-CR-4414]

Toledo Univ., OH.

airfoils

airfoil

airfoil

Eigenvalue

full-potential solver

Flight research

flight hardware

(USSR).

Flight simulation

Toronto Univ., Downsview (Ontario).

Aerodynamics Computational fluid dynamics

Nonstationary gasdynamics

Tsinghua Univ., Bejing (China).

hodograph method

Technology needs for high speed rotorcraft (3) p 195 N92-14039 [NASA-CR-177592] Thomson-CSF, Malakoff (France).

Mixed approach towards modular avionics conflicting

A unified viscous theory of lift and drag of 2-D thin airfoils

Aerodynamic aircraft design methods and their notable

Euler/Navier-Stokes solver with application to flows over

Heat transfer measurements from a smooth NACA 0012

irfoil p 218 A92-20215 Roughness effects on heat transfer from a NACA 0012

Time domain flutter analysis of cascades using a

TRW Space Technology Labs., Redondo Beach, CA.

Tsentralni Aerogidrodinamicheskil Inst., Moscow

aerodynamic design at Tsinghua University

Getting expert systems off the ground: Lessons learned from integrating model-based diagnostics with prototype

Aerothermodynamic configuration of first generation

Design of transonic compressor cascades using

The research progress on Hodograph Method of

aerospace planes (of Buran-type) and first flight results

procedure

p 199 N92-14051

p 178 N92-13997

p 193 N92-13930

p 170 A92-17429

p 219 A92-20217

p 176 A92-20747

p 202 N92-13977

p 220 N92-13985

p 220 N92-14217

p 211 N92-14975

p 202 N92-13973

p 177 N92-13974

p 177

p 194

p 207

N92-13979

N92-13981

N92-13982

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# FOREIGN TECHNOLOGY INDEX

### **AERONAUTICAL ENGINEERING** / A Continuing Bibliography (Supplement 277)

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April 1992

### 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.

### A

AUSTRALIA

- Drag balance for hypervelocity impulse facilities p 207 A92-18375
- Fatigue testing of a gas turbine fan disc p 217 A92-19818
- F/A-18 stabilator: Equivalent set of point forces required for pneumatic bag load case simulation
- [AD-A242637] p 206 N92-15073

### В

BELGIUM

Genuinely upwind algorithms for the multidimensional Euler equations ` p 175 A92-20733 BRAZIL

On-board data acquisition system for Embraer's CBA123 p 198 A92-19251 Analysis of aircraft performance during lateral

maneuvering for microburst avoidance p 205 A92-20207 The influence of a retarding rocket on parameter limits

for reentry trajectories p 211 N92-15037

### С

### CANADA

Enhanced visual technique for rapid inspection of aircraft p 214 A92-17290 structures Complex variable boundary element method for externa p 172 A92-18353 potential flows Implementation and usage of the RJ program Data Acquisition System Ground Station p 210 A92-19257 F27 aging aircraft programme emphasizes corrosion prevention p 186 A92-20024 Analysis and design of transonic airfoils using p 194 N92-13955 streamwise coordinates Aerodynamics p 202 N92-13977

Computational fluid dynamics	p 177	N92-13979	
Flight research	p 194	N92-13981	
Flight simulation	p 207	N92-13982	
Nonstationary gasdynamics	p 220	N92-13985	
Electronic systems in transportation	n		
TP-9983]	p 189	N92-14009	
A strategy for exploiting the full po	tential of	MLS based	
erminal procedures in Canada	p 190	N92-14025	
A unique approach to aircraft cor	nflict reso	olution using	
artificial intelligence techniques	p 190	N92-14029	
Rub induced rotor/stator vibration	n analysi	s on CF700	
angine			
NRC-TR-ENG-007]	p 202	N92-14060	
Filter debris analysis: A concrete	approa	ch to wear	
diagnosis			
DREP-TM-88-20]	p 222	N92-14345	
IINA, PEOPLE'S REPUBLIC OF			
Numerical and experimental study	y of jet i	mpingement	
or interaction effects at hyperso	nic and	supersonic	

or interaction effects at hypersonic and supersonic speeds [AIAA PAPER 91-5038] p 171 A92-17826 A low-altitude breakthrough system using optimal path

Lerrain following p 205 A92-20483 Numerical calculation of subsonic and supersonic aerodynamic loads around complex configuration vehicle p 175 A92-2048

Research on inverse, hybrid and optimization problems in engineering sciences with emphasis on turbomachine aerodynamics: Review of Chinese advances

p 201 N92-13939 Variational formulation of hybrid problems for fully 3-D

transonic flow with shocks in rotor p 176 N92-13953 An inverse method with regularity condition for transonic airfoil design p 177 N92-13969

Study of a new airfoil used in reversible axial fans p 177 N92-13970

Design of transonic compressor cascades using hodograph method p 202 N92-13973 The research progress on Hodograph Method of aerodynamic design at Tsinghua University

p 177 N92-13974 The stability of the steady state and bistable response

of a flexible rotor supported on squeeze film dampers p 222 N92-14350

### F

FRANCE

Potential hypersonic vehicles applications [AIAA PAPER 91-5086] p 169 A92-17854 Protective coatings of thermal barrier type

P 214 A92-20349 Recent progress in inverse methods in France

p 201 N92-13938 Mechanical qualification tests for materials used in the fabrication of aircraft parts

[CEAT-M5-5443/01] p 195 N92-14042 Optimization of the calculation margins of landing gears under extreme loads. Rupture static tests. Part 1: Program and test implantation

[CEAT-S8-6551-PARTIEL-1-PT-] p 195 N92-14043 Avionics standardization in Europe

p 199 N92-14050 Mixed approach towards modular avionics conflicting requirements p 199 N92-14051 Artificial Neural Network Approaches in Guidance and Control

[AGARD-LS-179] p 234 N92-14673 Aerothermodynamics for Space Vehicles

[ESA-SP-318] p 180 N92-14973 Analysis tools of ONERA and DLR for the aerothermodynamics of reentry vehicles p 211 N92-14977

Supersonic combustion studies p 211 N92-14977 Experimental investigation of transverse jet effects related to hypersonic space vehicles

p 182 N92-14995 Numerical simulations around models in hypersonic wind tunnels p 182 N92-14998 hypersonic wind tunnels using passive and active infrared thermography p 208 N92-15003 Ablation and temperature sensors for flight measurements in reentry body heat shields p 227 N92-15004 Hypersonic viscous shock layer in thermochemical p 183 N92-15014 nonequilibrium Hypersonic inviscid flow field simulations around reentry vehicles with flap deflection p 184 N92-15025 Numerical simulation of thermochemical non-equilibrium viscous flows around reentry bodies p 227 N92-15029

Heat transfer measurements in ONERA supersonic and

Transitional flows around re-entry bodies p 184 N92-15035 Computation of aerodynamic coefficients on Hermes-Ariane5 configuration p 184 N92-15040

### G

### GERMANY, FEDERAL REPUBLIC OF

Thrust nozzle test facility at DLR Cologne {AIAA PAPER 91-5024} p 206 A92-17818 Hypersonic airbreathing propulsion activities for Saender

[AIAA PAPER 91-5040] p 200 A92-17828 An experimental investigation of the combustion of a hydrogen jet injected parallel in a supersonic air stream [AIAA PAPER 91-5102] p 212 A92-17861 PVD coatings for aircraft turbine blades

p 216 A92-17950 Navsat - A civil complement to GPS and Glonass

[IAF PAPER 91-490] p 188 A92-18505 Influences of wind tunnel parameters on airfoil characteristics at high subsonic speeds

p 173 A92-18769 Base pressure measurements on a cone at Mach

numbers from M sub infinity = 5 to 7 p 173 A92-18770 Analysis of spiraling vortical flows around slender detta wings moving in an inviscid medium p 173 A92-18900

Three-dimensional calculation low-frequency of unsteady transonic flow in axial turbine stages p 174 A92-19110 Representation of geometric stiffening in multibody p 217 A92-19463 system simulation Multiaxial load spectra in a cooled gas turbine blade p 201 A92-19696 p 192 A92-19924 under in-service conditions Dornier 328 first flight Evaluation of a bounded high-resolution scheme for p 201 A92-20734 combustor flow computations Extended mapping and characteristics techniques for p 194 N92-13949 inverse aerodynamic design Supercritical blade design on stream surfaces of p 220 N92-13950 revolution with an inverse method Application of direct inverse analogy method (DIVA) and viscous design optimization techniques

p 176 N92-13951 Image-supported navigation for testing instrument landing systems p 189 N92-14012

DME growth elements and their use with MLS p 189 N92-14018

A Taxi And Ramp Management And Control system (TARMAC) p 207 N92-14027 Avionics systems development: Technological trends,

conflicts, and cost issues in a changing European environment p 199 N92-14054 Experimental investigations of exciting forces caused

by flow in labyrinth seals p 223 N92-14354 Evaluation of rotordynamic coefficients of look-through

labyrinths by means of a three volume bulk flow model p 223 N92-14356

Determination of rotordynamic coefficients for labyrinth seals and application to rotordynamic design calculations p 223 N92-14360

Hydraulic actuator system for rotor control p 224 N92-14363 Application of MSC/DYNA to shock and impact

[MBB-UD-0593-91-PUB] p 225 N92-14382

A92-18769 te at Mach A92-18770 F jender detta A92-18900 O A92-18900 O A92-19400 F A92-19110 F A92-19463 G A92-19463 G urbine blade

### FOREIGN TECHNOLOGY INDEX

SIMOUN and Scirocco wind tunnel nozzle viscous flow p 208 N92-14999 study

Equilibrium solution of the Euler and Navier-Stokes equations around a double ellipsoidal shape with monoand multi-blocks including real gas effects, part 1 p 227 N92-15030

Parallelization of a Direct Simulation Monte Carlo p 227 N92-15033 (DSMC) code for fluid dynamics Grid impact on 3D hypersonic flows

p 184 N92-15041 Review of the European hypersonic wind tunnel performance and simulation requirements

p 209 N92-15043 Monitoring load experience of individual aircraft

p 196 N92-15065 [NLR-TP-90084-U]

### Ρ

POLAND

Design of 3-dimensional complex airplane configurations with specified pressure distribution via optimization p 194 N92 13948

### R

**ROMANIA (RUMANIA)** A lifting line theory for supersonic flow applications [AIAA PAPER 91-5058] p 171 A92-17841 On a global aerodynamic optimization of a civil transport p 193 N92-13931 aircraft

### S

### SAUDI ARABIA

Similarity solutions for supersonic axisymmetric flows p 173 A92-18387 Hypersonic flows over slender circular cones at small

p 173 A92-19068 angles of attack SPAIN Flow and temperature computations for space vehicles

using adaptive finite element techniques p 181 N92-14990

Electronically steerable antenna for aircraft p 229 N92-15272

### SWEDEN

Aerospace software in Sweden p 233 A92-19406 Fatigue and damage tolerance verification of aircraft p 217 A92-19677 structures

Damage tolerance of the fighter aircraft 37 Viggen. I -Analytical assessment. II - Experimental verification p 192 A92-19819

The use of finite difference electromagnetic analysis in the design and verification of modern aircraft p 192 A92-20136

Hypersonic flow past delta wing flow simulated by Navier-Stokes solutions p 180 N92-14981 SWITZERLAND

Annular seals of high energy centrifugal pumps: Presentation of full scale measurement

p 224 N92-14362 A multiblock flow solver for inviscid hypersonic flows

p 181 N92-14986

### Т

### TAIWAN

- Some results on metal and composite patch reinforcement of aluminum honeycomb panel p 216 A92-18830
- Flutter analysis of anisotropic panels with patched cracks p 219 A92-20216
- Model oscillations at high angle of attack in a low speed
- wind tunnel test [IAF PAPER ST-91-001] p 175 A92-20649
- Control system design for the free drop test of external stores in a wind tunnel
- p 207 A92-20650 [IAF PAPER ST-91-002] Fair weather convection and light aircraft accidents
- [IAF PAPER ST-91-004] p 186 A92-20651 International aviation (selected article)
- p 170 N92-13991 International aviation (selected article) AD-A2409871 [AD-A240986]
- p 170 N92-13992 [AD-A240987] International aviation (selected articles)
- p 170 N92-13993 [AD-A241119] Ferrundi Company supplies 4500 model head up display
- devices to India's MIG-21 aircraft AD-A241044] p 229 N92-15367 TURKEY
- Vibration characteristics of pretwisted aerofoil cross-section blade packets under rotating conditions p 219 A92-20756

Numerical calculation of modulation transfer functions for low frequency mechanical vibrations

p 235 A92-19982 Experimental investigation of periodically excited p 218 A92-20213 rotating composite rotor blades ITALY

p 204 A92-18608 Dynamics of hang-gliders High temperature low cycle fatigue of single crystal nickel p 213 A92-19796 base superalloys

Fracture analysis and crack propagation in pressurized fuselage structures - Experimental and numerica investigations p 217 A92-19812 Prediction of fatigue crack growth in a Ti-6AI-4V fan disk forging under spectrum loading p 213 A92-19817 Incompressible steady aerodynamics using a standard

p 174 A92-20218 finite element code Nonequilibrium hypersonic inviscid steady flows p 176 A92-20737 Research on inverse methods and optimization in Italy

p 202 N92-13956 Knowledge based system applications for guidance and

control [AGARD-AR-284] p 205 N92-14065 Aerothermodynamic development of the CARINA re-entry vehicle: CFD analyses and experimental tests

p 211 N92-14980 High enthalpy nozzle flows p 182 N92-15000 Infrared measurements of aerodynamic heating in p 208 N92-15002 hypersonic wind tunnel

Linear acoustics in gas mixtures with rate processes p 238 N92-15013

Influence of chemical modeling on the solution of hypersonic shock layers p 183 N92-15016

### J

JAPAN

Ultrasonic motor utilizing elastic fin rotor p 215 A92-17414

CFD application to 2D/3D flow fields in Scramjet p 170 A92-17501 engine Supersonic inlet flow computation

p 171 A92-17502 Numerical simulation for various flowfields

of aero-engine components p 200 A92-17503

'Spaceplanes' R&D status of Japan [AIAA PAPER 91-5002] p 209 A92-17802 Scramjet research at the National Aerospace

Laboratory [AIAA PAPER 91-5076] p 200 A92-17849 Cabin structural vibration and noise for transport

ircraft p 192 A92-17876 Structure/control design synthesis of active flutter aircraft suppression system by goal programming

p 204 A92-18621 Aerodynamic aircraft design methods and their notable

applications: Survey of the activity in Japan p 193 N92-13930

Field telemetry of blade-rotor coupled torsional vibration at Matuura Power Station Number 1 unit p 222 N92-14348

Experiment of static and dynamic characteristics of spiral p 223 N92-14361 grooved seals JORDAN

Effect of suction on the stability of supersonic boundary lavers, I - Second-mode waves, II - First-mode waves p 174 A92-19611

### Κ

KOREA(SOUTH)

Resonance prediction for slotted circular wind tunne using finite element p 235 A92-18388 Static aeroelastic analysis for generic configuration wing p 174 A92-20201

### Ν

- NETHERLANDS
- Inviscid drag prediction for transonic transport wings using a full-potential method p 174 A92-20212 Review of aerodynamic design in the Netherlands p 193 N92-13929

The two-bay crack problem in fuselages built in GLARE and ARALL

[LR-653] p 196 N92-14044 Bulging of fatigue cracks in a pressurized aircraft fuselade

- [LR-655] p 196 N92-14045 Propeller-driven-small airplane noise certification p 237 N92-14798
- [LR-650] Aerothermodynamic challenges for ESA programmes p 180 N92-14974

Review of investigations on aeronautical fatigue in the Federal Republic of Germany p 225 N92-14397 [ETN-92-90317]

HONG KONG

Low cycle fatigue of cast nickel base turbine rotors p 226 N92-14405

Fatigue of repaired composite structures p 214 N92-14411

Environmental fatigue tests with composite materials p 214 N92-14413

Comparison between hot/wet test and RT/dry test on the Seastar horizontal stabilizer and fin p 226 N92-14414

Probabilistic lifing approach for aero engine disks made of powder nickel base alloys containing ceramic defects p 226 N92-14424

Airbus Industrie A330/A340: Full scale fatigue test of p 226 N92-14425 center fuselage and wing Methodology for assessment of skin repairs on Airbus

aircraft p 226 N92-14428 A concept for the revisions of structural inspection p 226 N92-14431

schedules Introduction to neural computing and categories of neural network applications to guidance, navigation and

p 234 N92-14674 control Simulation requirements for RCS plume: Flowfield interaction modelling on a winged reentry vehicle

p 181 N92-14985 Steps towards an efficient and accurate method solving

the Euler equations around a re-entry configuration at p 181 N92-14987 super- and hypersonic speed Base pressure measurements on a cone at hypersonic Mach numbers: A contribution to aerothermodynamics for

space vehicles p 181 N92-14992 Experimental study of hypersonic shock wave boundary layer interactions by means of infrared technique

p 182 N92-14994 Short time force measurement system

p 208 N92-15001 Verification and application of the NSFLEX method for p 182 N92-15005 hypersonic flow conditions

Viscous shock-layer equations for the calculation of reentry aerothermodynamics p 183 N92-15008

The IRS plasma wind tunnels for the investigation of thermal protection materials for reentry vehicles p 208 N92-15009

FALKE and COBRA technology development in aerodynamics and aerothermodynamics

p 183 N92-15017 High enthalpy testing in the Aachen (Fed. Republic of Germany) shock tunnel TH 2 p 208 N92-15021 Computational aerothermodynamic methods for

industrial applications to re-entry and hypersonic cruise p 227 N92-15027 problems Behaviour and modelling of the aerothermodynamics of ballistic entry vehicles in the high altitude flow regimes

p 184 N92-15031 Applicability of bridging methods to hypersonic rarefied flow aerodynamics of reentry vehicles

p 184 N92-15032 Aerothermodynamic challenges of the Saenger space-transportation system p 184 N92-15042

Development and evaluation of a finite element model for a fiber composite helicopter fuselage p 196 N92-15066 [MBB-UD-0584-90-PUB]

Project of an adaptive multiaxial autopilot with learning pilot control p 205 N92-15072 (FTN-92-90592)

The acoustic flashlight		
[MBB-Z-0359-90-PUB]	p 239	N92-15938

Aging aircraft programme entails major effort and

Numerical prediction of subsonic turbulent flows over

Autonomously aided strapdown attitude reference

Adaptive suppression of biodynamic interference in

helmet-mounted displays and head teleoperation

Nonlinear landing gear behavior at touchdown

p 219 A92-20356

p 192 A92-19606

p 169 A92-20023

p 172 A92-18358

p 204 A92-18610

p 197 A92-18611

### Н

Limitations to the large strain theory

INTERNATIONAL ORGANIZATION

slender bodies at high incidence

HONG KONG

INDIA

expense

system

D-2

ISRAEL

U.S.S.R.
Aerodynamic damping of blade vibrations in
turbomachines p 200 A92-18198
A probabilistic method for monitoring the remaining life
of aircraft gas turbine engine components using the
temperature limit criterion p 201 A92-18292
Soviet CFD - An international perspective
p 233 A92-20150
Holographic-interferometry methods employed for
vibration-strength testing of aviation-engine workpieces
p 219 A92-20771
a dynamic inverse problem a 220 M02 12062
JPBS report: Science and technology USSB: Space
[JPRS-USP-91-007] p 211 N92-14101
History of EPOS air-launched spaceplane project
p 211 N92-14103
Aerothermodynamic configuration of first generation
aerospace planes (of Buran-type) and first flight results
p 211 N92-14975
UNITED KINGDOM
Hypersonic materials p 212 A92-18002
Rolling in the tolerance p 216 A92-18005
Heavy metal p 207 A92-18100
Noise-driven flow p 1/3 A92-18680
and Beynolds number n 173 A92-18771
Mesoscale dynamics of cold fronts - Structures
described by dronsoundings in Fronts 87
p 230 A92-18902
Infra-red offers new landing aid competition
p 198 A92-18937
Aerospace software engineering in the United
Kingdom p 233 A92-19405
Short fatigue crack growth from blunt notches in an
aero-engine alloy p 212 A92-19760
Crack initiation and the short-to-long crack growth
Whole aircraft lightning indirect effects evaluation using
low level injection techniques p 102 A02-20134
Four decades of transpric fighter design
p 193 A92-20203
Flat-ended circular cylinder in hypersonic rarefied flow
p 174 A92-20304
Lightning protection requirements for aircraft: A
proposed specification
[RAE-TM-FS(F)-632-REV-ISSUE] p 187 N92-14007
Avionics software evolution p 199 N92-14052
The effects of manufacturing tolerances on the vibration
of aero-engine rotor-damper assemblies
The application of a cylindrical spherical floating ring
bearing as a device to control stability of
turbogenerators p 224 N92-14371
Flow over a delta wing at hypersonic speeds
p 181 N92-14993
Interference heating near fin/body junctions on
hypersonic vehicles p 182 N92-14996
Hypersonic aerothermodynamic computations using a
point-implicit TVD method p 183 N92-15006
Passenger knowledge of airline safety information
[URANFIELD-AEHU-9111] p 187 N92-15054

# **CONTRACT NUMBER INDEX**

### AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

### April 1992

### 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 shown. 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.

.

10 000 0101	- 005	100 44000
AF PROJ. 2401	p 225	N92-14386
AF PROJ. 2404	p 19/	N92-15069
AF-AFOSR-0091-90	p 234	N92-15658
AF-AFOSR-85-0273	p 172	A92-18367
AF-AFOSR-87-0366	p 176	A92-20739
AF-AFOSR-88-0298	p 197	A92-18611
AF-AFOSR-89-0310	p 216	A92-18369
CNR-88,00370,11	p 217	A92-19812
CNT PROJ. 6902	p 189	N92-14009
	p 189	N92-14018
DA PROJ. 1L1-61102-AH-43	D 180	N92-14972
DAAH01-85-DA-015	p 186	A92-20129
DAAH01-88-D-0002	p 204	A92-19103
DAAL03-86-G-0039	0 176	A92-20736
DAAL03-86-G-0044	n 175	A92-20727
DAAL03-87-G-0017	n 217	A92-19618
DAAL03-88-C-022	n 216	A92-18377
DAAL03-00-G-0129	n 217	A02-10618
DE AC04 76DB 00780	p 200	NO2 15202
DE ACO5 840P 31400	p 229	N02-15761
DTEA01 97 C 00014	p 200	NO2 14022
DTFA01-87-0-00014	p 190	N02 14064
	p 202	N92-14004
	p 191	N92-15061
DTFA03-88-C-00024	p 187	N92-15053
D1FA03-89-C-00023	p 191	N92-14034
F19628-89-C-0001	p 191	N92-15058
F33615-84-C-3202	p 235	N92-14779
F33615-87-C-1550	p 210	A92-19061
F33615-87-C-3402	p 171	A92-17842
F33615-88-C-3606	p 203	A92-18463
F33615-90-C-2066	p 202	N92-14059
F49620-86-C-0066	p 219	A92-20746
F49620-86-C-0133	p 219	A92-20741
NAGW-1072	p 171	A92-17822
NAGW-1128	p 197	A92-18611
NAG1-1116	p 234	N92-15658
NAG1-1119	p 237	N92-14789
NAG1-1133	p 207	A92-17819
NAG1-1158	p 180	N92-14969
NAG1-1188	p 233	A92-19619
NAG1-1198	p 179	N92-13999
NAG1-1201	p 207	A92-17819
NAG1-1278	p 178	N92-13995
NAG1-1341	p 203	A92-17840
NAG1-421	0 235	A92-18683
NAG1-619	p 193	A92-20202
NAG1-600	n 205	A92-20207
NAG1-030	p 205	NOD 14000
NAG1-/10	p 195	N92-14038
NAG1-907	p 203	A92-17837
NAG1-922	p 205	N92-14066
. NAG1-951	p 178	N92-13996

NAG2-209	p 204	A92-18625
NAG2-477	p 204	A92-18625
NAG2-542	p 221	N92-1426
	p 221	N92-1426
NAC0 191	- 202	N02 1425
NAG3-101	p 223	1432-1435
NAG3-323	p 233	A92-19605
NAG3-724	p 170	A92-17429
NAG3-72	p 218	A92-20215
	p 219	A92-20217
NASA ORDER L-74809-C	p 178	N92-13997
NAS1-16984	p 230	A92-20128
NAS1-17748	p 230	A92-20128
NAS1-18028	n 191	N92-15060
NAS1-18107	n 204	A92-18615
	n 234	N92-1565
NAS1 18940	0 174	402.2021
NAG1-10240	p 179	A00 10070
NAS1-10304	p 172	NO0 15072
NAS1-18985	p 209	N92-1507
NAS1-18605	p 185	N92-1504
	p 234	N92-15658
NAS1-18763	p 203	A92-17839
NAS1-18849	p 236	N92-14788
NAS1-18972	p 230	A92-17585
NAS1-19038	p 234	N92-14598
NAS2-13072	p 195	N92-14039
NAS3-23722	p 195	N92-14037
NAS3-25266	p 237	N92-14797
NAS3-25416	p 225	N92-14374
NAS8-36719	p 224	N92-14367
NAS8-36720	D 225	N92-14391
NAS9 27465	n 221	N92-14344
NACO 18057	p 221	A02 1750/
NA39-10037	p 231	A00 17000
NCC1-1002	p 171	M92-1/022
NCC2-507	p 221	N92-14313
NCC2-553	p 185	N92-15048
NCC2-575	p 191	N92-14036
NGL-22-009-640	p 205	A92-20207
NGL-31-001-252	p 204	A92-18620
NGT-01-008-021	p 234	N92-15870
	p 212	N92-15877
NR PROJ. C31-50	D 229	N92-15385
NR PROJECT 432-5201	p 174	A92-19611
NR PROJECT 432-5201 NSCRC-77-0210-D006-14	р 174 р 219	A92-19611 A92-20216
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776	p 174 p 219 p 188	A92-19611 A92-20216 A92-18172
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517	p 174 p 219 p 188 p 188	A92-19611 A92-20216 A92-18172 A92-18172
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-87-02993	p 174 p 219 p 188 p 188 p 188	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172
NR PROJECT 432-5201	p 174 p 219 p 188 p 188 p 188 p 188	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-87-02993 NSF ATM-89-12555 NSF ATM-89-12555 NSF CDM 0# 15326	p 174 p 219 p 188 p 188 p 188 p 188 p 188	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-87-02993 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 188	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 N92-13961 A92-19605
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSC 9120-2000	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 177 p 233 p 176	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 N92-13961 A92-19605 A92-20742
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-87-02993 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 NSP DMC-87-07648	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 177 p 233 p 176	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-19605
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-87-02993 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 NSG 4139	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 N92-13967 A92-19605 A92-20747 A92-19611
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-02555 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0693	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-19605 A92-20747 A92-19611 A92-18615
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-86-K-0683 N00014-80-J-1513	p 174 p 219 p 188 p 188 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204 p 204	A92-19611 A92-20218 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-13960 A92-13960 A92-20747 A92-19605 A92-19605 A92-19605
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-88-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 N00014-86-K-0693 N00014-80-J-1513 N00039-89-C-5301	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204 p 233 p 172	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-20747 A92-19615 A92-19605 A92-18655 A92-18655
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0693 N00014-85-K-0693 N00014-90-J-1513 N00039-89-C-5301 N00157-85-C-0042	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204 p 233 p 172 p 229	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-13960 A92-13960 A92-19605 A92-19605 A92-18615 A92-18605 A92-18685 N92-15385
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-87-02993 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-87-07648 NOG014-85-K-0011 N00014-85-K-0011 N00014-86-K-0693 N00014-80-J-1513 N00039-89-C-5301 N0017-85-C-0042 RP-1884-10	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 174 p 204 p 204 p 204 p 229 p 224	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-20747 A92-19605 A92-20747 A92-19605 A92-20747 A92-18615 A92-18685 N92-18385 N92-15385 N92-14385
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 N00014-85-K-0693 N00014-85-K-0693 N00014-85-K-0693 N00014-85-K-0011 N00014-80-J-1513 N00039-89-C-5301 N00167-85-C-0042 RP-1884-10 324-02-00	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 174 p 204 p 233 p 172 p 229 p 224 p 236	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-13960 A92-13960 A92-20747 A92-19605 A92-19605 A92-18385 N92-18385 N92-18385 N92-14365 N92-14365
NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0693 N00014-85-K-0693 N00014-85-C-3001 N00039-89-C-5301 N00187-85-C-0042 RP-1884-10 324-02-00 505-59-30-01	p 174 p 219 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204 p 233 p 176 p 174 p 204 p 233 p 176 p 224 p 229 p 224 p 236 p 178	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-20747 A92-19611 A92-18615 A92-18655 N92-14385 N92-14385 N92-14386 N92-14386 N92-14385 N92-14385
NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-87-02993 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0693 N00014-80-J-1513 N00039-89-C-5301 N0017-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-30-01	p 174 p 219 p 188 p 188 p 188 p 176 p 233 p 176 p 233 p 176 p 233 p 176 p 233 p 177 p 204 p 233 p 172 p 229 p 224 p 236 p 178 p 178	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-20747 A92-19605 A92-19605 A92-19605 N92-13385 N92-14366 N92-145666 N92-145666 N92-145666 N92-145666 N92-145666 N92-145666
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 N00014-85-K-0683 N00014-85-K-0683 N00014-86-K-0683 N00014-86-K-0683 N00014-86-K-0683 N00147-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-54-07	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 204 p 203 p 172 p 229 p 224 p 229 p 178 p 178 p 178 p 178 p 209	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19605 A92-19
NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0011 N00014-85-K-0693 N00014-85-C-0012 N00014-90-L-1513 N00014-90-L-1513 N00014-90-L-5301 N00167-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-54-07 505-59-54-07 505-62-50	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 204 p 233 p 172 p 224 p 224 p 226 p 178 p 178 p 178 p 178 p 179 p 195	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19605 A92-19605 A92-19605 A92-19605 A92-19605 A92-19616 A92-19616 A92-19616 A92-19605 A92-19605 A92-19616 A92-19605 A92-19
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NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0693 N00014-85-K-0693 N00014-85-C-3001 N00014-90-L-1513 N00014-90-L-1513 N00014-90-L-5301 N00167-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-54-07 505-62-52 505-63-58 	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 233 p 176 p 233 p 172 p 229 p 229 p 236 p 178 p 178 p 178 p 178 p 179 p 230	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18616 A92-19605 A92-19605 A92-19605 A92-19605 A92-18385 N92-15385 N92-15385 N92-13995 N92-15191 N92-15191 N92-15191
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSG-3139 N00014-85-K-0011 N00014-85-K-0011 N00014-85-K-0013 N00014-80-J-1513 N00039-89-C-5301 N00167-85-C-0042 RP-1884-10 324-02-00 505-59-34-01 505-59-54-07 505-62-50 505-62-52 505-63-58 505-63-58	p 174 p 219 p 188 p 188 p 188 p 188 p 177 p 233 p 176 p 174 p 233 p 176 p 234 p 172 p 229 p 224 p 236 p 178 p 178 p 178 p 178 p 178 p 195 p 179 p 214 p 219 p 188	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19601 A92-19611 A92-19611 A92-19611 A92-18382 N92-15382 N92-15393 N92-15073 N92-15071 N92-15400 N92-15400
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NGG-3139 N00014-85-K-0011 N00014-86-K-0693 N00014-86-K-0693 N00014-80-J-1513 N00039-89-C-5301 N00187-85-C-0042 RP-1884-10 324-02-00 505-59-34-01 505-59-54-07 505-62-52 505-63-58 505-63-50-12	P 174 P 219 P 188 P 188 P 188 P 188 P 233 P 176 P 233 P 176 P 233 P 176 P 233 P 176 P 233 P 172 P 224 P 236 P 178 P 299 P 195 P 174 P 230 P 178 P 178 P 185 P 185 P 185	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-18615 A92-19614 A92-18385 N92-15385 N92-15385 N92-14362 N92-14362 N92-14362 N92-14363 N92-15465 N92-15455 N92-155555 N92-155555 N92-155555 N92-1555555 N92-155555555 N92-1555555555555555555555555555555555555
NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG-3139 N00014-85-K-0011 N00014-85-K-0011 N00014-85-K-0693 N00014-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-54-07 505-63-50 505-63-50 505-63-50-12 505-63-50-15	P 174 P 219 P 188 P 188 P 188 P 188 P 177 P 233 P 177 P 233 P 177 P 204 P 204 P 224 P 224 P 229 P 224 P 229 P 224 P 178 P 178 P 178 P 179 P 195 P 195 P 195 P 185 P 185 P 185	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18616 A92-19605 A92-19605 A92-19605 A92-19605 A92-18385 N92-15385 N92-15385 N92-13995 N92-15191 N92-15045 N92-15045 N92-15055
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-86-15336 NSG-3139 N00014-86-K-0693 N0014-86-K-0693 N00014-86-K-0693 N00014-86-K-0693 N00014-86-K-0693 N00	P 174 P 219 P 188 P 188 P 188 P 188 P 187 P 273 P 177 P 233 P 176 P 233 P 176 P 233 P 174 P 233 P 174 P 233 P 174 P 229 P 229 P 224 P 236 P 179 P 229 P 229 P 274 P 178 P 178 P 179 P 229 P 279 P 179 P 185 P 185 P 195 P 195 P 195 P 195 P 185 P 206 P 195 P 195 P 206 P 179 P 179	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19601 A92-19601 A92-19611 A92-18615 A92-19601 A92-18385 N92-15385 N92-15385 N92-15395 N92-15405 N92-15405 N92-15505 N92-15075 N92-15075
NR PROJECT 432-5201 NSCRC-77-0210-D006-14 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 N00014-85-K-0693 N00014-85-K-0693 N00014-80-L-1513 N00039-89-C-5301 N00187-85-C-0042 RP-1884-10 324-02-00 505-59-34-01 505-59-54-07 505-62-52 505-63-50-12 505-63-50-15 505-64-10-10 505-59-54-01	P 174 P 219 P 188 P 188 P 188 P 188 P 177 P 233 P 176 P 174 P 204 P 177 P 229 P 224 P 178 P 279 P 224 P 178 P 178 P 178 P 178 P 178 P 179 P 229 P 229 P 224 P 195 P 197 P 230 P 195 P 197 P 214 P 230 P 195 P 197 P 219 P 195 P 197 P 219 P 195 P 197 P 219 P 197 P 219 P 197 P 209 P 197 P 197	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19615 A92-19615 N92-15385 N92-15385 N92-15385 N92-15385 N92-15045 N92-15045 N92-15075 N92-15077
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-87-02993           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N000167-85-C-0042           RP-1884-10           324-02-00           505-59-54-01           505-59-54-01           505-62-50           505-63-50-12           505-63-50-15           505-63-50-15           505-64-10-10           505-64-10-10	P 174 P 188 P 188 P 188 P 188 P 187 P 233 P 170 P 233 P 170 P 244 P 244 P 244 P 244 P 244 P 249 P 172 P 172 P 172 P 172 P 172 P 172 P 178 P 179 P 195 P 195 P 195 P 195 P 195 P 195 P 195 P 197 P 197	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18615 A92-19605 A92-19605 A92-19605 A92-19605 A92-18615 A92-18615 N92-15385 N92-15385 N92-15385 N92-15395 N92-15075 N92-15045 N92-15075 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSG ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-85-K-0011           N00014-86-K-0693           N0014-86-K-0693           N0014-85-C-0042           PP-1884-10           324-02-00           505-59-30-01           505-59-30-01           505-59-54-07           505-62-50           505-63-50-12           505-63-50-12           505-63-50-15           505-63-50-15           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10	P 174 P 219 P 188 P 188 P 188 P 188 P 188 P 177 P 236 P 174 P 204 P 172 P 224 P 172 P 229 P 224 P 230 P 172 P 229 P 230 P 24 P 230 P 24 P 250 P 29 P 20 P 20 P 20 P 20 P 20 P 20 P 20 P 20	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-18062 N92-15382 N92-15382 N92-15382 N92-15392 N92-15075 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-85-02517           NSF ATM-85-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-87-07648           NGG-3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-C-5301           N00039-89-C-5301           N00187-85-C-0042           RP-1884-10           324-02-00           505-59-54-01           505-59-54-07           505-63-50-12           505-63-50-12           505-63-50-12           505-63-50-15           505-63-50-15           505-64-10-10           505-68-10-10           505-68-10-10           505-68-11           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10	P 174 P 219 P 188 P 188 P 188 P 188 P 177 P 237 P 176 P 177 P 277 P 279 P 172 P 229 P 274 P 279 P 274 P 279 P 279 P 175 P 279 P 279 P 195 P 197 P 197	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18072 A92-19605 A92-19605 A92-19605 A92-19605 A92-18385 N92-15385 N92-15385 N92-15385 N92-15405 N92-15075 N92-15075 N92-15075 N92-15405
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-87-02993           NSF ATM-89-12555           NSF DMC-86-15336           NO014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N000167-85-C-0042           RP-1884-10           324-02-00           505-59-54-01           505-59-54-01           505-62-50           505-63-50-12           505-63-50-12           505-63-50-15           505-64-10-10           505-64-10-10           505-64-10-10           505-64-10-10           505-68-10	P 174 P 219 P 188 P 188 P 188 P 187 P 233 P 170 P 233 P 174 P 204 P 230 P 172 P 229 P 224 P 229 P 229 P 229 P 179 P 179 P 179 P 179 P 179 P 179 P 179 P 206 P 197 P 207 P 207 P 207 P 177 P 207 P 207 P 177 P 207 P 207 P 177 P 207 P 177 P 207 P 207 P 177 P 177 P 207 P 207	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18615 A92-19605 A92-19605 A92-19605 A92-19605 A92-18615 A92-18615 A92-18615 N92-15385 N92-15385 N92-15395 N92-15077 N92-15075 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-85-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF ATM-89-12555           NSF DMC-86-15336           NSF ATM-89-12555           NSF DMC-87-07648           NGG-3139           N00014-85-K-0011           N00014-86-K-0683           N0014-86-K-0683           N00014-86-K-0683           N0014-86-K-0693           N0014-85-C-0042           RP-1884-10           324-02-00           505-59-30-01           505-59-30-01           505-59-54-07           505-62-50           505-63-50-12           505-63-50-12           505-63-50-12           505-63-50-15           505-64-10-10           505-64-10-10           505-68-10           505-68-112           505-68-12           505-68-10	p         174           p         198           p         188           p         172           p         204           p         172           p         229           p         172           p         230           p         175           p         244           p         230           p         185           p         197           p         206           p         198           p         206           p         209           p         206           p         191           p         206           p         192           p         206           p         197           p         179           p <t< td=""><td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-18050 N92-15305 N92-15305 N92-15405 N92-15075 N92-15</td></t<>	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-18050 N92-15305 N92-15305 N92-15405 N92-15075 N92-15
NR PROJECT 432-5201 NSCRC-77.0210-D006-14 NSF ATM-82-05776 NSF ATM-82-05776 NSF ATM-85-02517 NSF ATM-89-12555 NSF DMC-86-15336 NSF DMC-86-15336 NSF DMC-87-07648 NSG 3139 N00014-85-K-0011 N00014-85-K-0011 N00014-85-K-0683 N00014-85-K-0683 N00014-85-C-0042 RP-1884-10 324-02-00 505-59-30-01 505-59-34-07 505-63-50 505-63-50 505-63-50 505-63-50-12 505-63-50-15 505-64-10-10 505-68-10	p         174           p         198           p         188           p         188           p         187           p         177           p         233           p         176           p         177           p         233           p         176           p         244           p         242           p         178           p         230           p         195           p         192           p         244           p         230           p         192           p         185           p         185           p         185           p <t< td=""><td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18615 A92-19605 A92-19605 A92-19605 A92-18385 N92-15385 N92-15385 N92-15405 N92-15075 N92-15076 N92-15076 N92-15076 N92-150777 N92-150777 N92-150777 N92-1507777 N92-1507777 N92-15077</td></t<>	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18615 A92-19605 A92-19605 A92-19605 A92-18385 N92-15385 N92-15385 N92-15405 N92-15075 N92-15076 N92-15076 N92-15076 N92-150777 N92-150777 N92-150777 N92-1507777 N92-1507777 N92-15077
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-87-02993           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N000167-85-C-0042           RP-1884-10           324-02-00           505-59-54-01           505-59-54-07           505-63-50           505-63-50           505-63-58           505-63-58           505-63-50-12           505-63-50-12           505-63-10-10           505-64-10-10           505-68-10           505-68-10	P 174 P 219 P 188 P 188 P 188 P 188 P 188 P 187 P 170 P 203 P 170 P 204 P 172 P 224 P 224 P 172 P 224 P 172 P 224 P 172 P 224 P 172 P 224 P 172 P 185 P 179 P 179 P 185 P 179 P 179 P 170 P 174 P 203 P 179 P 179 P 170 P 174 P 203 P 179 P 179 P 179 P 170 P 179 P 170 P 200 P 170 P 200 P 170 P 200 P 170 P 200 P 170 P 200 P 190 P 190 P 100 P 100	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19601 A92-19601 A92-19611 A92-18615 A92-19601 A92-18385 N92-15385 N92-15385 N92-15375 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15055 N92-14055 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-85-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-87-07648           NGG 3139           N00014-85-K-0011           N00014-86-K-0683           N0014-86-K-0683           N0014-86-K-0683           N0014-86-K-0693           S05-59-30-01           505-59-30-01           505-59-54-07           505-63-50-12           505-63-50-12           505-63-50-12           505-64-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10 </td <td>p         174           p         198           p         188           p         178           p         230           p         178           p         230           p         185           p         197           p         209           p         191           p         230           p         185           p         197           p         206           p         198           p         198           p         197           p         206           p         197           p         185           p         185           p         185           p         186           p         185           p         180           p         180           p         <t< td=""><td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-18615 A92-19611 A92-18615 A92-19611 A92-18615 N92-14362 N92-14362 N92-15045 N92-15045 N92-15057 N92-15057 N92-15057 N92-15055 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14055 N92-14</td></t<></td>	p         174           p         198           p         188           p         178           p         230           p         178           p         230           p         185           p         197           p         209           p         191           p         230           p         185           p         197           p         206           p         198           p         198           p         197           p         206           p         197           p         185           p         185           p         185           p         186           p         185           p         180           p         180           p <t< td=""><td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-18615 A92-19611 A92-18615 A92-19611 A92-18615 N92-14362 N92-14362 N92-15045 N92-15045 N92-15057 N92-15057 N92-15057 N92-15055 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14055 N92-14</td></t<>	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-18615 A92-19611 A92-18615 A92-19611 A92-18615 N92-14362 N92-14362 N92-15045 N92-15045 N92-15057 N92-15057 N92-15057 N92-15055 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14065 N92-14055 N92-14
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-89-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N00016-85-C-0042           RP-1884-10           324-02-00           505-59-30-01           505-59-54-07           505-63-50-15           505-63-50-15           505-63-50-15           505-63-50-15           505-63-50-15           505-64-10-10           505-64-10-10           505-64-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10	P 174 P 219 P 188 P 188 P 188 P 188 P 187 P 177 P 233 P 176 P 274 P 274 P 274 P 274 P 274 P 274 P 172 P 274 P 175 P 175	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19615 A92-19615 A92-19615 A92-19615 A92-19615 N92-15365 N92-15045 N92-15045 N92-15075 N92-15075 N92-15057 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-87-02993           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-86-K-0693           N00014-86-K-0693           N00014-80-J-1513           N00039-89-C-5301           N00167-85-C-0042           RP-1884-10           324-02-00           505-59-30-01           505-59-54-07           505-63-50           505-63-50           505-63-58           505-63-50-12           505-63-50-12           505-63-50-12           505-63-50-15           505-64-10-10           505-64-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-69-10           505-69-10           505-69-10           505-69-10	p         174,           p         198,           p         188,           p         172,           p         203,           p         174,           p         224,           p         224,           p         224,           p         224,           p         224,           p         224,           p         236,           p         178,           p         244,           p         200,           p         185,           p         197,           p         206,           p         197,           p         186,           p         187,           p         186,           p         187,           p         180,           p         180,	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-18052 N92-15382 N92-15382 N92-15382 N92-15382 N92-15072 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-80-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-87-07648           NGG-3139           N00014-85-K-0011           N00014-86-K-0683           N00014-86-K-0683           N00014-86-K-0683           N00014-86-K-0693           N00014-86-K-0693           N00014-86-K-0693           N00014-86-K-0693           N00014-86-K-0693           N00014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           N0014-86-K-0693           S05-59-30-01           S05-59-30-01           S05-59-30-01           S05-59-407           S05-64-101           S05-64-10-10           S05-64-10-10           S05-64-10-10           S05-68-10           S05-68-10           S05-68-10           S05-69-10     <	p         174           p         198           p         188           p         178           p         229           p         244           p         230           p         178           p         249           p         240           p         240           p         249           p         249           p         249           p         249           p         185           p         179           p         234           p <t< td=""><td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-18615 A92-19611 A92-18615 N92-15385 N92-15385 N92-15395 N92-15045 N92-15045 N92-15055 N92-15055 N92-15055 N92-15045 N92-15055 N92-15</td></t<>	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-18615 A92-19611 A92-18615 N92-15385 N92-15385 N92-15395 N92-15045 N92-15045 N92-15055 N92-15055 N92-15055 N92-15045 N92-15055 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-87-02993           NSF ATM-89-12555           NSF DMC-86-15336           NO014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N00014-80-J-1513           N000167-85-C-0042           RP-1884-10           324-02-00           505-59-30-01           505-59-54-07           505-63-50-15           505-63-50-12           505-63-50-15           505-63-50-15           505-64-10-10           505-64-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-69-10           505-69-10           505-69-10           505-69-10           505-69-10           505-69-10	P 174 P 219 P 188 P 188 P 188 P 188 P 187 P 177 P 233 P 176 P 273 P 174 P 244 P 244 P 244 P 244 P 279 P 172 P 229 P 172 P 172 P 229 P 172 P 173 P 176 P 177 P 279 P 178 P 179 P 179 P 179 P 179 P 195 P 195 P 197 P 195 P 197 P 195 P 197 P 195 P 197 P 195 P 185 P 179 P 185 P 178 P 178 P 178 P 178 P 197 P 197 P 185 P 185 P 178 P 185 P 208 P 179 P 185 P 185 P 185 P 208 P 185 P 208 P 185 P 208 P 185 P 208 P 185 P 208 P 208	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18615 A92-19656 N92-13965 N92-15365 N92-14365 N92-14365 N92-15045 N92-15045 N92-15045 N92-15057 N92-15
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-89-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSG 3139           N00014-85-K-0011           N00014-86-K-0693           N00014-86-K-0693           N0014-85-K-0011           N00014-86-K-0693           N0014-85-C-0042           PP-1884-10           324-02-00           505-59-30-01           505-59-30-01           505-59-30-01           505-63-50-12           505-63-50-12           505-63-50-15           505-63-50-15           505-68-10-10           505-68-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-69-10           505-69-10           505-69-10           505-69-10           505-69-10           505-69-10           505-03-10           505-03-10           505-03-10	P 174 P 219 P 188 P 188 P 188 P 188 P 188 P 188 P 177 P 204 P 172 P 204 P 172 P 224 P 175 P 176 P 175 P 176 P 175 P 176 P 175 P 176 P 175 P 176 P 175 P 176 P 176 P 177 P 224 P 178 P 176 P 177 P 224 P 178 P 200 P 178 P 178 P 200 P 179 P 200 P 179 P 200 P 179 P 179 P 200 P 179 P 179 P 200 P 179 P 202 P 185 P 202 P 185 P 202 P 179 P 202 P 202	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-19602 A92-18050 N92-15305 N92-15305 N92-15075 N92-15075 N92-15075 N92-15075 N92-15055 N92-15055 N92-15055 N92-15055 N92-15055 N92-15055 N92-15055 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15057 N92-15047 N92-15047 N92-15047 N92-15047 N92-15047 N92-15047 N92-14075 N92-14
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-85-02517           NSF ATM-85-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF ATM-89-12555           NSF DMC-87-07648           NGG-3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-L1513           N00014-80-L0513           N00014-80-L042           RP-1884-10           324-02-00           505-59-30-01           505-59-30-01           505-59-54-07           505-62-52           505-63-50-12           505-63-50-15           505-63-50-15           505-63-50-15           505-64-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-68-10           505-69-10           505-90-52-01           535-03-11-03           535-03-11-03           535-03-11-03	p         174           p         198           p         188           p         188           p         187           p         177           p         233           p         176           p         177           p         236           p         178           p         178           p         264           p         178           p         269           p         178           p         269           p         269           p         279           p         204           p         279           p         204           p         279           p         206           p         179           p         206           p         179           p         205           p         237           p         237	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18072 A92-19602 A92-19602 A92-19602 A92-19602 A92-18382 N92-15382 N92-15382 N92-15382 N92-15382 N92-15045 N92-15045 N92-15045 N92-15055 N92-14075 N92-15055 N92-14075 N92-15055 N92-14075 N92-14
NR PROJECT 432-5201           NSCRC-77.0210-D006-14           NSF ATM-82-05776           NSF ATM-82-05776           NSF ATM-89-02517           NSF ATM-89-12555           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSF DMC-86-15336           NSG-3139           N00014-85-K-0011           N00014-86-K-0693           N00014-80-J-1513           N00014-80-J-1513           N00014-80-J-1513           N000167-85-C-0042           RP-1884-10           324-02-00           505-59-30-01           505-59-30-01           505-59-54-07           505-62-50           505-63-58           505-63-59           505-63-50-12           505-63-50-12           505-63-50-15           505-64-10-10           505-68-10-10           505-68-10           505-68-10           505-68-10           505-68-10           505-69-10           505-69-10           505-69-10           505-69-10           505-63-11-03 </td <td>p         174,           p         198,           p         188,           p         172,           p         203,           p         174,           p         224,           p         236,           p         175,           p         206,           p         179,           p         206,           p         179,           p         237,           p         237,           p         237,           p         237,           p         237,           p         237,           p         237,</td> <td>A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-18051 N92-1507 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15055 N92-14065 N92-14065 N92-14065 N92-14075 N92-15055 N92-14075 N92-15055 N92-14075 N92-140</td>	p         174,           p         198,           p         188,           p         172,           p         203,           p         174,           p         224,           p         236,           p         175,           p         206,           p         179,           p         206,           p         179,           p         237,	A92-19611 A92-20216 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-18172 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-19611 A92-18051 N92-1507 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15075 N92-15055 N92-14065 N92-14065 N92-14065 N92-14075 N92-15055 N92-14075 N92-15055 N92-14075 N92-140

992-16-04-05	 p <u>2</u> 34	N92-14598
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		·

# **REPORT NUMBER INDEX**

### AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

April 1992

# 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-92013	p 195	N92-14039 * #
ACD-340	p 191	N92-14034 #
AD-A237667	p 202	N92-14059 #
AD-A240797	p 237	N92-14791 #
AD-A240986	. p 170	N92-13991 #
AD-A240987	p 170	N92-13992 #
AD-A241015	p 180	N92-14972 #
AD-A241044	p 229	N92-15367 #
AD-A241119	p 170	N92-13993 #
AD-A241313	p 225	N92-14386 #
AD-A241357	p 205	N92-14065 #
AD-A242478	p 196	N92-15067 #
AD-A242493	p 229	N92-15385 #
AD-A242598	. p 170	N92-14966 #
AD-A242637	p 206	N92-15073 #
AD-A242650	p 206	N92-15074 #
AD-A242656	. p 185	N92-15045 #
AD-A242690	. p 196	N92-15068 #
AD-A242757	. p 191	N92-15058 #
AD-A242768	. p 197	N92-15069 #
AGARD-AR-284	p 205	N92-14065 #
AGARD-LS-179	p 234	N92-14673 #
AGARD-PAPER-25	p 185	N92-15049 * #
AIAA PAPER 91-3069	p 192	A92-20000 #
AIAA PAPER 91-3069	p 192 p 230	A92-20000 # A92-17582 #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713	p 192 p 230 p 230	A92-20000 # A92-17582 # A92-17585 * #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713 AIAA PAPER 91-3726	p 192 p 230 p 230 p 231	A92-20000 # A92-17582 # A92-17585 * # A92-17594 * #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713 AIAA PAPER 91-3726 AIAA PAPER 91-3729	p 192 p 230 p 230 p 231 p 197	A92-20000 # A92-17582 # A92-17585 * # A92-17594 * # A92-17596 #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713 AIAA PAPER 91-3726 AIAA PAPER 91-3729 AIAA PAPER 91-3730	p 192 p 230 p 230 p 231 p 197 p 197	A92-20000 # A92-17582 # A92-17585 * # A92-17594 * # A92-17596 # A92-17597 * #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713 AIAA PAPER 91-3726 AIAA PAPER 91-3729 AIAA PAPER 91-3730 AIAA PAPER 91-3764	p 192 p 230 p 230 p 231 p 197 p 197 p 231	A92-20000 # A92-17582 # A92-17585 * A92-17594 * A92-17596 # A92-17597 # A92-17626 #
AIAA PAPER 91-3069 AIAA PAPER 91-3709 AIAA PAPER 91-3713 AIAA PAPER 91-3726 AIAA PAPER 91-3729 AIAA PAPER 91-3730 AIAA PAPER 91-3765	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 215	A92-20000 # A92-17582 # A92-17585 * A92-17594 * A92-17596 # A92-17597 # A92-17626 # A92-17627 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3764           AIAA PAPER 91-3766	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 215 p 197	A92-20000 # A92-17582 # A92-17585 * # A92-17596 # A92-17596 # A92-17626 # A92-17627 # A92-17627 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3730           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 215 p 197 p 215	A92-20000 # A92-17582 # A92-17585 * A92-17594 * A92-17594 * A92-17597 * A92-17626 # A92-17627 # A92-17628 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3779	<ul> <li>p 192</li> <li>p 230</li> <li>p 231</li> <li>p 231</li> <li>p 197</li> <li>p 197</li> <li>p 197</li> <li>p 231</li> <li>p 215</li> <li>p 197</li> <li>p 231</li> <li>m p 231</li> <li>m p 231</li> </ul>	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17596 # A92-17626 # A92-17626 # A92-17627 # A92-17628 # A92-17629 # A92-17637 *
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3720           AIAA PAPER 91-3730           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3767           AIAA PAPER 91-3779	<ul> <li>p 192</li> <li>p 230</li> <li>p 231</li> <li>p 231</li> <li>p 197</li> <li>p 197</li> <li>p 231</li> <li>p 215</li> <li>p 197</li> <li>p 231</li> <li>p 231</li> <li>p 231</li> <li>p 232</li> </ul>	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17597 * A92-17626 # A92-17627 # A92-17628 # A92-17628 # A92-17629 * A92-17629 * A92-17637 * A92-17645 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3730           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789	<ul> <li>p 192</li> <li>p 230</li> <li>p 231</li> <li>p 197</li> <li>p 197</li> <li>p 231</li> <li>p 197</li> <li>p 231</li> <li>p 232</li> <li>p 232</li> </ul>	A92-20000 # A92-17582 # A92-17585 * A92-17594 * A92-17597 * A92-17626 # A92-17627 # A92-17628 # A92-17629 * A92-17629 * A92-17629 * A92-17654 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3789           AIAA PAPER 91-3803	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 231 p 232 p 232 p 232	A92-20000 # A92-17582 # A92-17585 * # A92-17596 # A92-17596 # A92-17596 # A92-17626 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17645 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3767           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3804	p 192 p 230 p 231 p 231 p 197 p 231 p 231 p 215 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 232	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17596 # A92-17597 * A92-17627 # A92-17628 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17644 # A92-17664 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3767           AIAA PAPER 91-3767           AIAA PAPER 91-3767           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3804           AIAA PAPER 91-3841	p 192 p 230 p 231 p 197 p 197 p 197 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 231 p 231 p 231 p 231	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17597 # A92-17626 # A92-17627 # A92-17628 # A92-17628 # A92-17658 # A92-17657 * A92-17654 # A92-17654 # A92-17654 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3802           AIAA PAPER 91-3802           AIAA PAPER 91-3804           AIAA PAPER 91-3941           AIAA PAPER 91-3941	p 192 p 230 p 231 p 197 p 197 p 197 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 231 p 231 p 231 p 231	A92-20000 # A92-17582 # A92-17585 # A92-17586 # A92-17596 # A92-17596 # A92-17626 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17644 # A92-17664 # A92-17605 # A92-17608 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3720           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3767           AIAA PAPER 91-3789           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3802           AIAA PAPER 91-3803           AIAA PAPER 91-3804           AIAA PAPER 91-3804           AIAA PAPER 91-3804           AIAA PAPER 91-3804           AIAA PAPER 91-3941           AIAA PAPER 91-3941           AIAA PAPER 91-3941           AIAA PAPER 91-3941	p 192 p 230 p 230 p 231 p 197 p 231 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 233 p 231 p 231 p 231 p 209 p 209	A92-20000 # A92-17582 # A92-17585 * A92-17594 * A92-17596 # A92-17597 * A92-17627 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17645 # A92-17645 # A92-17605 # A92-17608 # A92-17608 # A92-17608 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3767           AIAA PAPER 91-3767           AIAA PAPER 91-3779           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3804           AIAA PAPER 91-3944           AIAA PAPER 91-3944           AIAA PAPER 91-5002           AIAA PAPER 91-5002	p 192 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 231 p 231 p 231 p 239 p 232 p 233 p 234 p 334 p 234 p 334 p 234 p 334 p	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17597 * A92-17626 # A92-17627 # A92-17628 # A92-17628 # A92-17628 # A92-1764 # A92-17654 # A92-17654 # A92-17608 # A92-17608 # A92-17608 # A92-17608 # A92-17608 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3802           AIAA PAPER 91-3802           AIAA PAPER 91-3802           AIAA PAPER 91-3941           AIAA PAPER 91-3941           AIAA PAPER 91-5002           AIAA PAPER 91-5015           AIAA PAPER 91-5021	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 231 p 239 p 231 p 239 p 231 p 232 p 232 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 231 p 231 p 231 p 231 p 231 p 231 p 232 p 233 p 233 p 233 p 234 p 235 p	A92-20000 # A92-17582 # A92-17585 # A92-17596 # A92-17596 # A92-17626 # A92-17626 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17644 # A92-17664 # A92-17605 # A92-17605 # A92-17802 # A92-17813 # A92-17818 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3720           AIAA PAPER 91-3720           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3803           AIAA PAPER 91-3822           AIAA PAPER 91-3844           AIAA PAPER 91-3944           AIAA PAPER 91-3015           AIAA PAPER 91-5021           AIAA PAPER 91-5021           AIAA PAPER 91-5024	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 232 p 233 p 232 p 233 p 33 p 33 	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17596 # A92-17597 * A92-17626 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17645 # A92-17645 # A92-17605 # A92-17608 # A92-17608 # A92-17802 # A92-17813 * A92-17818 # A92-1718 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3730           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3767           AIAA PAPER 91-3767           AIAA PAPER 91-3769           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3944           AIAA PAPER 91-3944           AIAA PAPER 91-5002           AIAA PAPER 91-5002           AIAA PAPER 91-50021           AIAA PAPER 91-50020	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 231 p 232 p 231 p 232 p 231 p 232 p 233 p	A92-20000 # A92-17582 # A92-17585 * A92-17587 # A92-17597 # A92-17597 # A92-17626 # A92-17627 # A92-17628 # A92-17628 # A92-17628 # A92-17628 # A92-17654 # A92-17608 # A92-17608 # A92-17608 # A92-17608 # A92-17808 # A92-17817 # A92-17818 # A92-17818 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3729           AIAA PAPER 91-3764           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3802           AIAA PAPER 91-3802           AIAA PAPER 91-3941           AIAA PAPER 91-5002           AIAA PAPER 91-5015           AIAA PAPER 91-5024           AIAA PAPER 91-5024           AIAA PAPER 91-5026	p 192 p 230 p 231 p 197 p 197 p 231 p 219 p 219 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 231 p 232 p 237 p 207 p 207	A92-20000 # A92-17582 # A92-17585 # A92-17596 # A92-17596 # A92-17597 * A92-17626 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17644 # A92-17664 # A92-17605 # A92-17605 # A92-17802 # A92-17813 * A92-17818 # A92-17818 # A92-17819 * #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3726           AIAA PAPER 91-3729           AIAA PAPER 91-3720           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3779           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3789           AIAA PAPER 91-3822           AIAA PAPER 91-3822           AIAA PAPER 91-3844           AIAA PAPER 91-3015           AIAA PAPER 91-5021           AIAA PAPER 91-5021           AIAA PAPER 91-5022           AIAA PAPER 91-5024           AIAA PAPER 91-5026           AIAA PAPER 91-5029           AIAA PAPER 91-5029	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 232 p 232 p 232 p 232 p 231 p 203 p 203 p 217 p 209 p 219 p 219 p 219 p 219 p 211 p 213 p 217 p 217	A92-20000 # A92-17582 # A92-17585 * A92-17584 * A92-17596 # A92-17597 * A92-17626 # A92-17628 # A92-17628 # A92-17645 # A92-17645 # A92-17645 # A92-17605 # A92-17605 # A92-17608 # A92-17813 * A92-17813 * A92-17818 # A92-17820 * A92-17822 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3713           AIAA PAPER 91-3726           AIAA PAPER 91-3728           AIAA PAPER 91-3729           AIAA PAPER 91-3720           AIAA PAPER 91-3720           AIAA PAPER 91-3730           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3766           AIAA PAPER 91-3767           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3803           AIAA PAPER 91-3822           AIAA PAPER 91-3844           AIAA PAPER 91-5015           AIAA PAPER 91-5020           AIAA PAPER 91-5021           AIAA PAPER 91-5022           AIAA PAPER 91-5024           AIAA PAPER 91-5022           AIAA PAPER 91-5023	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 232 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 231 p 231 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 231 p 231 p 231 p 231 p 232 p 232 p 232 p 232 p 231 p 217 p 217 p 207 p 207 p 207 p 217 p 215 p 217 p 215 p 217 p 215 p 217 p 215 p 215	A92-20000 # A92-17582 # A92-17585 * A92-17596 # A92-17597 * A92-17626 # A92-17627 # A92-17628 # A92-17628 # A92-17628 # A92-17645 # A92-17645 # A92-17645 # A92-17645 # A92-17608 # A92-17808 # A92-17817 # A92-17817 # A92-17817 # A92-17818 # A92-17820 * A92-17820 * A92-17822 # A92-17822 #
AIAA PAPER 91-3069           AIAA PAPER 91-3709           AIAA PAPER 91-3726           AIAA PAPER 91-3763           AIAA PAPER 91-3765           AIAA PAPER 91-3766           AIAA PAPER 91-3767           AIAA PAPER 91-3769           AIAA PAPER 91-3779           AIAA PAPER 91-3789           AIAA PAPER 91-3803           AIAA PAPER 91-3802           AIAA PAPER 91-3941           AIAA PAPER 91-3941           AIAA PAPER 91-5002           AIAA PAPER 91-5015           AIAA PAPER 91-5024           AIAA PAPER 91-5024           AIAA PAPER 91-5026           AIAA PAPER 91-5022           AIAA PAPER 91-5023           AIAA PAPER 91-5023           AIAA PAPER 91-5023           AIAA PAPER 91-5023	p 192 p 230 p 230 p 231 p 197 p 197 p 231 p 215 p 215 p 231 p 231 p 232 p 232 p 232 p 232 p 232 p 231 p 209 p 209	A92-20000 # A92-17582 # A92-17585 # A92-17596 # A92-17596 # A92-17597 * A92-17627 # A92-17627 # A92-17627 # A92-17628 # A92-17645 # A92-17645 # A92-17664 # A92-17664 # A92-17605 # A92-17605 # A92-17802 # A92-17818 # A92-17818 # A92-17820 * A92-17820 * A92-17823 # A92-17823 # A92-17823 #

AIAA PAPER 91-5040	P		
	n 200	492.17828	#
	μ 200	A92-17020	π
AIAA PAPER 91-5044	p 210	A92-17830 '	#
4144 PAPER 91-5048	n 210	A92-17834	#
	P 210	A32-17004	
AIAA PAPER 91-5054	p 203	A92-17837	#
AIAA PAPER 91-5055	p 203	A92-17838 *	#
ALAA DADED 01 5056	n 203	402.17830	#
AIAA FAFER 31-5050	p 200	A32-17000	. т.
AIAA PAPER 91-5057	p 203	A92-17840	#
AIAA PAPER 91-5058	p 171	A92-17841	#
AIAA PAPER 91-5060	n 171	A92-17842	#
	- 010	A00 17040 1	<u>"</u>
AIAA PAPER 91-5063	p 216	A92-17843	#
AIAA PAPER 91-5075	p 200	A92-17848	#
AIAA PAPER 91-5076	p 200	A92-17849	#
AIAA DADED 01 5001	0 210	A02 17851 1	- 4
AIAA FAFER 91-3001	p 210	A32-17031	Π.
AIAA PAPER 91-5086	p 169	A92-17854	#
AIAA PAPER 91-5091	p 172	A92-17857 *	#
AIAA PAPER 91-5102	n 212	A92-17861	#
	P 212	ADE HOUT	"
AIAA-92-0037	p 179	N92-14001	#
AIAA-92-0152	p 179	N92-13998 *	#
AIAA 02 0274	0 170	NO2 14002 *	#
AIAA-92-02/4	p 175	1192-14002	Π.
AIAA-92-0417	p 186	N92-15052	#
AIAA-92-0500	p 237	N92-14795 *	#
4144-92-0501	n 237	N92-14797 *	#
	- 105	NO2 15051 *	<i>"</i> "
AIAA-92-0647	p 185	N92-15051	#
ARL-STRUC-TM-571	p 206	N92-15073	#
			"
BRL-TR-3265	p 180	N92-14972	#
BB303122	n 187	N92-14007	#
01303122	p 107	1132-14007	π
CEAT-M5-5443/01	p 195	N92-14042	#
	- 405	100 44040	ц
CEAT-S8-6551-PARTIEL-1-PT-1	p 195	N92-14043	#
CONE-910968-10	n 238	N92-15761	#
	p 200	102 10701	"
CP-474	p 205	N92-14065	#
	- 107	NO2 15054	4
CHANFIELD-AERO-9111	p 187	N92-15054	Ħ
CTN-91-60231	p 189	N92-14009	
OTN 04 00074	- 122	NO2-14345	#
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C1N-91-602/1	p 222	1102 14040	
CTN-91-60273	p 202	N92-14060	#
CTN-91-60273	p 202 p 202	N92-14060	#
CTN-91-60271 CTN-91-60273	p 202	N92-14060	#
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393	р 202 р 191	N92-14060	# #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393	p 202 p 191	N92-14060	#
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597	p 202 p 191 p 229	N92-14060 N92-15060 * N92-15392	# # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000597	p 202 p 191 p 229 p 238	N92-14060 N92-15060 * N92-15392 N92-15761	# # ##
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740	p 202 p 191 p 229 p 238	N92-14060 N92-15060 * N92-15392 N92-15761	# # ##
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DE92-000740	p 202 p 202 p 191 p 229 p 238	N92-14060 N92-15060 * N92-15392 N92-15761	# # ## #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123	p 202 p 202 p 191 p 229 p 238 p 206	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073	# # ## #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000597 DE92-000740 DODA-AR-006-123	p 202 p 191 p 229 p 238 p 206	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073	# # ## #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DODA-AR-006-123	p 202 p 191 p 229 p 238 p 206 p 221	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270	# # ## # #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-TN91/50	p 202 p 191 p 229 p 238 p 206 p 221	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270	# # ## #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-TN91/50	p 202 p 191 p 229 p 238 p 206 p 221	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270	# # ## #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-TN91/50 DOT/FAA/CT-89/16	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053	# # ## # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-TN91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-89/29	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053	# # ## # # ##
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-89/28 DOT/FAA/CT-99/28	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15773 N92-14270 N92-15053 N92-15053 N92-15053	# # ## # # ###
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-89/29 DOT/FAA/CT-90/28 DOT/FAA/CT-90/28 DOT/FAA/CT-90/28	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053	# # ## # # ####
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/29 DOT/FAA/CT-90/28 DOT/FAA/CT-91/16	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 202	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15763 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-15053	# # ## # # ####;
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-90/28 DOT/FAA/CT-90/28 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16	p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 202 p 191	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14064	# # ## # # #####
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-189/16 DOT/FAA/CT-89/29 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16	p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 187 p 202 p 191	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-15053 N92-14034	# # ## # # #####
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-89/28 DOT/FAA/CT-91/16 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 202 p 191 p 191	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14064 N92-14034	# # ## # # ##### #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/29 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14064 N92-14034 N92-15061	# # ## # # ##### #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-89/28 DOT/FAA/CT-91/16 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CS-89/10	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 202 p 191 p 191	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-14054 N92-14034	# # ## # # ##### #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 202 p 191 p 191 p 191 p 190	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-14054 N92-14034 N92-15061 N92-14033	# # ## # # ##### # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/DS-89/10 DOT/FAA/RD-90/5	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 202 p 191 p 191 p 191	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14034 N92-14034 N92-15061 N92-14033	# # ## # # ##### # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-90/28 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 190	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-14054 N92-14034 N92-15061 N92-14033	# # ## # # ##### # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/28 DOT/FAA/CT-91/16	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 190 p 222	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15073 N92-15053 N92-15053 N92-15053 N92-15053 N92-15054 N92-14034 N92-15061 N92-14033 N92-14033	# # ## # # ##### # # #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-189/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/16	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15073 N92-14270 N92-14270 N92-15053 N92-15053 N92-15053 N92-14064 N92-14034 N92-14033 N92-14345	# # ## # # ##### # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/RD-90/5 DREP-TM-88-20 DTRC-91/017	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15761 N92-14270 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14054 N92-14033 N92-14033 N92-14033 N92-14345 N92-14966	# # ## # # ##### # # #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-189/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/17 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/17 DOT/FAA/CT-91/17 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/17 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/10 DOT/FAA/CT-91/1	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15073 N92-14270 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-14034 N92-14034 N92-14033 N92-14345 N92-14966	# # ## # # ##### # # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/RD-90/5 DREP-TM-88-20 DTRC-91/017 DTRC-91/017	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 190 p 222 p 170	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15053 N92-14270 N92-14270 N92-15053 N92-15053 N92-15053 N92-14054 N92-14034 N92-14033 N92-14033 N92-14035 N92-14966 N92-14966	# # ## # # ##### # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-191/50 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC-91/017 DTRC-91/017	p 202 p 203 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15073 N92-14070 N92-14070 N92-14053 N92-14064 N92-14034 N92-14034 N92-14033 N92-14345 N92-14366 N92-15385	# # ## # # ##### # # # # #
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/RD-90/5 DREP-TM-88-20 DTRC-91/017 DTRC/SD-CR-16/91	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15073 N92-14270 N92-15053 N92-15053 N92-15053 N92-15053 N92-15053 N92-14034 N92-14033 N92-14033 N92-14035 N92-14345 N92-14366 N92-15385	# # ## # # ##### # # # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-91/	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229 p 222	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14024 N92-15053 N92-14054 N92-14034 N92-14034 N92-14033 N92-14033 N92-14345 N92-14345 N92-14366	# # ## # # ##### # # # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-5628	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229 p 229	N92-14060 N92-15060 * N92-15060 * N92-15392 N92-15761 N92-15053 N92-14270 N92-15053 N92-15053 N92-15053 N92-14054 N92-14034 N92-14034 N92-14034 N92-14345 N92-14345 N92-14346	# # ## # # ##### # # # # #
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-1N91/50 DOT/FAA/CT-89/16 DOT/FAA/CT-91/	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 222 p 230 p 2222 p 230	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14024 N92-15053 N92-14054 N92-14034 N92-14034 N92-14033 N92-14033 N92-14966 N92-14966 N92-15385 N92-14346 *	# # ## # # ##### # # # # ###:
CTN-91-60273 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-90/28 DOT/FAA/CT-91/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-5628 E-5999 DOT/FAA/CT-91/10	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 202 p 191 p 202 p 191 p 202 p 191 p 202 p 191	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14270 N92-15053 N92-15053 N92-15053 N92-14064 N92-14034 N92-14034 N92-14035 N92-14345 N92-14345 N92-143466 N92-15191	# # ## # # ##### # # # # ####
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-5628 E-6399 E-6399 E-6399	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229 p 230 p 210 p 219	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15073 N92-14270 N92-15053 N92-14054 N92-14054 N92-14034 N92-14034 N92-14033 N92-14345 N92-14365 N92-14366 N92-15061 N92-15061 N92-15065 N92-14366	# # ## # # ##### # # # # #####
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/01 DTRC-91/017 DTRC/SD-CR-16/91 E-5628 E-5993 E-6399 E-6399 E-6399 E-6399 E-6399 E-6399 E-6399 E-6399 E-639	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 202 p 191 p 202 p 191 p 222 p 170 p 2222 p 230 p 224 p 191	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14270 N92-14270 N92-14053 N92-14053 N92-14064 N92-14034 N92-14034 N92-14033 N92-14345 N92-14345 N92-14346 N92-15191 N92-15191 N92-15191	# # ## # # ##### # # # # ######
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-5628 E-6679 E-6703 E-679 E-6704 E-705	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 222 p 230 p 214 p 191 p 191 p 191 p 229 p 191	N92-14060 N92-15060 * N92-15060 * N92-15073 N92-15073 N92-15053 N92-15053 N92-14054 N92-15053 N92-14054 N92-14034 N92-14034 N92-14034 N92-14033 N92-14345 N92-14365 N92-14366 N92-15061 N92-15065 N92-14366 N92-15065 N92-15065 N92-15067 N92-15067	# # ## # # ###### # # # # ######
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-101/50 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CT-91/6 DOT/FAA/CD-90/5 DREP-TM-88-20 DTRC-91/017 DTRC/SD-CR-16/91 E-5628 E-6399 E-6679 E-6703 E-6705	p 202 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 202 p 191 p 202 p 191 p 222 p 170 p 2222 p 230 p 224 p 223 p 224 p 191	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14270 N92-14053 N92-14053 N92-14064 N92-14034 N92-14034 N92-14033 N92-14345 N92-14345 N92-143466 N92-15385 N92-143466 N92-15385 N92-143466 N92-15385 N92-143466 N92-15385	# # ## # # ##### # # # # #######
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-6679 E-6703 E-6717 	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 202 p 191 p 191 p 190 p 222 p 170 p 229 p 222 p 234 p 222 p 234 p 222 p 234 p 222 p 234	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15073 N92-14270 N92-14270 N92-15053 N92-14054 N92-14054 N92-14054 N92-14054 N92-14054 N92-14055 N92-14055 N92-14055 N92-14055	# # ## # # ##### # # # # # ########
CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-189/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-5628 E-5993 E-679 E-6743 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-6743 E-6743 E-6743	p 202 p 203 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 191 p 202 p 191 p 202 p 191 p 222 p 170 p 222 p 230 p 224 p 230 p 224 p 230 p 222 p 230 p 223 p 230 p 221 p 191 p 229 p 238 p 206 p 221 p 191 p 197 p 202 p 238 p 206 p 221 p 197 p 202 p 237 p 238	N92-14060 N92-15060 * N92-15060 * N92-15761 N92-15761 N92-15053 N92-14270 N92-14053 N92-15053 N92-14064 N92-14034 N92-14034 N92-14033 N92-14345 N92-14345 N92-14345 N92-14346 N92-15191 * N92-15191 * N92-15191 * N92-15191 * N92-15191 * N92-15191 * N92-15191 * N92-15195 * N92-14063 * N92-14795 *	# # ## # # ##### # # # # # ########
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CTN-91-60271 CTN-91-60273 C1-1X2-TN-393 DE92-000597 DE92-000740 DODA-AR-006-123 DOT/FAA/CT-89/16 DOT/FAA/CT-89/16 DOT/FAA/CT-91/17 DTRC/SD-CR-16/91 E-6703 E-679 E-6703 E-6760 E-6761 E-6760 E-6761	p 222 p 202 p 191 p 229 p 238 p 206 p 221 p 187 p 187 p 187 p 187 p 187 p 191 p 191 p 191 p 190 p 222 p 170 p 229 p 214 p 170 p 229 p 234 p 234 p 191 p 191 p 191 p 191 p 195 p 191 p 221 p 191 p 195 p 195 p 195 p 195 p 206 p 221 p 191 p 222 p 191 p 195 p 206 p 221 p 191 p 197 p 206 p 221 p 191 p 197 p 207 p 197 p 222 p 191 p 197 p 222 p 191 p 197 p 223 p 197 p 197 p 197 p 227 p 197 p 197 p 227 p 237 p 135 p 135 p 135 p 135 p 135 p 135 p 237 p 135 p 135 p 135 p 135 p 135 p 237 p 135 p 135 p 135 p 135 p 135 p 237 p 135 p 135	N92-14060 N92-15060 * N92-15392 N92-15761 N92-15761 N92-15053 N92-14270 N92-14270 N92-14053 N92-15053 N92-14064 N92-14034 N92-14034 N92-14033 N92-14033 N92-14345 N92-14345 N92-14346 N92-15406 N92-15406 N92-15406 N92-15406 N92-15406 N92-15406 N92-15405 N92-14795 N92-14795 N92-14055 N92-14055	# # ## # # ##### # # # # # # ##########
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	p 180	N92-14973 #
ESD-TR-91-213	p 191	N92-15058 #
ETN-91-90195 ETN-92-90317 ETN-92-90319 ETN-92-90417 ETN-92-90418 ETN-92-90420 ETN-92-90432 ETN-92-90592 ETN-92-90510 ETN-92-90610 ETN-92-90610 ETN-92-90680 ETN-92-90704 ETN-92-90704 ETN-92-90798	p 225 p 225 p 187 p 237 p 196 p 196 p 196 p 205 p 239 p 196 p 196 p 196 p 196 p 196 p 196 p 196 p 195	N92-14382         #           N92-14397         #           N92-14007         #           N92-14044         #           N92-14045         #           N92-14045         #           N92-15072         #           N92-15072         #           N92-15066         #           N92-15054         #           N92-15054         #           N92-15054         #           N92-15054         #           N92-14042         #           N92-14043         #
FAA-AMS-420 FAA-AMS-420	р 169 р 170	N92-13926 # N92-13927 #
FR-721711-4-VOL-1 FR-721711-4-VOL-2	р 221 р 221	N92-14262 * # N92-14263 * #
FTD-ID(RS)T-0167-91 FTD-ID(RS)T-0170-91 FTD-ID(RS)T-0172-91 FTD-ID(RS)T-0461-91	p 170 p 170 p 229 p 170	N92-13991 # N92-13992 # N92-15367 # N92-13993 #
GITAER-91-6	p 178	N92-13995 * #
IAF PAPER ST-91-001 IAF PAPER ST-91-002 IAF PAPER ST-91-004	р 175 р 207 р 186	A92-20649 A92-20650 A92-20651
IAF PAPER 91-490	p 188	A92-18505
ICASE-91-88	р 234 р 185	N92-15658 * # N92-15047 * #
INT-PATENT-CLASS-F17C-11/00	p 228	N92-15203 *
ISBN-0-16-035630-X	n 238	NOD 44000 #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5	p 187 p 205 p 234 p 180	N92-14933 # N92-15054 # N92-14065 # N92-14673 # N92-14973 #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5	p 187 p 205 p 234 p 180 p 237	N92-14933 # N92-15054 # N92-14065 # N92-14673 # N92-14973 # N92-14791 #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007	p 230 p 187 p 205 p 234 p 180 p 237 p 211	N92-14933 # N92-15054 # N92-14065 # N92-14673 # N92-14973 # N92-14973 # N92-14791 #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007 KFF-FR	p 187 p 205 p 234 p 180 p 237 p 211 p 225	N92-14933 # N92-15054 # N92-14065 # N92-14065 # N92-14073 # N92-14973 # N92-14791 # N92-14101 #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007 KFF-FR L-16799 L-16926-VOL-2	p 235 p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235	N92-14933 # N92-15054 # N92-14065 # N92-14065 # N92-14073 # N92-14973 # N92-14791 # N92-14101 # N92-14374 * # N92-14374 * #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007 KFF-FR L-16799 L-16926-VOL-2 LR-650 LR-653 LR-655	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 196	N92-14933         #           N92-15054         #           N92-14065         #           N92-14065         #           N92-14073         #           N92-14973         #           N92-14073         #           N92-14074         #           N92-14374         #           N92-14079         #           N92-14044         #           N92-14045         #
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007 KFF-FR L-16799 L-16926-VOL-2 LR-650 LR-653 LR-655 M-676	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 196 p 211	N92-14933         #           N92-15054         #           N92-14065         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14011         #           N92-14374         *           N92-14798         *           N92-14044         *           N92-14045         *           N92-14108         *
ISBN-1-871564-31-X ISBN-92-835-0624-3 ISBN-92-835-0635-9 ISBN-92-9092-114-5 IWR-91-R-5 JPRS-USP-91-007 KFF-FR L-16799 L-16926-VOL-2 LR-650 LR-653 LR-655 M-676 MBB-UD-0584-90-PUB MBB-UD-0593-91-PUB	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 211 p 196 p 225	N92-14933         #           N92-15054         #           N92-14073         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14011         #           N92-14374         *           N92-14374         *           N92-14374         *           N92-14374         *           N92-14779         *           N92-14779         *           N92-14788         *           N92-14044         *           N92-14045         *           N92-14086         *           N92-14086         *           N92-14085         *           N92-14086         *           N92-14088         *           N92-14088         *           N92-14088         *           N92-14088         *
ISBN-1-871564-31-X         ISBN-92-835-0624-3         ISBN-92-9092-114-5         ISBN-92-9092-114-5         IWR-91-R-5         JPRS-USP-91-007         KFF-FR         L-16799         L-16926-VOL-2         LR-650         LR-655         MBB-UD-0584-90-PUB         MBB-UD-0593-91-PUB         MBB-Z-0359-90-PUB	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 237 p 196 p 211 p 225 p 196 p 211 p 225 p 237 p 196 p 225 p 239	N92-14933         #           N92-15054         #           N92-14065         #           N92-14065         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14791         #           N92-14791         #           N92-14794         #           N92-14968         *           N92-14968         #           N92-14778         #           N92-14044         #           N92-14045         #           N92-1408         *           N92-1408         #           N92-1408         #           N92-1408         #           N92-1408         #           N92-14382         #           N92-15938         #
ISBN-1-871564-31-X         ISBN-92-835-0624-3         ISBN-92-835-0635-9         ISBN-92-9092-114-5         IWR-91-R-5         JPRS-USP-91-007         KFF-FR         L-16799         L-16799         L-16755         MR-650         LR-655         MBB-UD-0584-90-PUB         MBB-UD-0593-91-PUB         MBB-Z-0359-90-PUB         MTR-11023	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 196 p 291 p 211 p 225 p 196 p 196 p 225 p 239 p 239 p 239 p 239 p 191	N92-14933         #           N92-15054         #           N92-14065         #           N92-14065         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14973         #           N92-14973         #           N92-14374         #           N92-14374         #           N92-14374         #           N92-14779         #           N92-14045         #           N92-14045         #           N92-14045         #           N92-15066         #           N92-15088         #           N92-15058         #
ISBN-1-871564-31-X         ISBN-92-835-0624-3         ISBN-92-835-0635-9         ISBN-92-9092-114-5         IWR-91-R-5         JPRS-USP-91-007         KFF-FR         L-16799         L-16926-VOL-2         LR-653         LR-655         MBB-UD-0584-90-PUB         MBB-UD-0593-91-PUB         MBB-Z-0359-90-PUB         MTR-11023         NADC-91080-60	p 187 p 205 p 234 p 180 p 237 p 211 p 225 p 179 p 235 p 237 p 196 p 237 p 196 p 225 p 196 p 225 p 239 p 191 p 206	N92-14933         #           N92-15054         #           N92-14055         #           N92-14065         #           N92-14065         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14791         #           N92-14374         *           N92-14374         *           N92-14798         #           N92-14798         #           N92-14044         #           N92-14045         #           N92-14085         #           N92-14086         #           N92-14088         #           N92-14088         #           N92-15066         #           N92-15058         #           N92-15074         #
ISBN-1-871564-31-X           ISBN-92-835-0624-3           ISBN-92-835-0635-9           ISBN-92-9092-114-5           IWR-91-R-5           JPRS-USP-91-007           KFF-FR           L-16799           L-16799           L-16926-VOL-2           LR-650           LR-653           LR-655           MBB-UD-0584-90-PUB           MBB-UD-0593-91-PUB           MBB-Z-0359-90-PUB           MTR-11023           NADC-91080-60           NAS 1.15:102687           NAS 1.15:104120           NAS 1.15:104120           NAS 1.15:104186           NAS 1.15:104186           NAS 1.15:105321           NAS 1.15:105321	p 187 p 187 p 205 p 234 p 180 p 180 p 237 p 110 p 225 p 179 p 196 p 235 p 237 p 196 p 237 p 196 p 237 p 197 p 206 p 225 p 237 p 196 p 237 p 196 p 237 p 196 p 237 p 197 p 205 p 237 p 196 p 235 p 237 p 196 p 245 p 236 p 236 p 237 p 196 p 245 p 236 p 246 p 236 p 246 p 247 p 246 p 246 p 246 p 247 p 246 p 247 p 246 p 247 p 246 p 247 p 246 p 247 p 247 p 246 p 247 p 247 p 247 p 247 p 247 p 247 p 246 p 247 p 247 p 247 p 246 p 247 p 247 p 246 p 247 p 247 p 247 p 248 p 246 p 249 p 249	N92-14933         #           N92-15054         #           N92-14073         #           N92-14073         #           N92-14073         #           N92-14973         #           N92-14973         #           N92-14973         #           N92-14973         #           N92-14974         #           N92-14374         #           N92-14374         #           N92-14374         #           N92-14378         #           N92-14779         #           N92-14798         #           N92-14045         #           N92-14045         #           N92-15066         #           N92-15058         #           N92-15058         #           N92-15058         #           N92-15058         #           N92-15076         #           N92-1507

### NAS 1.15:105347

	p 202	N92-14063 * #
NAS 1.15:105365	p 237	N92-14797 * #
NAS 1.15:105373	p 186	N92-15052 * #
NAS 1.15:105374	p 185	N92-15051 * #
NAS 1.15:105389	p 179	N92-14001 #
NAS 1 26:177592	0 195	N92-14039 * #
NAS 1.26:180083	p 178	N92-13995 * #
NAS 1.26:184263	p 221	N92-14344 * #
NAS 1.26:184829	p 191	N92-14036 * #
NAS 1.26:187316	p 185	N92-15048 * #
NAS 1.26:187616	p 236	N92-14788 #
NAS 1.26:188125	p 170	N92-13928 #
NAS 1.20.180929	p 195	N92-14038 * #
NAS 1.26:189044	p 195	N92-14037 * #
NAS 1.26:189053	p 225	N92-14374 * #
NAS 1.26:189457	p 180	N92-14969 * #
NAS 1.26:189461	p 237	N92-14/89 * #
NAS 1.20:169407 NAS 1.26:189469	p 221	N92-14066 * #
NAS 1.26:189509	p 179	N92-13999 * #
NAS 1.26:189514	p 221	N92-14262 * #
NAS 1.26:189515	p 221	N92-14263 * #
NAS 1.26:189551	p 191	N92-15060 * #
NAS 1.26:189556	p 209	N92-150// * #
NAS 1.20.109578	n 185	N92-15047 * #
NAS 1.26:4407	p 178	N92-13996 * #
NAS 1.26:4414	p 178	N92-13997 * #
NAS 1.26:4420	p 234	N92-14598 * #
NAS 1.55:3122	p 222	N92-14346 * #
NAS 1.60:3111	p 179	N92-14968 #
NAS 1.60:3181	p 211	N92-14100 #
	P 200	
NASA-CASE-NPO-17569-1-CU	p 228	N92-15203 *
NASA-CP-3122	p 222	N92-14346 * #
NASA-CR-177592	p 195	N92-14039 * #
NASA-CR-180083	p 178	N92-13995 * #
NASA-CR-184203	p 221	N92-14344 #
NASA-CR-187316	p 185	N92-15048 * #
NASA-CR-187616	p 236	N92-14788 * #
NASA-CR-188125	p 170	N92-13928 * #
NASA-CR-188929	p 225	N92-14391 * #
NASA-CH-189018	p 195	N92-14038 * #
NASA-CR-189044	n 225	N92-14374 * #
NASA-CR-189457	p 180	N92-14969 * #
NASA-CB-189461	p 237	N92-14789 * #
NASA-CR-189467	p 221	N92-14313 * #
NASA-CR-189467	p 221 p 205 p 179	N92-14313 * # N92-14066 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514	p 221 p 205 p 179 p 221	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515	p 221 p 205 p 179 p 221 p 221	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515 NASA-CR-189551	p 221 p 205 p 179 p 221 p 221 p 221 p 191	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15060 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515 NASA-CR-189551 NASA-CR-189556	p 221 p 205 p 179 p 221 p 221 p 191 p 209	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15077 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515 NASA-CR-1895515 NASA-CR-189555 NASA-CR-189556 NASA-CR-189578 NASA-CR-189578	p 221 p 205 p 179 p 221 p 221 p 191 p 209 p 234 p 185	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15067 * # N92-15658 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515 NASA-CR-189555 NASA-CR-189556 NASA-CR-189556 NASA-CR-189578 NASA-CR-189579 NASA-CR-189579	p 221 p 205 p 179 p 221 p 221 p 191 p 209 p 234 p 185 p 178	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15067 * # N92-15658 * # N92-15047 * #
NASA-CR-189467 NASA-CR-189469 NASA-CR-189509 NASA-CR-189514 NASA-CR-189515 NASA-CR-1895515 NASA-CR-189556 NASA-CR-189556 NASA-CR-189579 NASA-CR-189579 NASA-CR-4407 NASA-CR-4414	p 221 p 205 p 179 p 221 p 221 p 191 p 209 p 234 p 185 p 178 p 178	N92-14313 * # N92-14066 * # N92-14069 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15077 * # N92-15077 * # N92-15047 * # N92-13996 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189514           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189578           NASA-CR-189578           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 209 p 234 p 185 p 178 p 178 p 234	N92-14313 * # N92-14066 * # N92-1399 * # N92-14262 * # N92-14262 * # N92-15060 * # N92-15067 * # N92-15047 * # N92-13996 * # N92-13997 * #
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NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189551           NASA-CR-189578           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-1258-VOL-2           NASA-TM-102687           NASA-TM-102747           NASA-TM-102120	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 234 p 185 p 178 p 178 p 234 p 234 p 234 p 235 p 236 p 230 p 230 p 297	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15060 * # N92-15077 * # N92-15047 * # N92-13996 * # N92-13996 * # N92-14598 * # N92-14779 * # N92-15076 * # N92-15070 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189509           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189556           NASA-CR-189578           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-4414           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-102687           NASA-TM-102687           NASA-TM-102687           NASA-TM-104158	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 191 p 234 p 178 p 178 p 234 p 235 p 236 p 230 p 230 p 230 p 230 p 230 p 230	N92-14313 * # N92-14066 * # N92-13999 * # N92-14262 * # N92-14263 * # N92-15077 * # N92-15058 * # N92-15058 * # N92-13996 * # N92-13997 * # N92-14598 * # N92-14598 * # N92-15076 * # N92-15070 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189556           NASA-CR-189578           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-TM-102687           NASA-TM-104180           NASA-TM-104158           NASA-TM-104180           NASA-TM-104180	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 234 p 185 p 178 p 234 p 235 p 236 p 230 p 192 p 191 p 204 p 192 p 191 p 204 p 192 p 191 p 204 p 192 p 192 p 205 p 192 p 205 p 221 p 205 p 221 p 205 p 221 p 205 p 221 p 205 p 221 p 205 p 205 p 221 p 205 p 205	N92-14313 * # N92-14066 * # N92-13999 * N92-14262 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15077 * # N92-15076 * # N92-13997 * # N92-14598 * # N92-14598 * # N92-14779 * # N92-15076 * # N92-15070 * # N92-15075 * # N92-15079 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4402           NASA-CR-4420           NASA-TM-102687           NASA-TM-104158           NASA-TM-104158           NASA-TM-104180           NASA-TM-104180           NASA-TM-104186	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 234 p 185 p 178 p 234 p 235 p 236 p 236 p 230 p 230 p 197 p 285 p 185 p 185 p 185	N92-14313 * # N92-14066 * # N92-13099 * # N92-14262 * # N92-14263 * # N92-15060 * # N92-15060 * # N92-15067 * # N92-13096 * # N92-13097 * # N92-13097 * # N92-14598 * # N92-14598 * # N92-15076 * # N92-15076 * # N92-15070 * # N92-15070 * # N92-15070 * # N92-15070 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189514           NASA-CR-189515           NASA-CR-189515           NASA-CR-189556           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4407           NASA-CR-4420           NASA-TM-102687           NASA-TM-104186           NASA-TM-104180           NASA-TM-104180           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186<	p 221 p 205 p 179 p 221 p 221 p 221 p 221 p 221 p 234 p 185 p 178 p 234 p 235 p 236 p 236 p 230 p 230 p 197 p 235 p 185 p 185 p 185 p 185 p 185 p 197 p 211	N92-14313 ° # N92-14066 * N92-13999 * N92-14262 ° # N92-14263 * N92-15060 * N92-15060 * N92-15068 * N92-15077 * N92-15078 * N92-15079 * N92-14779 * N92-15070 * N92-15070 * N92-15070 * N92-15079 * N92-15079 * N92-15079 * N92-15079 *
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189509           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189551           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-102687           NASA-TM-102687           NASA-TM-102687           NASA-TM-104126           NASA-TM-10458           NASA-TM-10458           NASA-TM-104180           NASA-TM-104180           NASA-TM-104525           NASA-TM-104525           NASA-TM-104525           NASA-TM-105321           NASA-TM-10536	p 221 p 220 p 275 p 179 p 221 p 221 p 209 p 234 p 178 p 178 p 178 p 234 p 178 p 234 p 178 p 234 p 235 p 206 p 197 p 206 p 197 p 206 p 197 p 206 p 197 p 221	N92-14313 ° # N92-14066 ° # N92-13999 ° # N92-14262 ° # N92-14263 ° # N92-15060 ° # N92-15060 ° # N92-15077 ° # N92-15078 ° # N92-13996 ° # N92-14598 ° # N92-15070 ° # N92-15191 ° # N92-13998 ° # N92-13998 ° #
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NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189509           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-102687           NASA-TM-102687           NASA-TM-104186           NASA-TM-104180           NASA-TM-104180           NASA-TM-104321           NASA-TM-105321           NASA-TM-105336           NASA-TM-105348	$ p 221 \\ p 220 \\ p 270 \\ p 270 \\ p 221 \\ p 221 \\ p 221 \\ p 221 \\ p 209 \\ p 234 \\ p 178 \\ p 178 \\ p 178 \\ p 234 \\ p 235 \\ p 236 \\ p 230 \\ p 192 \\ p 206 \\ p 192 \\ p 230 \\ p 192 \\ p 206 \\ p 192 \\ p 200 \\ p 2$	N92-14313 * #           N92-14066 * #           N92-13999 * #           N92-13999 * #           N92-14262 * #           N92-14263 * #           N92-15058 * #           N92-15658 * #           N92-13996 * #           N92-13997 * #           N92-14598 * #           N92-14598 * #           N92-15076 * #           N92-15076 * #           N92-15070 * #           N92-15049 * #           N92-15050 * #           N92-15050 * #           N92-15049 * #           N92-15050 * #           N92-1506 * #           N92-1507 * #           N92-1508 * #           N92-1509 * #           N92-15408 * #           N92-14063 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4402           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-102687           NASA-TM-102687           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-105321           NASA-TM-105336           NASA-TM-105336           NASA-TM-105337           NASA-TM-105338           NASA-TM-105347           NASA-TM-105655	p 221 p 205 p 179 p 221 p 221 p 221 p 191 p 209 p 137 p 185 p 178 p 178 p 178 p 234 p 234 p 235 p 234 p 236 p 230 p 197 p 236 p 237 p 206 p 237 p 206 p 237 p 207 p 237 p 234 p 235 p 207 p 234 p 235 p 235 p 236 p 236 p 236 p 236 p 236 p 236 p 236 p 236 p 237 p 236 p 237 p 236 p 237 p 236 p 237 p 237	N92-14313 * #           N92-14066 * #           N92-13999 * #           N92-13999 * #           N92-14262 * #           N92-14263 * #           N92-15058 * #           N92-15558 * #           N92-13996 * #           N92-14598 * #           N92-15507 * #           N92-14598 * #           N92-15076 * #           N92-15076 * #           N92-15070 * #           N92-1500 * #           N92-1500 * #           N92-1502 * #           N92-1503 * #           N92-1504 * #           N92-1503 * #           N92-1603 * #           N92-1603 * #           N92-14797 * #
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4402           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-CR-4420           NASA-TM-102687           NASA-TM-104287           NASA-TM-104180           NASA-TM-104180           NASA-TM-104186           NASA-TM-105321           NASA-TM-105338           NASA-TM-105338           NASA-TM-105373           NASA-TM-105373           NASA-TM-105373	p 221 p 205 p 179 p 221 p 291 p 291 p 293 p 185 p 178 p 178 p 178 p 234 p 235 p 235 p 234 p 235 p 234 p 235 p 191 p 239 p 237 p 219 p 185 p 214 p 237 p 237 p 229 p 191 p 237 p 229 p 191 p 237 p 237 p 237 p 229 p 191 p 234 p 235 p 235 p 235 p 191 p 234 p 235 p 237 p 235 p 235	N92-14313 * # N92-14066 * N92-13999 * N92-14262 * N92-14263 * N92-15060 * N92-15060 * N92-15060 * N92-15068 * N92-15068 * N92-15076 * N92-14779 * N92-14779 * N92-14779 * N92-15070 * N92-14797 * N92-15052 * N92-15052 * N92-15052 * N92-15052 *
NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189509           NASA-CR-189514           NASA-CR-189515           NASA-CR-189551           NASA-CR-189551           NASA-CR-189551           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4420           NASA-CR-4420           NASA-CR-1902687           NASA-TM-102687           NASA-TM-102687           NASA-TM-104126           NASA-TM-104180           NASA-TM-104186           NASA-TM-104186           NASA-TM-104186           NASA-TM-105321           NASA-TM-105338           NASA-TM-105338           NASA-TM-105337           NASA-TM-105373           NASA-TM-105374           NASA-TM-105374           NASA-TM-105374           NASA-TM-105374	p 221 p 205 p 179 p 221 p 209 p 221 p 191 p 209 p 185 p 178 p 178 p 178 p 235 p 235 p 235 p 235 p 235 p 237 p 206 p 230 p 197 p 237 p 197 p 221 p 235 p 237 p 237 p 197 p 237 p 237 p 237 p 197 p 197 p 237 p 197 p 237 p 197 p 197 p 197 p 237 p 197 p 197 p 197 p 197 p 237 p 197 p 237 p 197 p 237 p 237 p 237 p 237 p 197 p 237 p 337 p 337	N92-14313 ° # N92-14066 * N92-13999 * N92-14262 ° # N92-14263 ° # N92-15060 ° # N92-15060 ° # N92-15078 ° # N92-15078 ° # N92-15078 ° # N92-15070 ° # N92-15050 ° # N92-15052 ° # N92-15052 ° # N92-15051 ° # N92-15052 ° # N92-15051 ° #
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NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189551           NASA-CR-189551           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-4407           NASA-CR-102687           NASA-TM-102687           NASA-TM-102687           NASA-TM-104120           NASA-TM-104158           NASA-TM-104180           NASA-TM-104186           NASA-TM-105321           NASA-TM-105336           NASA-TM-105337           NASA-TM-105373           NASA-TM-105374           NASA-TM-105389           NASA-TM-105393           NASA-TM-105393           NASA-TM-105393	p 221 p 205 p 179 p 221 p 221 p 209 p 191 p 209 p 185 p 178 p 178 p 278 p 278 p 278 p 278 p 278 p 278 p 278 p 179 p 237 p 206 p 197 p 237 p 237 p 185 p 179 p 237 p 185 p 214 p 179 p 179 p 237 p 185 p 179 p 191 p 192 p 191 p 234 p 178 p 178 p 235 p 192 p 192 p 235 p 192 p 197 p 235 p 197 p 235 p 197 p 179 p 221	N92-14313 * #         N92-14066 *         N92-13999 *         N92-14263 *         N92-14263 *         N92-15060 *         N92-15077 *         N92-15658 *         N92-1568 *         N92-15677 *         N92-1568 *         N92-1568 *         N92-15678 *         N92-15676 *         N92-15070 *         N92-15070 *         N92-15070 *         N92-15070 *         N92-1509 *         N92-1509 *         N92-1509 *         N92-1509 *         N92-15050 *         N92-15050 *         N92-15050 *         N92-15051 *         N92-15052 *         N92-15051 *         N92-15051 *         N92-15052 *         N92-15051 *         N92-14002 *         N92-14002 *
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NASA-CR-189467           NASA-CR-189469           NASA-CR-189509           NASA-CR-189519           NASA-CR-189515           NASA-CR-189515           NASA-CR-189515           NASA-CR-189578           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-189579           NASA-CR-4407           NASA-CR-4407           NASA-CR-4420           NASA-TM-102687           NASA-TM-102687           NASA-TM-104180           NASA-TM-104180           NASA-TM-104180           NASA-TM-105321           NASA-TM-105336           NASA-TM-105374           NASA-TM-105374           NASA-TM-105393           NASA-TP-3181           NLR-TP-30084-U           NRC-TR-ENG-007           NTSB/AAR-91/01/	p 221 p 205 p 179 p 221 p 209 p 231 p 209 p 191 p 209 p 178 p 178 p 178 p 278 p 278 p 278 p 278 p 278 p 278 p 278 p 279 p 277 p 206 p 237 p 279 p 271 p 279 p 271 p 279 p 271 p 278 p 277 p 279 p 277 p 277 p 277 p 279 p 277 p 277	N92-14313 • #         N92-14066 • #         N92-13999 • #         N92-14263 • #         N92-14263 • #         N92-15060 • #         N92-15068 • #         N92-15658 • #         N92-1568 • #         N92-1479 • #         N92-1507 • #         N92-1505 • #         N92-14002 • #         N92-14002 • #         N92-14008 • #         N92-14060 #         N92-14000 #         N92-14000 #         N92-14000 #         N92-14000 #         N92-14000 #         N92-14000 #

OTN-021385	p 225	N92-14382	#
PB91-179234	n 169	N92-13926	#
PB91-202051	n 170	N92-13927	#
PR91-910405	0 187	N92-14006	π #
PB91-910407	n 187	N92-15055	#
1031-310407	p 107	1152-15055	π
RAE-TM-FS(F)-632-REV-ISSUE-1	p 187	N92-14007	#
REPT-3/1990	p 239	N92-15938	#
REPT-5416-B	p 187	N92-14006	#
REPT-91RC13695	p 225	N92-14391	* #
RI/RD-91-230	p 225	N92-14391	• #
RPT/F0094.93A	p 225	N92-14374	#
R90-916528-80	p 195	N92-14037	• #
SAND-91-1124	p 229	N92-15392	#
SCT 0088 44	n 101	N02-16061	#
	p 100	N02 14000	<i>π</i>
SC1-91HH-26	p 190	N92-14033	#
SR90-R-5253-76	p 229	N92-15385	#
TP-499	p 236	N92-14788	• #
TP-9983	p 189	N92-14009	
UDH-TH-90-108	p 187	N92-15053	#
US-PATENT-APPL-SN-545236	p 228	N92-15203	,
US-PATENT-CLASS-62-461	p 228	N92-15203	
US-PATENT-CLASS-624-3.2	p 228	N92-15203	
US-PATENT-CLASS-624-467	p 228	N92-15203 *	
US-PATENT-CLASS-624-500	p 228	N92-15203 *	
US-PATENT-CLASS-624-51.2	p 228	N92-15203 *	
US-PATENT-5,063,747	p 228	N92-15203 *	
WL-TB-91-2051	n 202	N92-14059	#
WI_TR-01-2067	n 197	N02.15060	#
WI-TD-01-3079-V/OL-3	P 13/	N02-14399	#
WL-IN-91-30/8-VUL-3	h 552	1192-14300	Ħ

WRDC-TR-90-3052-VOL-2 ..... p 235 N92-14779 \* #

### REPORT NUMBER INDEX

# **ACCESSION NUMBER INDEX**

### AERONAUTICAL ENGINEERING / A Continuing Bibliography (Supplement 277)

April 1992

### **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.

A92-17288	p 214	A92-17857 * #	p 172
A92-17289	p 214	A92-17861 #	p 212
A92-17290	p 214	A92-17876	p 19?
A92-17292	p 215	A92-17950	n 216
A92-17293	p 215	AB2 18002	n 212
A92-17294	p 169	A92-10002	P 212
A92-17348	p 215	A92-18005	p 216
A92-17349	p 209	A92-18100	p 207
A92-17414	p 215	A92-18172	p 188
A92-17422	p 188	A92-18198	p 200
A92-17429 *	p 170	A92-18292	p 201
A92-17501	p 170	A92-18352	p 1/2
A92-17502	p 171	A92-18353	p 1/2
A92-17503	p 200	A92-18358	p 1/2
A92-17562	p 215	A92-18361	p 1/2
A92-17582 #	p 230	A92-18362	p 216
A92-17585 *#	p 230	A92-18363	p 1/2
A92-17594 *#	p 231	A92-18365	p 1/2
A92-17596 #	p 197	A92-1836/	p 1/2
A92-17597 *#	p 197	A92-18309	p 210
A92-17605 #	p 231	A92-18372 *	p 1/2
A92-17608 #	p 231	A92-18373	p 210
A92-17626 #	p 231	A92-18375	p 207
A92-17627 #	p 215	A92-18377	p 216
A92-17628 #	p 197	A92-18385	p 172
A92-17629 *#	p 231	A92-18367	p 1/3
A92-17637 *#	p 231	A92-18388	p 235
A92-17645 #	p 232	A92-18403	p 203
A92-17654 #	p 232	A92-18484	p 232
A92-17664 #	p 232	A92-10402	p 100
A92-17802 #	p 209	A92-10303	p 100
A92-17813 *#	p 232	A92-10001	p 204
A92-17817 #	p 171	A92-10000	p 204
A92-17818 #	p 206	A92-10010	p 204
A92-17819 *#	p 207	A92-10011	p 10/
A92-17820 *#	p 209	A92-10013	p 204
A92-17822 #	p 171	A92-10010	p 202
A92-17823 #	p 215	A02-10020	p 204
A92-17824 #	p 209	A02-10021	p 204
A92-17825 *#	p 210	A02-10022	p 204
A92-17826 #	p 171	A92-10023	n 204
A92-17828 #	p 200	A02-18625 *	n 204
A92-17830 *#	p 210	A02 18626	p 204
A92-17834 #	p 210	A02 18680	n 173
A92-17837 *#	p 203	A02-10000 *	0 225
A92-17838 *#	p 203	A02-10005	n 173
A92-17839 *#	p 203	A92-10703	p 173
A92-17840 * #	p 203	A92-10/70	n 173
A92-17841 #	p 171	A92-18830	n 216
A92-17842 #	p 171	A02-18809	n 212
A92-17843 *#	p 216	A02-18000	0 172
A92-17848 #	p 200	A92-18000	0 230
A92-17849 #	p 200	A02-18027	n 109
A92.17851 * #	n 210	A02-1000/	n 210
A00 17054 #	p 160	. 402-19001	p 210
A92-17854 #	p 169	A92-19006	P 1/3

A92-19084		p 232
A92-19091		D 216
A02 10004		
A92-19034		P 232
A92-19103		p 204
402-10107		0 205
A32-10107		0.000
A92-19110		p 1/4
A92-19202		p 217
102 10202		- 100
A92-19211		p 188
A92-19214		p 188
102 10214		- 100
A92-19216		p 168
A92-19231		p 217
400 40054		- 100
A92-19251		b 188
A92-19252		p 198
402 10257		0.210
M32-19201		P 210
A92-19273		p 205
A02-10275		n 201
A02-10270		P 201
A92-19278		p 189
A92-19279		n 189
102 10210		- 000
A92-19386		p 233
A92-19405		p 233
400 10406		- 222
A92-19400		p 200
A92-19463		p 217
492.10605	*	n 233
A32-10000		200
A92-19606		p 192
A92-19609	*	p 233
100 10000		- 174
A92-19611		p 174
A92-19618		p 217
402 10610	*	n 222
P95-18018		P 200
A92-19677		p 217
492-19696		n 201
A32-13030		0.01
A92-19754	•	p 212
A92-19760		p 212
102 10700		- 010
A92-19767		p 213
A92-19796		p 213
A02.10700		0 212
A92-19/99		P 213
A92-19812		p 217
402-10817		n 213
A32-13017		P 210
A92-19818		p 217
A92-19819		o 192
100 10010		- 010
A92-19820		p 213
A92-19828	•	p 213
100 10004		0 102
A92-19924		p 1az
A92-19925		p 192
A02.10077		n 218
A92-19911		P 210
A92-19982		n 235
A92.19986		0 218
A92-19986		p 218
A92-19986 A92-19988		р 218 р 218
A92-19986 A92-19988 A92-20000	#	р 218 р 218 р 218 р 192
A92-19986 A92-19988 A92-20000	#	p 218 p 218 p 192 p 192
A92-19986 A92-19988 A92-20000 A92-20023	#	p 218 p 218 p 192 p 169
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024	#	p 218 p 218 p 192 p 169 p 186
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025	#	p 218 p 218 p 192 p 169 p 186 p 198
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20024	#	p 218 p 218 p 192 p 169 p 186 p 198
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025 A92-20126	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025 A92-20126 A92-20127	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 186 p 186
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025 A92-20126 A92-20126	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 186 p 186
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025 A92-20126 A92-20127 A92-20128	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 186 p 186 p 230
A92-19986 A92-19988 A92-20003 A92-20023 A92-20023 A92-20025 A92-20126 A92-20127 A92-20128 A92-20128	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 186 p 230 p 186
A92-19986 A92-19988 A92-20000 A92-20023 A92-20024 A92-20025 A92-20126 A92-20126 A92-20128 A92-20128 A92-20120	#	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 186 p 230 p 186 p 230 p 230 p 213
A92-19986 A92-19988 A92-20020 A92-20023 A92-20025 A92-20126 A92-20126 A92-20127 A92-20128 A92-20129 A92-20130	#	<ul> <li>p 218</li> <li>p 218</li> <li>p 192</li> <li>p 169</li> <li>p 186</li> <li>p 198</li> <li>p 186</li> <li>p 186</li> <li>p 230</li> <li>p 186</li> <li>p 230</li> <li>p 186</li> <li>p 230</li> <li>p 186</li> <li>p 213</li> </ul>
A92-19986 A92-19988 A92-20000 A92-20023 A92-20023 A92-20025 A92-20126 A92-20126 A92-20128 A92-20128 A92-20130 A92-20130	#	p 218 p 218 p 192 p 169 p 196 p 198 p 196 p 198 p 186 p 230 p 186 p 213 p 213 p 213 p 192
A92-19986 A92-20000 A92-20000 A92-20023 A92-20025 A92-20126 A92-20127 A92-20127 A92-20128 A92-20129 A92-20130 A92-20136	# •	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192
A92-19986 A92-19988 A92-20000 A92-20023 A92-20023 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20130 A92-20130 A92-20130	# •	p 218 p 218 p 192 p 169 p 196 p 198 p 198 p 196 p 198 p 186 p 230 p 230 p 213 p 213 p 192 p 192 p 192
A92-19986 A92-20000 A92-20023 A92-20023 A92-20024 A92-20126 A92-20126 A92-20127 A92-20128 A92-20128 A92-20129 A92-20134 A92-20136 A92-20136	# •	p 218 p 218 p 189 p 186 p 198 p 198 p 198 p 198 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 192 p 169
A92-19986 A92-20000 A92-20023 A92-20026 A92-20026 A92-20126 A92-20126 A92-20128 A92-20129 A92-20130 A92-20130 A92-20130 A92-20134 A92-20146	# •	p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 192 p 169 p 169
A92-19986 A92-20000 A92-20023 A92-20023 A92-20025 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20130 A92-20130 A92-20136 A92-20145 A92-20145	# •	p 218 p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 169 p 169 p 233
A92-19986 A92-20000 A92-20023 A92-20023 A92-20025 A92-20126 A92-20126 A92-20127 A92-20128 A92-20130 A92-20130 A92-20130 A92-20134 A92-20146 A92-20146		p 218 p 218 p 192 p 169 p 186 p 198 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 192 p 169 p 169 p 233
A92-19986 A92-20000 A92-20023 A92-20023 A92-20025 A92-20126 A92-20126 A92-20127 A92-20128 A92-20129 A92-20130 A92-20130 A92-20136 A92-20146 A92-20146 A92-20120		p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 186 p 213 p 186 p 213 p 192 p 192 p 169 p 169 p 169 p 174
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20129 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146	# •	p 218 p 218 p 218 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 233 p 192 p 169 p 233 p 174
A92-19986 A92-19986 A92-20000 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20127 A92-20128 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20146 A92-20201	*	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 169 p 169 p 169 p 174 p 193
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20202	# •	p 218 p 218 p 218 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 192 p 192 p 169 p 133 p 174 p 193 p 193
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20127 A92-20128 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20146 A92-20201 A92-20202 A92-20202	* *	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 169 p 169 p 169 p 169 p 174 p 193 p 193 p 205
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20150 A92-20202 A92-20202	# •	p 218 p 218 p 218 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 192 p 169 p 130 p 174 p 193 p 193 p 2054
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20127 A92-20128 A92-20130 A92-20130 A92-20130 A92-20136 A92-20146 A92-20146 A92-20146 A92-20201 A92-20201 A92-20202 A92-20202 A92-20204 A92-20205	*	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 213 p 192 p 192 p 169 p 169 p 169 p 169 p 174 p 193 p 193 p 193 p 205 p 174
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20202 A92-20202 A92-20203 A92-20204 A92-20206	# •	p 218 p 218 p 218 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 233 p 192 p 169 p 133 p 174 p 193 p 205 p 174 p 218
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20127 A92-20128 A92-20127 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20146 A92-20201 A92-20201 A92-20201 A92-20202 A92-20200 A92-20205 A92-20205 A92-20205	# •	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 192 p 169 p 174 p 192 p 192 p 192 p 192 p 192 p 192 p 193 p 192 p 192 p 193 p 192 p 192 p 198 p 199 p 199 p 199 p 199 p 199 p 192 p 192 p 192 p 192 p 192 p 192 p 192 p 192 p 192 p 193 p 193 p 193 p 193 p 205 p 174 p 205
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20202 A92-20203 A92-20203 A92-20204 A92-20206 A92-20206 A92-20206	* * * * *	p 218 p 218 p 218 p 169 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 192 p 192 p 192 p 192 p 193 p 174 p 193 p 205 p 174 p 205
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20127 A92-20128 A92-20127 A92-20130 A92-20130 A92-20130 A92-20130 A92-20146 A92-20146 A92-20146 A92-20204 A92-20200 A92-20206 A92-20205 A92-20207 A92-20208	*	p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 192 p 192 p 192 p 169 p 169 p 169 p 169 p 169 p 174 p 193 p 193 p 205 p 174 p 218 p 205 p 193
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20208 A92-20209 A92-20209 A92-20209 A92-20206 A92-20207 A92-20207 A92-20207 A92-20208	*	p 218 p 218 p 218 p 169 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 192 p 192 p 169 p 133 p 174 p 193 p 205 p 174 p 205 p 174 p 205 p 174 p 205 p 193 p 193
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20127 A92-20127 A92-20128 A92-20127 A92-20130 A92-20130 A92-20130 A92-20146 A92-20146 A92-20146 A92-20201 A92-20201 A92-20202 A92-20204 A92-20205 A92-20206 A92-20208 A92-20208 A92-20208	*	p 218 p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 192 p 192 p 192 p 169 p 174 p 193 p 193 p 205 p 174 p 218 p 192 p 192 p 192 p 192 p 193 p 193
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20208 A92-20208 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209	# • •	p 218 p 218 p 189 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 189 p 189 p 169 p 169 p 169 p 169 p 169 p 174 p 193 p 205 p 218 p 218 p 192 p 192 p 192 p 192 p 192 p 192 p 198 p 199 p 215 p 217 p 199 p 215 p 217 p 219 p 218 p 218 p 219 p 219 p 218 p 218 p 218 p 219 p 218 p 218 p 219 p 219 p 218 p 219 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 219 p 218 p 219 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 218 p 218 p 219 p 218 p 218 p 218 p 218 p 219 p 218 p 217 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 218 p 217 p 218 p 219 p 217 p 218 p 219 p 217 p 219 p 219 p 219 p 219 p 217 p 219 p 217 p 219 p 218 p 217 p 218 p 219 p 218 p 219 p 219 p 218 p 218
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20127 A92-20127 A92-20128 A92-20127 A92-20130 A92-20130 A92-20130 A92-20146 A92-20146 A92-20146 A92-20201 A92-20201 A92-20202 A92-20204 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208	# • •	<pre>p 218 p 218 p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 213 p 192 p 192 p 192 p 169 p 169 p 169 p 174 p 218 p 205 p 174 p 218 p 205 p 193 p 193 p 193 p 193 p 194</pre>
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20208 A92-20208 A92-20208 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209	# • •	p 218 p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 189 p 189 p 169 p 169 p 169 p 169 p 169 p 174 p 193 p 205 p 218 p 218 p 192 p 192 p 192 p 192 p 192 p 198 p 199 p 198 p 198 p 198 p 199 p 198 p 199 p 198 p 199 p 215 p 193 p 194 p 215 p 217 p 193 p 217 p 217 p 218 p 217 p 217 p 218 p 217 p 217 p 218 p 218 p 217 p 218 p 217 p 218 p 218
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20127 A92-20128 A92-20129 A92-20130 A92-20130 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20205 A92-20201 A92-20205 A92-20206 A92-20206 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20212 A92-20213	# •	p 218 p 218 p 218 p 192 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 213 p 192 p 192 p 192 p 169 p 169 p 169 p 169 p 169 p 174 p 193 p 193 p 193 p 193 p 193 p 193 p 174 p 218
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20208 A92-20208 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20209 A92-20201 A92-20211 A92-20213 A92-20213 A92-20214	# •	p 218 p 218 p 218 p 169 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 189 p 169 p 169 p 169 p 169 p 174 p 193 p 205 p 174 p 205 p 174 p 205 p 174 p 218 p 174 p 174 p 174 p 174 p 174
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20128 A92-20129 A92-20130 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20202 A92-20202 A92-20202 A92-20206 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20212 A92-20213 A92-20213 A92-20213 A92-20213 A92-20213	# • •	P 218 P 218 P 218 P 218 P 169 P 186 P 186 P 186 P 213 P 186 P 213 P 186 P 213 P 192 P 169 P 233 P 174 P 193 P 205 P 218 P 205 P 218 P 205 P 218 P 205 P 218 P 218 P 218 P 205 P 218 P 218 P 218 P 218 P 217 P 218 P
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20126 A92-20126 A92-20126 A92-20128 A92-20128 A92-20128 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20204 A92-20204 A92-20204 A92-20206 A92-20207 A92-20208 A92-20207 A92-20208 A92-20207 A92-20208 A92-20207 A92-20208 A92-20207 A92-20208 A92-20207 A92-20208 A92-2019 A92-2019 A92-2019 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-2018 A92-20208 A92-2	# • •	p 218 p 218 p 218 p 189 p 189 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 189 p 189 p 189 p 189 p 192 p 169 p 193 p 174 p 205 p 174 p 205 p 174 p 218 p 174 p 278 p 174 p 278
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20128 A92-20129 A92-20130 A92-20130 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20200 A92-20200 A92-20200 A92-20200 A92-20200 A92-20208 A92-20208 A92-20208 A92-20208 A92-20213 A92-20213 A92-20213 A92-20215 A92-20216	* • • • •	
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A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20128 A92-20129 A92-20130 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20205 A92-20206 A92-20206 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20218 A92-20218 A92-20218 A92-20218 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216 A92-20216	*	
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20026 A92-20127 A92-20128 A92-20128 A92-20127 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20145 A92-20204 A92-20204 A92-20205 A92-20208 A92-20208 A92-20208 A92-20211 A92-20211 A92-20214 A92-20215 A92-20218	*	p 218 p 218 p 218 p 169 p 169 p 186 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 189 p 189 p 189 p 189 p 189 p 192 p 169 p 193 p 174 p 205 p 174 p 205 p 174 p 218 p 193 p 174 p 218 p 219 p 218 p 219 p 215 p 217 p 217 p 215 p 217 p 217 p 217 p 218 p 218 p 213 p 219 p 216 p 213 p 219 p 216 p 213 p 219 p 215 p 217 p 217
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20128 A92-20129 A92-20130 A92-20130 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20205 A92-20202 A92-20208 A92-20208 A92-20208 A92-20208 A92-20208 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218 A92-20217 A92-20217 A92-20217 A92-20217 A92-20217	# • • • • •	
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20026 A92-20127 A92-20128 A92-20128 A92-20128 A92-20130 A92-20130 A92-20130 A92-20130 A92-20146 A92-20145 A92-20145 A92-20204 A92-20204 A92-20205 A92-20208 A92-20208 A92-20208 A92-20208 A92-20201 A92-20211 A92-20211 A92-20214 A92-20215 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218	# • • •	p 218 p 218 p 218 p 169 p 169 p 186 p 186 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 230 p 186 p 213 p 192 p 169 p 169 p 169 p 174 p 205 p 174 p 205 p 174 p 218 p 174 p 218 p 219 p 174 p 218 p 219 p 174 p 218 p 219 p 218 p 219 p 213 p 192 p 218 p 219 p 219 p 219 p 217 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 218 p 219 p 217 p 218 p 219 p 217 p 219 p 217 p 219 p 217 p 219 p 217 p 219 p 217 p 217
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20128 A92-20129 A92-20130 A92-20130 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20205 A92-20202 A92-20202 A92-20208 A92-20208 A92-20208 A92-20208 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218 A92-20216 A92-20217 A92-20217 A92-20217 A92-20301 A92-20301	# • • • •	
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20128 A92-20130 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20145 A92-20145 A92-20204 A92-20204 A92-20205 A92-20208 A92-20207 A92-20208 A92-20201 A92-20211 A92-20211 A92-20214 A92-20215 A92-20218 A92-20218 A92-20218 A92-20218 A92-20304 A92-20306	# • • • • • • • • •	
A92-19986 A92-19986 A92-20020 A92-20020 A92-20024 A92-20024 A92-20126 A92-20127 A92-20128 A92-20129 A92-20134 A92-20134 A92-20134 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20146 A92-20205 A92-20202 A92-20202 A92-20206 A92-20208 A92-20208 A92-20208 A92-20218 A92-20218 A92-20218 A92-20218 A92-20218 A92-20301 A92-20304 A92-20304 A92-20304	*	
A92-19988 A92-19988 A92-20020 A92-20020 A92-20024 A92-20024 A92-20127 A92-20128 A92-20128 A92-20128 A92-20130 A92-20130 A92-20130 A92-20130 A92-20145 A92-20145 A92-20145 A92-20204 A92-20204 A92-20205 A92-20208 A92-20208 A92-20208 A92-20201 A92-20201 A92-20211 A92-20212 A92-20214 A92-20215 A92-20214 A92-20215 A92-20218 A92-20218 A92-20218 A92-20304 A92-20306 A92-20324	# • • •	

A92-20356 A92-20378 • A92-20483 A92-20483 A92-20483 A92-20649 A92-20650 A92-20720 A92-20720 A92-20726 • A92-20727 A92-20729 • A92-20735 • A92-20735 • A92-20735 • A92-20735 • A92-20736 A92-20738 • A92-20738 • A92-20738 • A92-20738 • A92-20738 • A92-20742 A92-20742 A92-20742 A92-20746 A92-20760 A92-20764 A92-20764 A92-20764 A92-20764	p 219  p 175  p 175  p 205  p 175  p 207  p 186  p 186  p 186  p 187  p 175  p 176  p 176  p 219  p 176  p 219  p 176  p 219  p 176  p 219  p 176  p 176  p 176  p 219  p 176  p 176  p 219  p 176  p 219  p 176  p 219  p 176  p 219  p 176  p 176  p 219  p 2
N92-13926 # N92-13927 # N92-13927 # N92-13930 * N92-13930 * N92-13930 * N92-13933 * N92-13933 * N92-13938 * N92-13939 * N92-13948 * N92-13950 * N92-13950 * N92-13950 * N92-13955 * N92-13955 * N92-13956 * N92-13956 * N92-13959 * N92-13969 * N92-13967 * N92-13979 * N92-13985 * N92-13995 * N92-13995 * N92-13995 * N92-13995 * N92-13995 * N92-13995 * N92-13996 * N92-13996 * N92-13999 * N92-14007 * N92-14007 * N92-14007 * N92-14007 * N92-14025 * N92-14027 *	p 169 p 170 p 170 p 170 p 193 p 193 p 193 p 193 p 201 p 201 p 201 p 194 p 200 p 176 p 176 p 176 p 176 p 176 p 194 p 194 p 220 p 177 p 194 p 194 p 209 p 177 p 202 p 177 p 207 p 170 p 170 p 170 p 178 p 178 p 179 p 179 p 179 p 179 p 189 p 189 p 189 p 180 p 190 p 207

N92-	14029	#	p 190
N92-	14033	#	p 190 p 191
N92-	14036	• #	p 191
N92-	14037	•#	p 195
N92	14039	•#	p 195
N92-	14042	#	p 195
N92-1	14043	#	p 195 n 196
N92-	14045	#	p 196
N92-	14047	#	p 198
N92-	14048	# #	p 198 p 198
N92-	4050	#	p 199
N92-1	14051	#	p 199
N92-	14052	#	p 199
N92-1	4054	#	p 199
N92-1	14055	#	p 199
N92-1	4058	#	p 200
N92-1	4059	#	p 202
N92-1	14060	• #	p 202 n 202
N92-1	4064	#	p 202
N92-1	4065	#	p 205
N92-1	4066	`# *#	p 205 p 210
N92-	14101	#	p 211
N92-1	14103	#	p 211
N92-1	4210	*#	p 211
N92-1	14217	*#	p 220
N92-1	14262	*#	p 221
N92-1	4203	#	p 221
N92-	14309	#	p 221
N92-	14310	*#	p 221
N92-	14344	•#	p 221
N92-	14345	#	p 222
N92-1	14346	# #	p 222
N92-	14349	•#	p 222
N92-	14350	#	p 222
N92-	14351	•#	p 222 p 223
N92-	4356	•#	p 223
N92-1	14357	*#	p 223
N92-	14361	•#	p 223
N92-	14362	*#	p 224
N92-1	14363	*#	p 224
N92-	14366	*#	p 224
N92-	4367	*#	p 224
N92 N92	14370	*#	p 224 n 224
N92-1	14373	•#	p 225
N92-1	14374	*#	p 225
N92-	14386	# #	p 225 p 225
N92-	14391	*#	p 225
N92-	14397	#	p 225
N92-	14411	# #	p 214
N92-	14413	#	p 214
N92-	14414 14424	# #	p 226
N92-	14425	#	p 226
N92-	14428	#	p 226
N92-	14431	*#	p 226 p 234
N92-	14673	#	p 234
N92-	14674	#	p 234
N92-	14779	•#	p 234
N92-	14780	#	p 236
N92-	14782	*#	p 236
N92-	14/83 14784	-# •#	p 236
N92-	14785	•#	p 236

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### N92-14786

N92-14977 N92-14980

N92-14981

N92-14984 N92-14985 N92-14986

N92-14987 N92-14990 N92-14992 N92-14993

N92-14994

N92-14995 N92-14996 N92-14998

N92-14999 N92-15000 N92-15001 N92-15002

N92-15003 N92-15004 N92-15005

N92-15006

N92-15008 N92-15009 N92-15013 N92-15014 N92-15016 N92-15017

N92-15020 N92-15021 N92-15025 N92-15027 N92-15029

N92-15030 N92-15031 N92-15032

N92-15033 N92-15035 N92-15037 N92-15039 \*

N92-15042 # N92-15043 # N92-15045 # N92-15047 \* N92-15048 \* N92-15049 \* N92-15050 \*

N92-15051 \*# N92-15052 \*# N92-15053 #

N92-15054 N92-15055

N92-15058

N92-15065 N92-15066 N92-15067 N92-15068 N92-15069

N92-15070 \* N92-15072 # N92-15073 #

N92-15074

N92-15075 \* # N92-15076 \* #

N92-15076 # N92-15077 \*# N92-15083 \*#

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N92-15060 N92-15061

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p 211 p 211 # #

p 180 ### p 211 p 181

p 181

p 181 p 181

p 181 р 181 р 182

p 182 p 182 p 182

p 208 p 182 p 208

p 208 p 208 p 227

p 227 p 182 p 183 p 183 p 208 p 238 p 183 p 183 p 183 p 183

p 183 p 183 p 208 p 184 p 227 p 227

p 227 p 184 p 184

p 227 p 184

p 211

p 184 p 184 p 184 p 184 p 184 p 209

p 185 p 185 p 185

p 185 p 185 p 185 p 185 p 186 p 186 p 187

p 187 p 187 p 191

p 191 p 191 p 196 p 196 p 196 p 196 p 196

p 205 p 206 p 206

р 206 р 206

p 209 p 227 p 228

р 228 p 228 p 228 p 228 p 228 p 214

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N92-14786 *#	p 236	N92-15203 *	p 228
N92-14786 * # N92-14787 * # N92-14788 * # N92-14789 * # N92-14791 # N92-14795 * # N92-14797 * # N92-14793 #	p 236 p 236 p 236 p 237 p 237 p 237 p 237 p 237 p 237 p 237 p 237	N92-15203 * N92-15272 # N92-15365 # N92-15385 # N92-15392 # N92-15402 * N92-15406 * N92-15658 * N92-15761 #	p 228 p 229 p 229 p 229 p 229 p 229 p 229 p 229 p 230 p 234 p 238
N92-14925 # N92-14927 # N92-14933 # N92-14966 # N92-14968 * N92-14968 * N92-14969 * N92-14972 # N92-14973 # N92-14975 #	p 238 p 238 p 238 p 170 p 179 p 180 p 180 p 180 p 180 p 180 p 180 p 180 p 180 p 180	N92-15870 *# N92-15877 *# N92-15937 # N92-15938 #	p 234 p 212 p 238 p 239

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