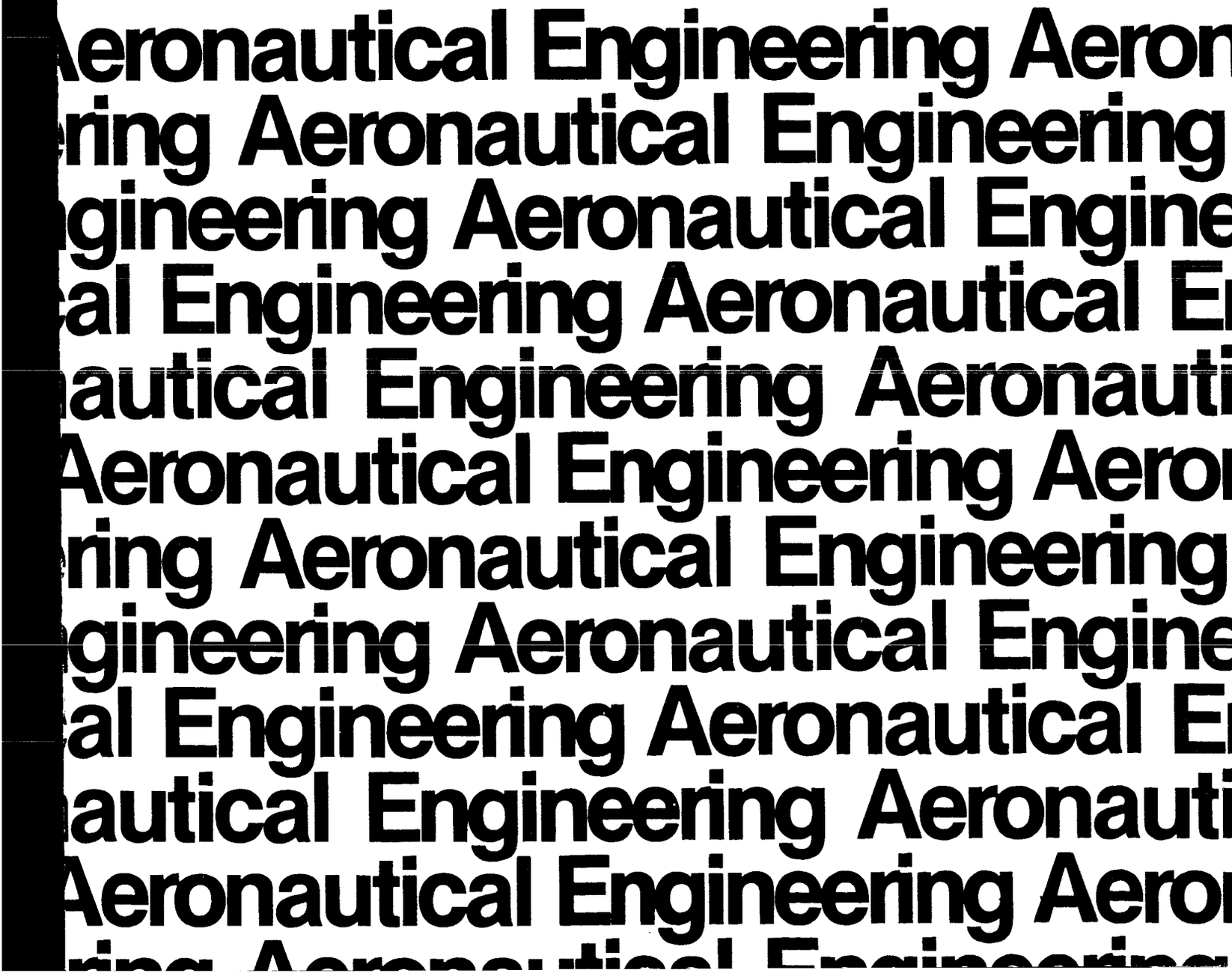
NASA

# Aeronautical Engineering
A Continuing Bibliography with Indexes

NASA SP-7037(219)
November 1987

National Aeronautics and Space Administration



## ACCESSION NUMBER RANGES

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

| | |
|---|---|
| STAR (N-10000 Series) | N87-25267 — N87-26853 |
| IAA (A-10000 Series) | A87-42685 — A87-47019 |

This bibliography was prepared by the NASA Scientific and Technical Information Facility operated for the National Aeronautics and Space Administration by RMS Associates.

NASA SP-7037(219)

# AERONAUTICAL ENGINEERING

## A CONTINUING BIBLIOGRAPHY WITH INDEXES

## (Supplement 219)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in October 1987 in

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

NASA
Scientific and Technical Information Division 1987
National Aeronautics and Space Administration
Washington, DC

This supplement is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161, price code A08.

# INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 586 reports, journal articles and other documents originally announced in October 1987 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

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

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

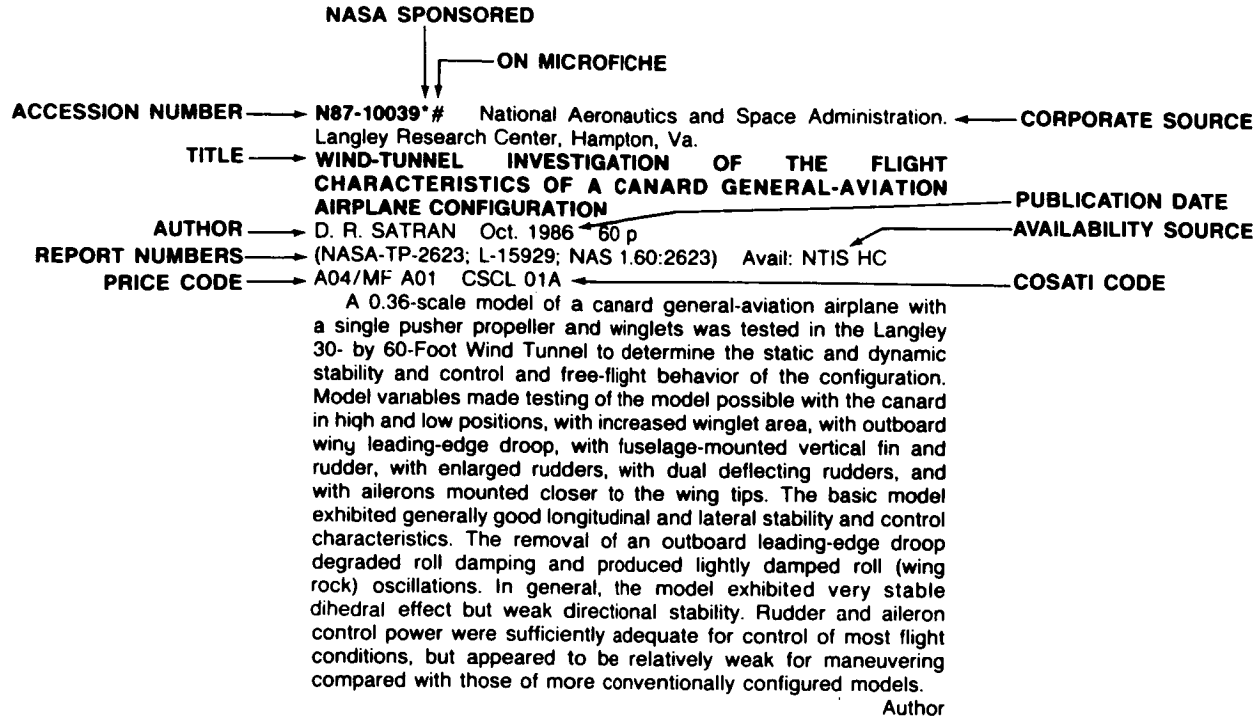
Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cummulative index will be published.

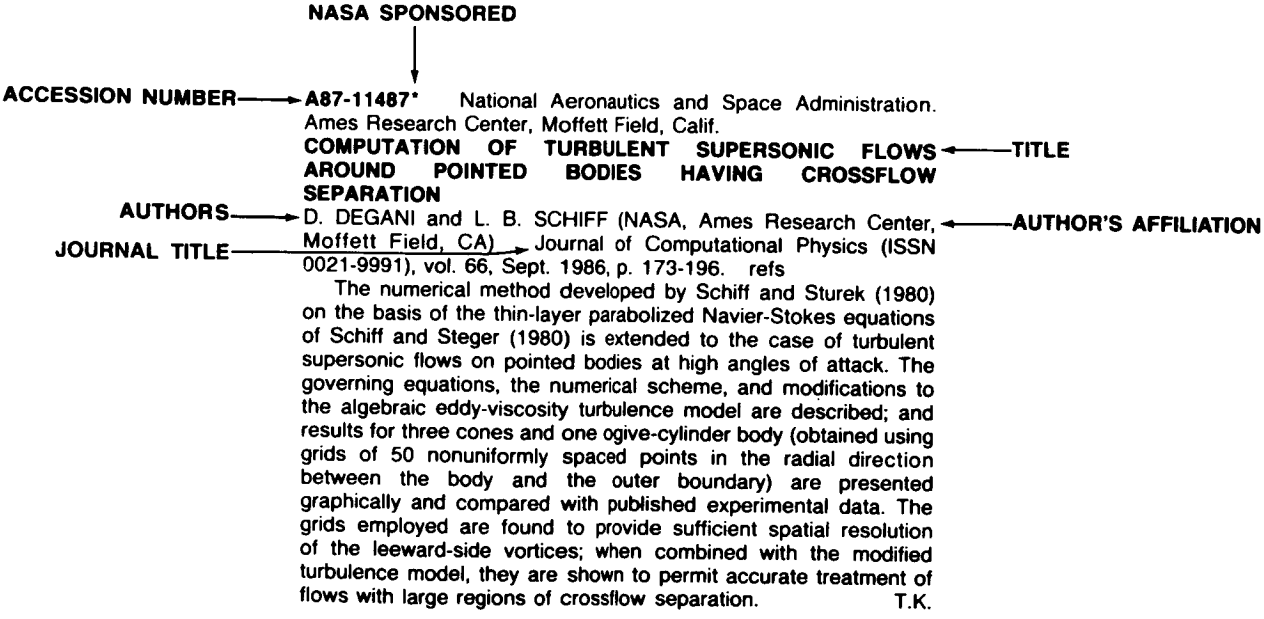
Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

# TABLE OF CONTENTS

# TYPICAL REPORT CITATION AND ABSTRACT




# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



# AERONAUTICAL ENGINEERING

*A Continuing Bibliography (Suppl. 219)*

NOVEMBER 1987

## 01

## AERONAUTICS (GENERAL)

**A87-42857**
**AIRCRAFT STRUCTURAL MAINTENANCE RECOMMENDATIONS BASED ON FRACTURE MECHANICS ANALYSIS**

ANTHONY G. DENYER (Rockwell International Corp., Los Angeles, CA) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 291-310. refs

The implementation of the Force Management phase of the Aircraft Structural Integrity program for a USAF aircraft is discussed. The case study considered demonstrates use of linear elastic fracture mechanics to show that the T-39 wing performs to the structural criteria defined by the MIL-STD-1530 and MIL-A-83444. The initial task of the fracture mechanics analysis was the durability and damage tolerance assessment (DATA) of the structure, based on the current service usage, the result of which were used to make structural life-enhancement recommendations. The DATA was followed by the individual aircraft tracking program the purpose of which is to compute the rate at which the available structural life of an individual aircraft is being used and to estimate the remaining structural life. The economic crack growth procedure used, both to ascertain the accumulated damage based on the flight records and to estimate the remaining structural life, is described. I.S.

**A87-43401#**
**HELICOPTER ACTIVITIES IN GERMANY**

VOLKER VON TEIN (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 22 p.

After a short presentation of the history of helicopter technology in Germany, the current activities are described. In this context an update on the BO 105 and BK 117 programs is given. Next, statistical information about all types of helicopters operating in Germany and the related infrastructure is presented. Then the most important technology programs covering rotor technology, vibration suppression, advanced composite airframes, avionics/cockpits, and flight controls are presented. A further main topic is the description of the most important future helicopter projects with German participation, such as the PAH 2, NH 90, and the Advanced Light Helicopter. Author

**A87-43426#**
**SPANISH CONTRIBUTION TO ROTORCRAFT DEVELOPMENT - HOMAGE TO DE LA CIERVA**

ANGEL GARCIA-FRAILE (Guardia Civil, Madrid, Spain) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 28 p. refs

A development history and historical influence evaluation are presented for the autogiros designed and built by Juan de la Cierva. The autogiro, an antecedent of the helicopter, employs a vertical-axis rotor with slight positive pitch which turns freely to generate lift when the aircraft suspended to which the rotor is attached moves under the power of a conventional propulsion system. Attention is given to the Da Vinci, Cornu, Brequet, and Pascara designs that preceded de la Cierva's work, and to the Flettner, Focke, Sikorsky and Fairey designs that derived some measure of inspiration from the de la Cierva autogiro after his death in 1936. O.C.

**A87-43723#**
**TECHNOLOGICAL CHANGE AND SKILL REQUIREMENTS - A CASE STUDY OF NUMERICALLY CONTROLLED RIVETING IN COMMERCIAL AIRCRAFT MANUFACTURE**

ERIC BASQUES and BRADLEY T. SHAW (U.S. Congress, Office of Technology Assessment, Washington, DC) ASME, Winter Annual Meeting, Anaheim, CA, Dec. 7-12, 1986. 6 p. refs
(ASME PAPER 86-WA/TS-2)

**A87-44228#**
**THE AIRBUS RUDDER - AN EXAMPLE OF NEW FABRICATION TECHNOLOGIES [DAS AIRBUS-SEITENLEITWERK - EIN BEISPIEL NEUER FERTIGUNGSTECHNOLOGIEN]**

GOTTHARD MENZE (Messerschmitt-Boelkow-Blohm GmbH, Werk Stade, West Germany) Luft- und Raumfahrt (ISSN 0173-6264), vol. 8, 1st Quarter 1987, p. 14-18. In German.

New technologies used to fabricate the A320 rudder are described. It was determined that in order to develop an Airbus rudder with maximum strength and long life it was necessary to utilize lightweight materials. The use of carbon-fiber-reinforced plastics as the construction material for the rudder is examined. The basic principles of the double-T construction method used to develop the grid structure for the rudder are reviewed. The production and assembly procedures and equipment used to fabricate the rudder are discussed. Particular attention is given to the prepreg blank, tape layering machine, wrapping and rigging machine, autoclave, machine processing, and ultrasound testing. I.F.

**A87-44255** Operations Research, Inc., Rockville, Md.
**ROTORCRAFT RESEARCH - A NATIONAL EFFORT (THE 1986 ALEXANDER NIKOLSKY HONORARY LECTURESHIP)**

JOHN F. WARD (ORI, Inc., Aeronautics and Space Technology Div., Rockville, MD) American Helicopter Society, Journal (ISSN 0002-8711), vol. 32, April 1987, p. 3-20. Research supported by the American Helicopter Society, ORI, Inc., U.S. Army, and NASA. refs

The present history of rotary-wing and VTOL aircraft development initiatives in the U.S. notes that most such R&D efforts have tended to be 'threat-driven'; the threat has in recent years passed from one of a primarily military character to one of global civilian market growth competition. Recommendations are made concerning remaining research requirements in rotorcraft fluid dynamics, structural mechanics, and human factors engineering. Next-generation configurations to be intensively developed encompass tilt-rotors, advancing blade concept helicopters, convertible X-wings, and folding-blade tilt-rotors. O.C.

**A87-44731**
**MATERIALS IN HELICOPTERS - A REVIEW**
D. HOLT (Westland, PLC, Yeovil, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 17-28.

The application of advanced materials to the construction of helicopter structures and mechanical components is motivated by the desire to improve airworthiness and safety, reduce empty weight fraction, reduce purchase and operating costs, and improve operational performance capability. In introducing a novel material, attention must be given to intrinsic variability in basic material properties and variability due to manufacturing processes, as well as to the behavior to be expected from the material in the course of use throughout its operational environment and service life. An examination is presently made of glass and carbon fiber-reinforced plastics, thermoplastic matrices, welded titanium alloy, gearbox case magnesium alloy castings, and superplastically formed structures. O.C.

**A87-44733**
**HELICOPTER LUBRICATION**
H. A. SPIKES (Imperial College of Science and Technology, London, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 59-74. refs

After discussing those characteristics of helicopters that render them generally difficult to satisfactorily lubricate, attention is given to the role specifically played by current lubricants in such helicopter mechanical systems as the transmission, and to the present development status of materials for the fabrication of such mechanical systems. Because helicopter gas turbine engines are likely to become hotter and faster in operation in future years, lubricants with both thermal stability and higher viscosity will be required and may lead to the development of nonester-based synthetic lubricants whose thermal stability is maintained into the 350-370 C range. O.C.

**A87-44750**
**CORROSION PROTECTION**
R. G. MITCHELL and B. BELL (British Airways, PLC, Hounslow, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 440-449.

A comprehensive consideration is undertaken of the factors affecting the corrosion of civil aircraft structural components, giving attention to the most effective methods for the prevention and solution of corrosion problems. Base structural materials become susceptible to corrosion whenever paints, platings and other protective finishes are damaged. While most common forms of corrosion associated with metallic structures are electrolytic, composite materials' joining to metallic ones also leads to battery-like situations. Numerous other possible problem areas are presently identified, and recommendations are made. O.C.

**A87-45159#**
**ENGINE MAINTENANCE IMPROVEMENT CONSIDERATIONS**
C. L. CALLIS and C. E. CURRY (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p. refs
(AIAA PAPER 87-1716)

Major considerations used to improve engine maintainability in military and commercial applications are identified. In particular, reliability and maintainability factors are developed through logistics support analysis, and the concept of reliability-centered maintenance is discussed. Five different turboprop systems are analyzed to show how reliability and maintainability methodology can be used to achieve the largest improvement in operational capability for the least cost. V.L.

**A87-46177*#** National Aeronautics and Space Administration, Washington, D.C.
**CIVIL PROPULSION TECHNOLOGY FOR THE NEXT TWENTY-FIVE YEARS**
ROBERT ROSEN and JOHN R. FACEY (NASA, Washington, DC) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 3-13.

The next twenty-five years will see major advances in civil propulsion technology that will result in completely new aircraft systems for domestic, international, commuter and high-speed transports. These aircraft will include advanced aerodynamic, structural, and avionic technologies resulting in major new system capabilities and economic improvements. Propulsion technologies will include high-speed turboprops in the near term, very high bypass ratio turbofans, high efficiency small engines and advanced cycles utilizing high temperature materials for high-speed propulsion. Key fundamental enabling technologies include increased temperature capability and advanced design methods. Increased temperature capability will be based on improved composite materials such as metal matrix, intermetallics, ceramics, and carbon/carbon as well as advanced heat transfer techniques. Advanced design methods will make use of advances in internal computational fluid mechanics, reacting flow computation, computational structural mechanics and computational chemistry. The combination of advanced enabling technologies, new propulsion concepts and advanced control approaches will provide major improvements in civil aircraft. Author

**A87-46182#**
**U.S. AERONAUTICAL R&D GOALS - SST: BRIDGE TO THE NEXT CENTURY**
JOHN M. SWIHART (Boeing Co., Seattle, WA) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 55-65.

The present technology development status evaluation of SST-related research trends in the past 15 years of NASA-sponsored efforts gives initial attention to the comparative advantages obtainable through next-generation subsonic transport technology. An assessment is then made of the gains over first-generation SST performance that would be obtainable through incorporation of supersonic flow laminarization to improve lift/drag and thereby reduce gross weight and sonic boom, the use of thermoplastic matrix resin composites and superplastically formed titanium alloy matrix structures, novel flight management systems, and advanced variable cycle engines employing supersonic fans and generating more acceptable noise levels. The further range of design options available for hypersonic transport design is discussed. O.C.

**A87-46708#**
**THE REAL WORLD - A MAINTAINER'S VIEW**
CHARLES M. WORM (USAF, Coordinating Office for Logistics Research, Wright-Patterson AFB, OH) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987,—p. 86-90.

Military aircraft maintainers believe that aircraft designers do not fully understand what it really takes to keep the aircraft flying. This paper discusses that perception and presents several examples of problems caused by poor accessibility and design. Examples of design improvements to facilitate easier and faster field servicing and repair are also described. Author

**A87-46716**
**SPARING TO OPTIMIZE NAVAL AIRSHIP AVAILABILITY**
LARRY S. MICKEL and EUGENE E. NEWMAN (Westinghouse Electric Corp., Baltimore, MD) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 264-267. refs

Long relegated to the status of airborne bulletin boards, current technological advances in Lighter-Than-Air (LTA) craft have renewed interest in airships for both commercial and military applications. The proposed use of these long endurance patrol craft to support Naval Surface Action Groups has triggered maintenance planning for airship support above the world's oceans. This paper describes a logistically optimal spares distribution technique for maximizing naval airship operational availability.
Author

**N87-25267*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**WIND SHEAR/TURBULENCE INPUTS TO FLIGHT SIMULATION AND SYSTEMS CERTIFICATION**
ROLAND L. BOWLES, ed. and WALTER FROST, ed. (FWG Associates, Inc., Tullahoma, Tenn.) Jul. 1987 272 p Workshop held in Hampton, Va., 30 May - 1 Jun. 1984
(NASA-CP-2474; L-16329; NAS 1.55:2474) Avail: NTIS HC A12/MF A01 CSCL 01B

The purpose of the workshop was to provide a forum for industry, universities, and government to assess current status and likely future requirements for application of flight simulators to aviation safety concerns and system certification issues associated with wind shear and atmospheric turbulence. Research findings presented included characterization of wind shear and turbulence hazards based on modeling efforts and quantitative results obtained from field measurement programs. Future research thrusts needed to maximally exploit flight simulators for aviation safety application involving wind shear and turbulence were identified. The conference contained sessions on: Existing wind shear data and simulator implementation initiatives; Invited papers regarding wind shear and turbulence simulation requirements; and Committee working session reports.

**N87-25291#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensbereich Apparate.
**AIRCRAFT TECHNOLOGIES OF THE NINETIES IN MBB PASSENGER AIRCRAFT PROJECTS [FLUGZEUG-TECHNOLOGIE DER 90ER JAHRE IN VERKEHRSFLUGZEUG-PROJEKTEN VON MBB]**
UWE GANZER 1986 40 p In GERMAN; ENGLISH summary Presented at the DGLR-Jahrestagung, Munich, West Germany, 8-10 Oct. 1986
(MBB-UT-21/86; DGLR-86-108; ETN-87-99962) Avail: Issuing Activity

Technologies for passenger aircraft in the nineties are treated. The impact of new technologies on the economics of an aircraft is considered. The propfan propulsion concept, laminar and carbon fiber reinforced airfoils, as well as cockpit and flight control techniques are reviewed, in order to identify problems involved in the development of these techniques. ESA

**N87-25293*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**FLIGHT DURATION, AIRSPEED PRACTICES AND ALTITUDE MANAGEMENT OF AIRPLANES INVOLVED IN THE NASA VGH GENERAL AVIATION PROGRAM**
JOSEPH W. JEWEL, JR. Aug. 1987 180 p
(NASA-TM-89074; L-16236; NAS 1.15:89074) Avail: NTIS HC A09/MF A01 CSCL 01B

Flight duration, airspeed, and altitude information obtained from NASA velocity gravity height (VGH) recorders is presented for each of 95 general aviation airplanes flown in twin- and single-engine executive, personal, instructional, commercial survey, aerial application, aerobatic, commuter, and float operations. These data complement normal acceleration data obtained from the same airplanes and reported in NASA-TM-84660, and together they provide a data base for the design and analysis of general aviation airplane operations. Author

**N87-25990#** Rand Graduate Inst. for Policies Study, Santa Monica, Calif.
**NATIONAL AEROSPACE PLANE PROGRAM: PRINCIPAL ASSUMPTIONS, FINDINGS AND POLICY OPTIONS**
SCOTT PACE Dec. 1986 24 p Presented at a course on the Uses of History in Public Policy, Santa Monica, Calif., Fall 1986
(RAND/P-7288-RGS) Avail: NTIS HC A02/MF A01

Top-level issues raised by the National Aerospace Plane Program (NASP) are examined. Its principle points are: major uncertainties in the rate of NASP technical progress, cost projections, and potential applications of NASP technology. NASP development costs and possible increases may force tradeoffs with other research and development efforts in subsonic aircraft and launch vehicle technology. The FY88-89 budget will require decisions on major funding increases for flying technology demonstrators. The high classification of some NASP technologies is limiting independent evaluation and may reduce commercial spinoffs. Major policy options that should be examined further are: maintain NASP research efforts, but deemphasize operational applications; hedge NASP research by expanding efforts in other space and aeronautical transport programs; and increase NASA responsibility for NASP work and ease classification restrictions. NASP is a promising technical effort that has made significant progress in the last year. The need for routine access to space and aeronautical leadership makes NASP a national priority. The costs and uncertainties of NASP, however, make it imperative to examine strategies for reducing its risks. Author

# 02

# AERODYNAMICS

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

**A87-43009*#** North Carolina State Univ., Raleigh.
**AN INTERACTIVE APPROACH TO SURFACE-FITTING COMPLEX GEOMETRIES FOR FLOWFIELD APPLICATIONS**
FRED R. DEJARNETTE (North Carolina State University, Raleigh), H. HARRIS HAMILTON, II (NASA, Langley Research Center, Hampton, VA), and F. MCNEIL CHEATWOOD AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 10 p. refs
(Contract NCC1-22; NCC1-100)
(AIAA PAPER 87-1476)

Numerical flowfield methods require a geometry subprogram which can calculate body coordinates, slopes, and radii of curvature for typical aircraft and spacecraft configurations. The objective of this paper is to develop a new surface-fitting technique which addresses two major problems with existing geometry packages: computer storage requirements and the time required of the user for the initial set-up of the geometry model. In the present method, coordinates of cross sections are fit in a least-squares sense using segments of general conic sections. After fitting each cross section, the next step is to blend the cross-sectional curve-fits in the longitudinal direction using general conics to fit specific meridional half-planes. For the initial setup of the geometry model, an interactive, completely menu-driven computer code has been developed to allow the user to make modifications to the initial fit for a given cross section or meridional cut. Graphic displays are provided to assist the user in the visualization of the effect of each modification. The completed model may be viewed from any angle using the code's three-dimensional graphics package. Geometry results for the modeling of the Space Shuttle and a proposed Aeroassist Flight Experiment (AFE) geometry are

presented, in addition to calculated heat-transfer rates based on these models. Author

**A87-43038*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**THE THERMAL ENVIRONMENT OF TRANSATMOSPHERIC VEHICLES**
MICHAEL E. TAUBER (NASA, Ames Research Center, Moffett Field, CA) and HENRY G. ADELMAN (Eloret Institute, Sunnyvale, CA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 15 p. refs
(AIAA PAPER 87-1514)

A transatmospheric vehicle using primarily air-breathing propulsion must fly in the denser part of the atmosphere to achieve adequate acceleration to reach orbital speed. The potentially long ascent times, combined with the need for a low-drag configuration, result in a severe aerothermodynamics environment. To achieve low drag, the vehicle must have a relatively sharp nose and wing leading edges. The ascent peak stagnation point and equilibrium wall temperatures for the wing leading edge can reach values of 4000 K and 3000 K, respectively, for high dynamic pressure trajectories, making some form of mass addition cooling mandatory. The corresponding temperatures during entry are about 1500 K lower. The vehicle windward centerline temperatures are more moderate, however, with values peaking around 1500 K. Therefore, radiative cooling should be effective over large areas of the vehicle. The windward, centerline heat loads are relatively insensitive to the dynamic pressure of the ascent trajectory, in contrast to the stagnation point and wing leading edge. The windward surface entry heat loads are much lower, but depend strongly on the flightpath. Author

**A87-43063*#** Vigyan Research Associates, Inc., Hampton, Va.
**DIRECT SIMULATION OF AEROTHERMAL LOADS FOR AN AEROASSIST FLIGHT EXPERIMENT VEHICLE**
VIRENDRA K. DOGRA (Vigyan Research Associates, Inc., Hampton, VA), JAMES N. MOSS, and ANN L. SIMMONDS (NASA, Langley Research Center, Hampton, VA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 12 p. refs
(AIAA PAPER 87-1546)

Results of a numerical study using the direct simulation Monte Carlo (DSMC) method are presented for the hypersonic flow about an elliptically blunted cone. The flow conditions are those for a proposed Aeroassist Flight Experiment (AFE) vehicle. The altitude range considered is that from 130 to 90 km which encompasses most of the transitional flow regime for the AFE vehicle, that is, the region bounded by free molecular and continuum flow. Freestream velocities of 9.9 to 7.5 km/sec are considered. The numerical simulations show that noncontinuum effects are evident for all cases considered. The onset of chemical dissociation occurs at a simulated altitude of about 130 km. Results presented highlight the thermal and chemical nonequilibrium nature of the flowfield and the impact of these effects on the surface heating and body drag. A calculation which included the additional effects of ionization and thermal radiation demonstrates that the inclusion of such efects would not significantly alter the surface quantities calculated in the present study. The radiative heating is negligible when compared with the convective heating, and the same would be true for the other conditions considered. Author

**A87-43084*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A COMPUTATIONAL STUDY OF THE FLOWFIELD SURROUNDING THE AEROASSIST FLIGHT EXPERIMENT VEHICLE**
PETER A. GNOFFO and FRANCIS A. GREENE (NASA, Langley Research Center, Hampton, VA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 13 p. refs
(AIAA PAPER 87-1575)

A symmetric total variation diminishing (STVD) algorithm has been applied to the solution of the three-dimensional hypersonic flowfield surrounding the Aeroassist Flight Experiment (AFE) vehicle. Both perfect-gas and chemical nonequilibrium models have been used. The perfect-gas flows were computed at two different Reynolds numbers, including a flight trajectory point at maximum dynamic pressure, and on two different grids. Procedures for coupling the solution of the species continuity equations with the Navier-Stokes equations in the presence of chemical nonequilibrium are reviewed and tested on the forebody of the AFE and on the complete flowfield assuming noncatalytic wall and no species diffusion. Problems with the STVD algorithm unique to flows with variable thermodynamic properties (real gas) are identified and algorithm modifications are suggested. A potential heating problem caused by strong flow impingement on the nozzle lip in the near wake at 0-deg angle of attack has been identified. Author

**A87-43299**
**VISCOUS-INVISCID INTERACTIONS IN EXTERNAL AERODYNAMICS**
R. C. LOCK (City University, London, England) and B. R. WILLIAMS (Royal Aircraft Establishment, Farnborough, England) Progress in Aerospace Sciences (ISSN 0376-0421), vol. 24, no. 2, 1987, p. 51-171. refs

Interactive methods for the numerical modeling of viscous flows are examined in an extensive analytical review, and typical results are presented in graphs. The fundamental physics of viscous-inviscid interactions is reviewed, and consideration is given to three-dimensional interactive flows, coupling methods, methods for two-dimensional incompressible and transonic flows, methods for axisymmetric transonic flows, and three-dimensional methods. The limitations of currently available techniques are indicated, and the potential for extending their applicability is assessed. T.K.

**A87-43376#**
**FLOW OVER A TRAILING FLAP AND ITS ASYMMETRIC WAKE**
S. ACHARYA, D. ADAIR, and J. H. WHITELAW (Imperial College of Science and Technology, London, England) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 897-904. refs

Detailed measurements of pressure and velocity characteristics are reported for the attached flow on a trailing flap and in its downstream asymmetric wake. The results indicate that the flow over the flap is subjected to an adverse pressure gradient. Near the trailing edge, an inflection point develops in the streamwise velocity profile and the flow approaches intermittent separation. The wake is asymmetric with a destabilizing curvature on the suction side and a stabilizing curvature on the pressure side. Streamwise variations in the near wake are primarily confined to the inner layer, and further downstream the mean velocity and turbulence quantities attain self-similar profiles. Nonequilibrium effects are present in the near wake and imply that mixing length models are not appropriate. Both the pressure gradient term and the cross-stream gradient of the turbulent stresses are found to be important. Streamwise gradients of the turbulent stresses are, however, small. Author

**A87-43377#**
**TIME-CONSISTENT PRESSURE RELAXATION PROCEDURE FOR COMPRESSIBLE REDUCED NAVIER-STOKES EQUATIONS**
S. V. RAMAKRISHNAN and S. G. RUBIN (Cincinnati, University, OH) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 905-913. refs
(Contract N00014-79-C-0849; F49620-85-C-0027)

A time-consistent global pressure relaxation procedure for the unsteady, compressible, reduced Navier-Stokes equations is presented. The shock-capturing capability of the procedure is investigated with different forms of pressure gradient splitting. An efficient conservative method for capturing shocks is detailed. The transient behavior of laminar, high Reynolds number, low subsonic flow past a sine-wave airfoil geometry is analyzed using the new reduced Navier-Stokes-based algorithm. These solutions are compared with steady and unsteady results previously obtained with a modified interacting boundary-layer procedure. The strong influence of grid refinement and the type of differencing of the streamwise convection term on the existence or stability of

separated laminar solutions is reaffirmed. More stable turbulent flow results are also presented. Finally, an unsteady solution for the flow past a finite flat plate at incidence is described in order to demonstrate the time accuracy of the algorithm. Author

**A87-43392*#** Arizona Univ., Tucson.
**COMPUTATION OF UNSTEADY TRANSONIC AERODYNAMICS WITH TRUNCATION ERROR INJECTION**
K.-Y. FUNG and J.-K. FU (Arizona, University, Tucson) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 1018-1020. Previously cited in issue 19, p. 2740, Accession no. A85-40744. refs
(Contract AF-AFOSR-83-0071; NGT-03-002-800)

**A87-43412#**
**A UNIFIED APPROACH FOR POTENTIAL AND VISCOUS FREE-WAKE ANALYSIS OF HELICOPTER ROTORS**
L. MORINO and B. K. BHARADVAJ (Boston University, MA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 12 p. refs
(Contract DAAG29-83-K-0050)

A unified formulation for the potential and viscous free-wake analysis of helicopter rotors in incompressible flows is presented. The wake is treated as a vortex layer (with zero thickness for potential flows and finite thickness for viscous flows). The numerical algorithm for the discretization is outlined. Numerical results are in good agreement with the numerical results of Rao and Schatzle and the experimental ones of Landgrebe and of Shivananda. Author

**A87-43413#**
**A PARAMETRIC INVESTIGATION OF A FREE WAKE ANALYSIS OF HOVERING ROTORS**
A. ROSEN (Technion - Israel Institute of Technology, Haifa) and A. GRABER DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 23 p. refs

A recently developed free-wake model of a hovering rotor (Rosen and Graber, 1985) is used to study the influence of different parameters on the accuracy and efficiency of the calculations. The parameters investigated include: the spanwise and chordwise distribution of cells over the blade, the length of the near wake, the length of the straight vortex elements of which the near wake is assembled, the vortex core size, relaxation factors, and the influence of including a correction for the self-induction in the near wake due to the curvature of the real trailing vortex elements. This parametric investigation is aimed at giving future users of free-wake analysis guidelines on how to arrive at a numerical model which is accurate and still efficient. A free-wake analysis of a rotor having swept blades is included in order to learn about the influence of the sweep-back ont he aerodynamic behavior. Author

**A87-43414#**
**A PRESCRIBED RADIAL DISTRIBUTION CIRCULATION OF A HOVERING ROTOR BLADE**
C. MARESCA, D. FAVIER, and M. NSI MBA (Aix-Marseille II, Universite, Marseille, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 24 p. refs
(Contract DRET-84-009)

A prescribed radial-distribution circulation has been deduced from new experimental results obtained on hovering rotor blades. A synthetic empirical law of circulation is used as input data of an iterative numerical code predicting the wake geometry, the rotor flow, and airloads. Compared to a previous code using a prescribed distribution of induced velocities (Pouradier and Horowitz, 1980), improvements concerning running time and precision on wake characteristics have been obtained. Moreover, it has been shown that, in the case of a highly nonlinear twisted blade, the code becomes efficient when introducing the experimental values of the bound circulation along the blade as input data. Particularly, the wake geometry given by the code shows good agreement with experiments. Author

**A87-43415#**
**INVESTIGATION OF BLADE-VORTICES IN THE ROTOR-DOWNWASH**
B. JUNKER (DFVLR, Institut fuer Flugmechanik, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 25 p.

The flow field of a rotor consists of induced downwash, the fuselage wake, and strong rotor-blade vortices. This paper deals with the investigation of those vortices. The trace and the diameter of the vortex were identified by a simple measuring method (Junker, 1985). Results of different wind-tunnel investigations, such as level flight, descend, climb, and transition are presented and discussed. The tests were conducted in the DNW wind tunnel using the closed 8 x 6-m test section. The test results provide a better understanding of the rotor downwash structure. Author

**A87-43416#**
**THE USE OF DISCRETE VORTICES TO PREDICT LIFT OF A CIRCULATION CONTROL ROTOR SECTION WITH A TRAILING EDGE BLOWING SLOT**
C. W. HUSTAD (Kongsberg Vapenfabrikk A/S, Norway) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 19 p. refs

This paper describes a method which applies discrete vortices to predict the flow around the trailing edge (TE) of a circulation-control rotor (CCR) section. The vortices are shed from the blowing lip with a frequency and strength determined by the blowing parameters and lip geometry. As the vortices develop downstream, viscosity and entrainment cause vortex growth, with eventual overlapping resulting in a pairing process. Once initiated this process breaks down the discrete vortex structure, resulting in a large-scale eddy flow representative of the flow in the wake of the CCR section. The proposed model shows distinct similarities with the observed flow field, and it is suggested that discrete vortex modeling may offer an alternative, or at the very least suggest improvements, to the finite-difference methods which have been used to predict the TE Coanda flow. Author

**A87-43417*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**FULL POTENTIAL MODELING OF BLADE-VORTEX INTERACTIONS**
H. E. JONES and F. X. CARADONNA (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986. Paper. 28 p. Previously announced in STAR as N87-18532. refs

A comparison is made of four different models for predicting the unsteady loading induced by a vortex passing close to an airfoil. (1) The first model approximates the vortex effect as a change in the airfoil angle of attack. (2) The second model is related to the first but, instead of imposing only a constant velocity on the airfoil, the distributed effect of the vortex is computed and used. This is analogous to a lifting surface method. (3) The third model is to specify a branch cut discontinuity in the potential field. The vortex is modeled as a jump in potential across the branch cut, the edge of which represents the center of the vortex. (4) The fourth method models the vortex expressing the potential as the sum of as known potential due to the vortex and an unknown perturbation due to the airfoil. The purpose of the current study is to investigate the four vortex models described above and to determine their relative merits and suitability for use in large three-dimensional codes. Author

**A87-43418#**
**COMPUTATION OF THE FLOW FIELDS OF PROPELLERS AND HOVERING ROTORS USING EULER EQUATIONS**
N. KROLL (DFVLR, Institut fuer Entwurfs-Aerodynamik, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p. refs

A numerical procedure for the calculation of the flow fields of propellers and hovering rotors is described. The method solves the three-dimensional Euler equations, which are formulated in terms of the flow variables in a blade-attached Cartesian reference frame. The solution algorithm is based on the finite-volume method originated by Jameson et al. (1981), using explicit Runge-Kutta time-stepping schemes. Calculations are presented for subsonic and transonic flows around a two-bladed propeller and a two-bladed model helicopter rotor in hover. The theoretical results show good agreement with the experimental data. Author

**A87-43419#**
**APPLICATION OF A 3D EULER CODE TO TRANSONIC BLADE TIP FLOW**
H. STAHL (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 19 p. refs

The unsteady three-dimensional rotational transonic flow on the rotor blade of a helicopter in fast forward flight is investigated analytically by means of numerical computations with the EUFLEX code (Eberle, 1984). The computational grid, boundary conditions, and numerical procedure are described, and the results obtained for Psi = 90 deg with different grid refinements and dimensions and with grid lines attracted to the surface, are presented graphically. It is shown that best results are obtained with maximum resolution of the body surface, with attracted grid lines, and with grid boundaries far enough from the body to assure far-field conditions. The overall pressure distribution on the blade is lowered by decaying velocity outboard of the blade tip. T.K.

**A87-43420#**
**THE EFFECT OF PITCH RATE ON THE DYNAMIC STALL OR A MODIFIED NACA 23012 AEROFOIL AND COMPARISON WITH THE UNMODIFIED CASE**
ANDREW J. NIVEN and A. MCD. GALBRAITH (Glasgow, University, Scotland) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 15 p. Sponsorship: Ministry of Defence of England. refs (Contract MOD-2048/026)XR/STR)

An investigation into the effects of trailing-edge separation on dynamic stall was carried out by modifying and re-testing a NACA 23012 aerofoil. An enhancement in rear separation was obtained by modifying the trailing-edge geometry. To maintain similar flow conditions at the leading-edge, the original aerofoil geometry within this area was left unaltered. The paper presents data obtained from oscillatory and ramp tests and shows the modified aerofoil to have an earlier dynamic stall initiation. It is suggested that this initiation was triggered, at the lower angle of incidence, by the enhanced rear separation. Author

**A87-43421*#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
**UNSTEADY SEPARATION CHARACTERISTICS OF AIRFOILS OPERATING UNDER DYNAMIC STALL CONDITIONS**
WOLFGANG GEISSLER (DFVLR, Institut fuer Aeroelastik, Goettingen, West Germany), LAWRENCE W. CARR (NASA, Ames Research Center; U.S. Army, Aeromechanics Laboratory, Moffett Field, CA), and TUNCER CEBECI (California State University, Long Beach) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p. refs

Unsteady viscous/inviscid interaction phenomena are investigated for airfoils operating under dynamic stall conditions, using coupling procedures between a time-dependent inviscid panel method and two-dimensional unsteady boundary layer codes. Two strategies are pursued: a coupling of the inviscid panel method with the boundary layer code, and a strong coupling of the inviscid panel method with the boundary layer code. Attention is given to the main features of the unsteady time-marching panel method and boundary layer codes, as well as to numerical stability and the phenomenon of unsteady separation. O.C.

**A87-43422#**
**THE INFLUENCE OF WINGLETS ON ROTOR AERODYNAMICS**
R. MUELLER (Aachen, Rheinisch-Westfaelische Technische Hochschule, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p. refs

Impulsive noise emission and dynamic blade loads of helicopters are to some extent caused by Blade Vortex Interactions (BVI). In this paper, a winglet arrangement is described which reduces the influence of BVI by increasing the distance between tip vortices and rotor blades at their first encounter. For hover flight, a free-wake analysis method has been developed to calculate the influence of the winglet. It is shown that a winglet can produce a smaller gradient of the spanwise load distribution, leading to a higher spreading of the vorticity. Although it is expected that the winglet in forward flight could have an adverse influence due to large azimuthal variations of its incidence, the measured pressure variations are smaller. Calculations, based on the theory of Naumann and Yeh (1972), show a favorable influence of a winglet on the unsteady forces under certain flight conditions. Author

**A87-43424#**
**THE USE OF COMPUTER MODELS IN HELICOPTER DRAG PREDICTION**
DAVID R. CLARK and BRIAN MASKEW (Analytical Methods, Inc., Redmond, WA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 25 p. refs

The paper presents a brief review of the developments in airframe drag prediction capability in the last decade. In particular, it details the inability of the first generation panel methods to more than adequately calculate the flow about helicopter fuselages and their failure, despite early promise to be able to predict absolute levels of drag. The development of a second generation of panel methods led the way to an improved flow modeling capability and, in particular, to the ability to model the behavior of viscous flow and to predict and track the development of regions of separate flow. The paper shows, however, that even these models fall short in their ability to accurately predict drag. They do, however, provide the jumping off point for the development of a new generation of panel methods which take full account of the unsteady motion of the large-scale separated flow. These methods are discussed and early results on a series of bluff bodies and typical helicopter tail boom cross sections are presented. In most cases the correlation between predicted and measured drag is excellent. Author

**A87-43438#**
**INVESTIGATION OF HELICOPTER TWIN-ROTOR CHARACTERISTICS**
H. AZZAM and P. TAYLOR (Southampton, University, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 11 p. Research supported by the Ministry of Defence (Procurement Executive). refs

The general application of the reported wake models to the interference problems between two rotors is restricted. The free convection of a limited number of revolutions of the tip vortex trajectory is only considered in the free wake models to reduce the computational costs. Meanwhile, the far wake is either ignored or prescribed by using a vortex ring or a helical wake of constant radius. The objective of this paper is to demonstrate the important effects of the far wake structure on the twin-rotor behavior. This leads to the proposed prescribed wake model. This model is found to describe the performance of coaxial, nonoverlapped tandem and twin-tail rotors adequately. The flapping angles of the

nonoverlapped tandem were found to be reasonably predicted.
Author

**A87-43603**
**EFFECT OF FABRICATION-RELATED DEVIATIONS OF THE GEOMETRICAL PARAMETERS OF BLADE PROFILES ON FLOW IN A COMPRESSOR [VLIIANIE TEKHNOLOGICHESKIKH OTKLONENII GEOMETRICHESKIKH PARAMETROV PROFILEI LOPATOK NA TECHENIE V KOMPRESSORE]**
L. G. BOIKO, V. N. ERSHOV, and V. N. IANEVICH Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 10-14. In Russian.

A two-dimensional mathematical model for the investigation of flow in a multistage axial compressor is examined. It is demonstrated that this model can be used to study the effect of fabrication-related deviations of the geometrical characteristics of the blade profiles on flow in the compressor. An assessment is made of the effects of the chord, the maximum thickness of the profile, and the setting angle on the flow characteristics in an individual stage and in a six-stage compressor. B.J.

**A87-43604**
**INVESTIGATION OF FLOW STRUCTURE IN A COMPRESSOR WITH TWO TYPES OF GUIDES [ISSLEDOVANIE STRUKTURY POTOKA V KOMPRESSORE S NAPRAVLIAIUSHCHIMI APPARATAMI DVUKH SKHEM ISPOLNENIIA]**
A. F. BREKHOV, L. N. BUSKIK, and A. V. SKLIAR Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 14-17. In Russian.

The effects of two types of guides on the aerodynamic characteristics of a two-stage axial compressor are evaluated: (1) a shrouded guide and (2) a cantilever guide with a radial clearance at the hub equal to 1.5 percent of the blade height. In the case of the second design, flow through the clearance localizes the vortex flow in the hub region, leading to an increase in the total pressure behind the guide. Since the compressor in the experiment had relatively short blades, the localization of the near-hub vortex flows had a favorable effect on the flow structure over the entire height of the guide blades in both stages of the compressor.
B.J.

**A87-43608**
**CALCULATION OF THE BOUNDARY LAYER AT THE INLET SECTION OF A COMPRESSOR CASCADE [K RASCHETU POGRANICHNOGO SLOIA NA VKHODNOM UCHASTKE KOMPRESSORNOI RESHETKI]**
N. M. ZUBOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 26-28. In Russian.

The application of a simple integral method to the calculation of a turbulent boundary layer at the inlet section of a transonic compressor cascade is considered. Calculated parameters of the boundary layer are compared with experimental data for transonic flow past a half-profile in a channel. It is concluded that the proposed method can be effectively used to calculate the conditional thicknesses of the boundary layer at the inlet section of a compressor cascade. B.J.

**A87-43618**
**INVESTIGATION OF ROTATING ADDITIONAL BLADES ON THE PERIPHERY OF AN AXIAL-COMPRESSSOR ROTOR [OB ISSLEDOVANII POVOROTNYKH DOPOLNITEL'NYKH LOPATOK NA PERIFERII RABOCHEGO KOLESA OSEVOGO KOMPRESSORA]**
V. IU. NEZYM and V. G. PROKOPOVICH Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 71-74. In Russian.

Experimental results on rotating additional blades in the inlet region of an axial-compressor rotor confirm that the peripheral inlet region plays an important role in the occurrence of rotating stall. The additional blades can be used to control the flow in the peripheral zone. While practically preserving the level of efficiency, it is possible to move the rotating-stall boundary toward lower air flow rates. B.J.

**A87-43704#**
**EFFECT OF SWIRL ON THE PERFORMANCE OF A RADIAL VANELESS DIFFUSER WITH COMPRESSIBLE FLOW AT MACH NUMBERS OF 0.7 AND 0.8**
S. M. YAHYA, D. P. AGRAWAL (Indian Institute of Technology, New Delhi, India), and D. N. REDDY (Osmania University, Hyderabad, India) ASME, Winter Annual Meeting, Anaheim, CA, Dec. 7-12, 1986. 6 p. refs
(ASME PAPER 86-WA/FE-6)

The present investigation deals with the flow development and performance characteristics of a parallel wall radial vaneless diffuser for varying degree of swirl (24 deg to 35 deg) at entry Mach numbers of 0.7 and 0.8. Test results are presented for the constant passage width (b/D1 of 0.138) and at various radius ratios (1.0 to 2.9) of the diffuser. The results show that the pressure recovery decreases with the increase in swirl angle, and that for the given swirl, performance of the diffuser deteriorates with the increase in entry Mach number. It is further observed that the swirl plays an important role in the velocity distortion at the inlet of diffuser. Author

**A87-44019**
**THE EFFECT OF TRIP WIRE ROUGHNESS ON THE PERFORMANCE OF THE WORTMANN FX 63-137 AIRFOIL AT LOW REYNOLDS NUMBERS**
A. F. HUBER, II and T. J. MUELLER (Notre Dame, University, IN) Experiments in Fluids (ISSN 0723-4864), vol. 5, no. 4, 1987, p. 263-272. Research supported by the University of Notre Dame. refs
(Contract N00014-83-K-0239)

An experimental investigation was conducted on the performance and boundary layer characteristics of the Wortmann FX 63-137 airfoil with and without trip wire roughness. Data were obtained through use of a three-component strain gage force balance and static pressure measurement equipment at a test Reynolds number (based on chord c) of 100,000. Prediction of transition location by the criterion due to Tani (1964) and Gibbings (1959) was found to have limited application. Most trip wire locations resulted in degraded performance, but for some locations, minimum drag was reduced, maximum lift to drag ratio was increased, and hysteresis was averted. Author

**A87-44902*#** Boeing Co., Seattle, Wash.
**NAVIER-STOKES SIMULATION OF A HYPERSONIC GENERIC WING/FUSELAGE**
JOHN C. WAI, SAMUEL C. DAO (Boeing Military Airplane Co., Seattle, WA), and DENNY S. CHAUSSEE (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 13 p. refs
(AIAA PAPER 87-1192)

An unsteady thin-layer Navier-Stokes code is used to calculate a generic wing/fuselage configuration at a Mach number of 25 and freestream conditions corresponding to an altitude of 220,000 feet. Calculations were performed with the assumptions of a perfect gas and with chemical equilibrium, and the boundary layer was assumed to be turbulent and to have a surface temperature prescribed at 1255 K. Results for the two different gas assumptions were compared in terms of distributions of pressure, density, temperature, Mach number, ratio of specific heat, and heat transfer. Numerical problems arising in the calculations were identified.
R.R.

**A87-44904*#** Sterling Software, Palo Alto, Calif.
**ADVANCES IN THE COMPUTATION OF TRANSONIC SEPARATED FLOWS OVER FINITE WINGS**
UNVER KAYNAK (Sterling Software, Palo Alto, CA) and JOLEN FLORES (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 20 p. refs
(Contract NCA2-OR-745-309)
(AIAA PAPER 87-1195)

The transonic flow around a low-aspect-ratio infinite wing in a wind tunnel is investigated by means of numerical simulations, with a focus on shock-induced separated flows. A coarse global grid with far-field boundaries matching those of the test section is subdivided into zones: the flow in the clustered zones near the wing is analyzed by solving the Reynolds-averaged Navier-Stokes equations, while that farther from the wing is modeled with the Euler equations. The results are presented graphically, and it is shown that a mushroomlike separated flow with two counterrotating vortices can be simulated when the correct shock strength is imposed (by careful selection of the artificial dissipation, the boundary conditions, the grid refinement, the algebraic turbulence model, and the geometry representation). T.K.

**A87-44905*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**TRANSONIC ANALYSIS OF THE F-16A WITH UNDER-WING FUEL TANKS - AN APPLICATION OF THE TRANAIR FULL-POTENTIAL CODE**
MICHAEL D. MADSON (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 9-10, 1987. 14 p. refs
(Contract NAS2-12513)
(AIAA PAPER 87-1198)

Initial results obtained using the TranAir transonic full-potential code are presented for a fully configured F-16A geometry, including two 370-gal under-wing fuel tanks, at freestream Mach numbers of 0.6 and 0.9 and angle of attack of 4 deg. The geometry is modeled using surface panels, and the flow field is defined by a rectangular array of flow-field grid points. The paneled geometry is embedded within this rectangular flow field. By avoiding the use of surface-conforming flow-field grids, the modeling generality afforded by surface panels can be utilized to analyze very complex configurations in the transonic flow regime. Author

**A87-44906*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**SIMULATION OF TRANSONIC VISCOUS FLOW OVER A FIGHTER-LIKE CONFIGURATION INCLUDING INLET**
JOLEN FLORES, NEAL M. CHADERJIAN, and REESE L. SORENSON (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 15 p. refs
(AIAA PAPER 87-1199)

The simulation of transonic viscous flow over a modified F-16A including inlet is presented. A zonal approach is utilized which allows appropriate clustering suitable for viscous calculations on all solid surfaces. Computational efficiency is enhanced by solving the thin-layer Navier-Stokes equations in viscous zones adjacent to the aircraft and the Euler equations on those coarse zones away from the aircraft. The flow conditions for this transonic case are freestream Mach number of 0.9, angle of attack of 4.12 deg, and a Reynolds number (based on root chord) of 4.5 million. A total of 19 zones are utilized yielding a total of 350,000 grid points. This case required about 3000 iterations to reduce the residual by three orders, which takes about 10 hr of CPU time on the Cray X-MP/48 computer. Pressure distributions on the wing and on cross sections through the inlet region compare favorably with the experimental data for this transonic case. Author

**A87-44913*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**NUMERICAL SIMULATION OF VORTICAL FLOWS OVER A STRAKE-DELTA WING**
KOZO FUJII and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 15 p. refs
(AIAA PAPER 87-1229)

The vortical flow fields over a double-delta wing with sweep angles 80 and 60 deg are investigated by means of numerical simulations based on the LU-ADI code of Fujii and Obayashi (1986) for the three-dimensional thin-layer Navier-Stokes equations. The results obtained using an 850,000-point grid at angle of attack alpha = 6-40 deg are presented graphically, compared with experimental data, and characterized in detail. Qualitatively accurate simulations are obtained for transition phenomena such as strake/wing-vortex interaction at alpha = 12 deg, bubble-type vortex breakdown near the trailing edge at alpha = 30 deg, and spiral-type breakdown at alpha = 35 deg. It is suggested that quantitative simulations can be achieved at higher grid resolution. T.K.

**A87-44914*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**AN EXPERIMENTAL INVESTIGATION OF A SUPERCRITICAL AIRFOIL AT TRANSONIC SPEEDS**
GEORGE C. MATEER, H. LEE SEEGMILLER, THOMAS J. COAKLEY, LAWRENCE A. HAND (NASA, Ames Research Center, Moffett Field, CA), and JOACHIM SZODRUCH (Messerschmitt-Boelkow-Blohm GmbH, Bremen, West Germany) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 11 p. refs
(AIAA PAPER 87-1241)

Benchmark experimental data obtained in the two-dimensional, transonic flow field surrounding a supercritical airfoil are presented. Airfoil surface and tunnel wall pressure and LDV measurements are used to describe the flow on the model, above the wing and in the wake. Comparisons are made with calculations using the Reynolds-averaged Navier-Stokes equations. The results illustrate the performance of two turbulence models in both separated and attached flows. The largest differences between theory and experiment occurred in separated flows with the Johnson and King turbulence model providing the best estimates. Author

**A87-44915#**
**A NEW SIMULATION OF AIRFOIL DYNAMIC STALL DUE TO VELOCITY AND INCIDENCE FLUCTUATIONS**
D. FAVIER, A. AGNES, C. BARBI, and C. MARESCA (Aix-Marseille II, Universite, France) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 20 p. Research supported by the Ministere de la Defense Armee de l'Air. refs
(AIAA PAPER 87-1242)

The effects of simultaneous velocity and incidence fluctuations on the 2D aerodynamic behavior of a NACA0012 airfoil are investigated in this paper. A new mechanical system allows to drive the airfoil in pitching and in for and aft motions, as well as in a simultaneous combination of these two basic unsteady motions. In response of the simultaneous velocity and incidence variations, the time-dependent lift and drag fluctuations are measured for increasing values of the reduced frequency and amplitude parameters including dynamic stall conditions. Complementary informations on the dynamic stall occurring in combined motion are provided by skin friction and pressure measurements along the airfoil surface. Author

**A87-44920*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**EXPERIMENTAL STUDY OF THE VORTEX FLOW BEHAVIOR ON A GENERIC FIGHTER WING AT SUBSONIC AND TRANSONIC SPEEDS**
GARY E. ERICKSON (NASA, Ames Research Center, Moffett Field, CA) and LAWRENCE W. ROGERS (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 23 p. refs
(AIAA PAPER 87-1262)

A subsonic and transonic investigation of the vortex flow behavior of a generic fighter configuration with 55-deg cropped delta wing has been conducted in order to improve current understanding of vortical motions on a wing with deflected leading edge flap at moderate and high angles-of-attack. The leading edge vortex strength was reduced, and the vortex was flatter and closer to the wing surface, as the Mach number increased. Transonically, at high angles-of-attack, the test data suggested the development of a cross-flow shock wave above the vortex sheet which coexisted with a rear shock wave. Subsonically, a deflected leading edge flap was able to sustain a concentrated vortex on the forward-facing surface. O.C.

**A87-44921*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A UNIQUE MEASUREMENT TECHNIQUE TO STUDY LAMINAR-SEPARATION BUBBLE CHARACTERISTICS ON AN AIRFOIL**
J. P. STACK (NASA, Langley Research Center, Hampton, VA), S. M. MANGALAM, and S. A. BERRY (Analytical Services and Materials, Inc., Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 9 p. refs
(Contract NAS1-18235)
(AIAA PAPER 87-1271)

A 'nonintrusive', multielement heat-transfer sensor was designed to study laminar-separation bubble characteristics on a NASA LRN (1)-1010 low-Reynolds number airfoil. The sensor consists of 30 individual nickel films, vacuum-deposited on a thin substrate (0.05 mm) that was bonded to the airfoil model with the sensor array placed streamwise on the airfoil upper surface. Experiments were conducted on a 15-cm chord model in the 50,000-300,000 chord Reynolds number range. Time history as well as spectral analysis of signals from surface film gauges were simultaneously obtained to determine the location of laminar separation and the subsequent behavior of the separated shear layer. In addition to the successful determination of laminar separation, a new phenomenon involving a large phase shift in dynamic shear stresses across the separation and reattachment points was observed. Author

**A87-44929#**
**VISUALIZATION OF THREE-DIMENSIONAL STRUCTURES ABOUT A PITCHING FORWARD SWEPT WING**
J. B. WISSLER, F. T. GILLIAM (U.S. Air Force Academy, Colorado Springs, CO), M. C. ROBINSON (Colorado, University, Boulder), and J. M. WALKER (USAF, Frank J. Seiler Research Laboratory, Colorado Springs, CO) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 10 p. refs
(AIAA PAPER 87-1322)

Three-dimensional forced unsteady flow separation about a 30 deg forward swept wing was visualized for a constant pitch rate motion from 0 to 60 deg. The development of both wing tip and inboard leading edge vortices were observed with characteristics similar to those found in straight wing tests. The off-axis pitch geometry appeared to delay the initiation of the wing tip vortex to large angles at attack, indicative of a delayed lift response. The results are contrasted with previous straight wing findings using similar pitch motions and swept wing results obtained using sinusoidal motion histories. Author

**A87-44931#**
**FORCED UNSTEADY VORTEX FLOWS DRIVEN BY PITCHING AIRFOILS**
JOHN M. WALKER (USAF, Frank J. Seiler Research Laboratory, Colorado Springs, CO) and DAVID C. CHOU (New Mexico, University, Albuquerque) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 14 p. refs
(AIAA PAPER 87-1331)

Experiments were conducted with a NACA 0015 airfoil pitching rapidly to high angles of attack to study the initiation, development, and evolution of dynamic stall vortex flows. The airfoil was pitched about its quarter-chord axis from zero to sixty degrees geometric angle of attack at rates from 115 deg/sec to 1380 deg/sec and at flow speeds from 10 to 80 ft/sec (chord Reynolds numbers from 25,000 to 200,000). Smoke-wire flow visualization, dynamic surface pressure measurement, and near-surface hot-film velocity magnitude measurement experiments were performed and correlated to determine the nature of the elicited time dependent vortex flows. Lift, pressure drag, and moment coefficients were calculated to be far in excess of the maximum steady flow values and were shown to be functions of the non-dimensional pitch rate. Author

**A87-44932#**
**COMPARISONS OF UNSTEADY FLOW FIELDS ABOUT STRAIGHT AND SWEPT WINGS USING FLOW VISUALIZATION AND HOTWIRE ANEMOMETRY**
J. ASHWORTH, S. HUYER, and M. LUTTGES (Colorado, University, Boulder) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 13 p. refs
(Contract F49620-83-K-0009)
(AIAA PAPER 87-1334)

The dynamic spatial and temporal differences in the unsteady flow fields produced about three sinusoidally oscillating wings differing in sweep angle are verified using flow visualization and hot-wire anemometry techniques. The measured local velocity fluctuations showed the position, size, and relative velocities of the flow-field structures. Chordwise anemometric investigations performed over the complete pitching cycle verified the formation, development, and convection of the visualized leading-edge vortex structure. From a spanwise comparison of flow-visualization and anemometry data, it is found that wing sweep angles produced major changes in vortex initiation, development, and convection velocity. R.R.

**A87-44933*#** Kansas Univ.; Lawrence.
**INCOMPRESSIBLE NAVIER-STOKES COMPUTATIONS OF VORTICAL FLOWS OVER DOUBLE-DELTA WINGS**
CHUNG-HAO HSU (Kansas, University, Lawrence), PETER-MICHAEL HARTWICH (Vigyan Research Associates, Inc., Hampton, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 10 p. refs
(Contract NAG1-455; NAS1-17919)
(AIAA PAPER 87-1341)

An implicit flux-difference splitting scheme is used to compute incompressible laminar vortical flows about a thin round-edged double-delta wing with 80 deg and 60 deg leading-edged sweep for the strake and the main wing respectively. The numerical scheme combines approximate factorization in crossflow planes with a symmetric planar Gauss-Seidel relaxation in the remaining spatial direction. It is second-order accurate spatially by applying TVD-like upwind discretization to the inviscid fluxes and central differencing to the viscous shear fluxes. The interaction between the two primary vortices emanating from the apex and kink leading-edges is successfully simulated. The computed trajectories of vortical cores compare well with experimental data. Author

**A87-44934*#** California Univ., Davis.
**VORTEX BREAKDOWN SIMULATION**
M. HAFEZ, J. AHMAD (California, University, Davis), G. KURUVILA, and M. D. SALAS (NASA, Langley Research Center, Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 20 p. refs
(AIAA PAPER 87-1343)

In this paper, steady, axisymmetric inviscid, and viscous (laminar) swirling flows representing vortex breakdown phenomena are simulated using a stream function-vorticity-circulation formulation and two numerical methods. The first is based on an inverse iteration, where a norm of the solution is prescribed and the swirling parameter is calculated as a part of the output. The second is based on direct Newton iterations, where the linearized equations, for all the unknowns, are solved simultaneously by an efficient banded Gaussian elimination procedure. Several numerical solutions for inviscid and viscous flows are demonstrated, followed by a discussion of the results. Some improvements on previous work have been achieved: first order upwind differences are replaced by second order schemes, line relaxation procedure (with linear convergence rate) is replaced by Newton's iterations (which converge quadratically), and Reynolds numbers are extended from 200 up to 1000. Author

**A87-44938*#** Toledo Univ., Ohio.
**AN LDA INVESTIGATION OF THREE-DIMENSIONAL NORMAL SHOCK-BOUNDARY LAYER INTERACTIONS IN A CORNER**
R. M. CHRISS, T. G. KEITH, JR. (Toledo, University, OH), W. R. HINGST, A. J. STRAZISAR, and A. R. PORRO (NASA, Lewis Research Center, Cleveland, OH) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 12 p. refs
(Contract NAG3-309)
(AIAA PAPER 87-1369)

Nonintrusive, three-dimensional, measurements have been made of a normal shock wave-turbulent boundary layer interaction. The measurements were made in the corner of the test section of a continuous supersonic wind tunnel in which a normal shock wave had been stabilized. LDA, surface pressure measurement and flow visualization techniques were employed for two freestream Mach number test cases: 1.6 and 1.3. The former contained separated flow regions and a system of shock waves. The latter was found to be far less complicated. The reported results are believed to accurately define the flow physics of each case and may be used as benchmark data to verify three-dimensional computer codes. Author

**A87-44943#**
**AERO-OPTICAL ANALYSIS OF COMPRESSIBLE FLOW OVER AN OPEN CAVITY**
PHILIP E. CASSADY, STANLEY F. BIRCH, and P. JOHN TERRY (Boeing Aerospace Co., Seattle, WA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 13 p. Research supported by the Boeing Aerospace Co. and Boeing Commercial Airplane Co. refs
(AIAA PAPER 87-1399)

The propagation of light from a distant point source to an idealized optical detector mounted above an open hole in the body of an aircraft in transonic high-altitude flight is investigated theoretically, with a focus on the effects of the compressible turbulent shear layer forming between the hole and the ambient air. The flow is simulated numerically (using codes based on the two-dimensional time-dependent Navier-Stokes equations) for altitudes 40,000-50,000 ft and Mach numbers 0.6-0.8; the optical effects are evaluated (using FFT ray-tracing and image-formation codes) for look angles from -60 to +60 deg; and the results are presented graphically. Image distortion is found to comprise mainly wavefront tilt (with little higher-order distortion), while image blur is attributed to coherent structures in the turbulent shear layer. T.K.

**A87-44945*#** High Technology Corp., Hampton, Va.
**STATIONARY DISTURBANCES IN THREE-DIMENSIONAL BOUNDARY LAYERS OVER CONCAVE SURFACES**
F. S. COLLIER, JR. and M. R. MALIK (High Technology Corp., Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 15 p. refs
(Contract NAS1-18240)
(AIAA PAPER 87-1412)

A two-dimensional boundary layer on a concave surface is known to be susceptible to centrifugal instability which manifests itself in the form of stationary streamwise counter-rotating vortices commonly known as Goertler vortices. In this paper, the problem of the stability of a three-dimensional boundary layer on a concave surface is considered. Linear stability equations, including streamline and surface curvature effects, are solved for an infinitely swept wing. The results indicate that the Goetler vortex structure begins to transform into co-rotating vortices when the crossflow Reynolds number is increased. This transition is almost complete when the crossflow Reynolds number is in excess of 45. It is shown that the centrifugal effects destabilize the crossflow vortices. Some comparisons with available experimental results are made. Author

**A87-44946*#** High Technology Corp., Hampton, Va.
**PREDICTION AND CONTROL OF TRANSITION IN HYPERSONIC BOUNDARY LAYERS**
MUJEEB R. MALIK (High Technology Corp., Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 13 p. refs
(Contract NAS1-18240)
(AIAA PAPER 87-1414)

In this paper, the role of compressible linear stability theory in prediction of boundary layer transition at supersonic and hypersonic speeds is investigated. Computations for sharp cones, using the e exp N method with N = 10, show that the first oblique Tollmien-Schlichting mode is responsible for transition at adiabatic wall conditions for freestream Mach numbers up to 7. For cold walls, the two-dimensional second mode dominates the transition process at lower hypersonic Mach numbers due to the well-known destabilizing effect of cooling on the second mode. It is shown that pressure gradient and suction may be used to stabilize this mode. Some results on the real gas effects on hypersonic boundary-layer stability are presented. Author

**A87-44947*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**STABILITY AND TRANSITION IN SUPERSONIC BOUNDARY LAYERS**
GORDON ERLEBACHER (NASA, Langley Research Center, Hampton, VA) and M. YOUSUFF HUSSAINI (NASA, Langley Research Center; Institute for Computer Applications in Science and Engineering, Hamp AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 13 p. refs
(AIAA PAPER 87-1416)

The full three-dimensional time-dependent compressible Navier-Stokes equations are numerically solved by a Fourier-Chebyshev collocation algorithm to study the stability of supersonic flows over a flat plate. Several non-linear numerical experiments suggest the existence of a secondary instability which might provide a possible route to transition. The interaction of the modes involved in this secondary instability is possibly amenable to a Floquet theory. Pertinent differences between this instability and the more common incompressible K-type instabilities are pointed out. Author

**A87-44948#**
**LINEAR INSTABILITY WAVES IN SUPERSONIC TURBULENT MIXING LAYERS**
SAAD A. RAGAB (Virginia Polytechnic Institute and State University, Blacksburg) and J. L. WU AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 17 p. refs
(Contract N00014-87-K-0168)
(AIAA PAPER 87-1418)

The structures of supersonic turbulent mixing layers are presumed to be spatially growing instability waves superimposed on mean flows which are also spatially diverging. The objective of the work presented here is to determine these waves, and to evaluate the effect of certain parameters such as mean velocity and temperature profiles on the stability characteristics (growth rate, most amplified frequency, etc.). Linear stability theory of nonparallel mean flow has been used. Three-dimensional waves in the form of axisymmetric as well as helical modes interacting with axisymmetric basic state are considered. The basic state is determined by solving the axisymmetric turbulent boundary-layer equations for the configuration of unconfined coaxial mixing. A mixing length model is used for turbulence closure. Increasing the Mach number of the outer stream or increasing the temperature of the inner stream (gas generator) significantly reduces the growth rate and gain along the mixing layer length. Author

**A87-44949#**
**SIMULATIONS OF RAMJET COMBUSTOR FLOW FIELDS. I - NUMERICAL MODEL, LARGE-SCALE AND MEAN MOTIONS**
SURESH MENON and WEN-HUEI JOU (Flow Research Co., Kent, WA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 20 p. refs
(Contract N00014-84-C-0359)
(AIAA PAPER 87-1421)

An account is given of the results of a research effort using large-eddy numerical simulation to understand the flow pressure oscillations in a ramjet combustor. The numerical technique used in solving the compressible Navier-Stokes equations and the implementation of the proper boundary conditions are presented, together with simulations ensuring that the calculated flow field is independent of grid resolution. The separated shear layer is shown to be unstable, so that concentrated vortices are formed by the growth of instability waves. Where the separated shear layer reattaches on the nozzle wall, strong counter-rotating vortices are produced which may be the primary acoustic sources. O.C.

**A87-44950#**
**SIMULATIONS OF RAMJET COMBUSTOR FLOW FIELDS. II - ORIGIN OF PRESSURE OSCILLATIONS**
WEN-HUEI JOU and SURESH MENON (Flow Research Co., Kent, WA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 14 p. refs
(Contract N00014-84-C-0359)
(AIAA PAPER 87-1422)

The vorticity fluctuations and pressure fluctuations present in the flow inside a ramjet combustor appear to be coherent; an attempt is presently made to identify the mechanism leading to the observed fluctuations, extracting acoustic information from computed results by visualization of the instantaneous dilatation field. The dilatation field near the impingement point of the shear layer on the nozzle wall is analyzed by multipole expansion of the computed dilatation field. The spectra of pressure and vorticity fluctuations are analyzed to reveal the existence of two types of fluctuation: the resonant acoustic mode and the coupled mode. A simple model is proposed for the coupled mode. O.C.

**A87-44951#**
**NUMERICAL INVESTIGATION OF THE FLOW STRUCTURE AROUND A RAPIDLY PITCHING AIRFOIL**
MIGUEL R. VISBAL and JOSEPH J. S. SHANG (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 19 p. refs
(AIAA PAPER 87-1424)

A numerical study is presented for unsteady laminar flow past a NACA 0015 airfoil which is pitched, at a nominally constant rate, from zero incidence to a very high angle of attack. The flow field simulation is obtained by solving the full two-dimensional compressible Navier-Stokes equations on a moving grid employing an implicit approximate-factorization algorithm. An assessment of the accuracy of the computed solutions is presented, and the numerical results are shown to be of sufficient quality to merit physical interpretation. The highly unsteady flow field structure is described and is found to be in qualitative agreement with available experimental observations. A discussion is provided for the effects of pitch rate and pitch axis location on the induced vortical structures and on the airfoil aerodynamic forces. Author

**A87-44952*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**THE NUMERICAL SIMULATION OF SUBSONIC FLUTTER**
THOMAS W. STRGANAC, MARIA V. MITCHUM (NASA, Langley Research Center, Hampton, VA), and DEAN T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 11 p.
(AIAA PAPER 87-1428)

The present paper describes a numerical simulation of unsteady, subsonic aeroelastic responses. The technique accounts for aerodynamic nonlinearities associated with angles of attack, vortex-dominated flow, static deformations, and unsteady behavior. The fluid and the wing together are treated as a single dynamic system, and the equations of motion for the structure and flowfield are integrated simultaneously and interactively in the time domain. The method employs an iterative scheme based on a predictor-corrector technique. The aerodynamic loads are computed by the general unsteady vortex-lattice method and are determined simultaneously with the motion of the wing. Two models are used to demonstrate the technique: a rigid wing on an elastic support experiencing plunge and pitch about the elastic axis, and a continuous wing rigidly supported at the root chord experiencing spanwise bending and twisting. The time domain solution coupled with the unsteady vortex-lattice method provides the capability of graphically depicting wing and wake motion. Several graphs that illustrate the time domain behavior of the wing and wake are presented. Author

**A87-44953*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**TRANSONIC WALL INTERFERENCE ASSESSMENT AND CORRECTIONS FOR AIRFOIL DATA FROM THE 0.3-METER TCT ADAPTIVE WALL TEST SECTION**
LAWRENCE L. GREEN and PERRY A. NEWMAN (NASA, Langley Research Center, Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 25 p. refs
(AIAA PAPER 87-1431)

The wall interference assessment/correction code presented is nonlinear, involves four walls, and is applicable to transonic airfoil data from wind tunnels with shaped, solid top and bottom walls. Attention is given to its application to data from the NASA 0.3-m Transonic Cryogenic Tunnel Adaptive Test Section, for two sizes of a NACA 0012 airfoil and to simulated data for an inviscid two-dimensional full-potential code. This study indicates that while adaptive wall wind tunnels significantly reduce some aspects of wall-interference effects (by comparison to straight solid and slotted wall wind tunnels), residual wall and other interference effects are present. O.C.

**A87-44955#**
**FLOW-FIELD MEASUREMENTS OF AN AIRFOIL WITH A DEFLECTED SPOILER USING AN LDV SYSTEM**
S. BODAPATI, M. J. FOREMAN (U.S. Naval Postgraduate School, Monterey, CA), and C. S. LEE (Stanford University, CA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 11 p. Research supported by the Boeing Airplane Co. and U.S. Army. refs
(AIAA PAPER 87-1438)

Typical experiments were carried out in a small, low-speed wind tunnel to obtain the mean and fluctuating flow fields of an airfoil with a deflected spoiler using a two-component laser Doppler velocimetry (LDV) system. The mean wake profiles and turbulent shear stresses were evaluated and compared with the available hot-wire and predicted results. Velocity and turbulent stress contour plots are also presented. Hot-wire results were not available close to the trailing edge because of the reverse flow. The predicted results were evaluated using a two dimensional vortex tracing method. The hot-wire anemometer gives reasonably accurate results where there is no reverse flow and the flow is not highly turbulent. The LDV gives accurate results close to the trailing edge where other methods fail. In general the LDV results are in better agreement with the calculated results. Author

**A87-45094#**
**STUDY ON THE INTERFERENCE BETWEEN THE LOCAL SEPARATION ON A WING SURFACE AND OUTER FLOW-FIELD**
KENJI YOSHIDA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 399, 1987, p. 197-203. In Japanese, with abstract in English. refs

This paper presents a theoretical consideration on the interference between the local separated region and its outer flow. To simplify the analysis, a straight wing with an infinite span is assumed to have locally nonuniform distribution of transition points. Using the boundary-layer theory and lifting-line theory, the influence of such local disturbances on the boundary layer and its outer flow is investigated in detail. From this, three-dimensional characteristics of the local separation are deduced. Once the local separation occurs, the thickness of separated region is increased by the effect of trailing vortices, and the thickness of the boundary layer near its region is decreased. The effect of three-dimensional boundary layer is opposite to that of trailing vortices. Moreover, the separated region is localized by the influence of induced cross flow as well as trailing vortices. Author

**A87-45182*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INVESTIGATION OF A DELTA-WING FIGHTER MODEL FLOW FIELD AT TRANSONIC SPEEDS**
E. ANN BARE, DAVID E. REUBUSH (NASA, Langley Research Center, Hampton, VA), RAYMOND HADDAD, ROSS W. HATHAWAY (McDonnell Aircraft Co., St. Louis, MO), and MIKE COMPTON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-1749)

The paper reports a flow-field investigation on a 7.52-percent scale model of an advanced fighter aircraft design conducted in the NASA-Langley 16-ft Transonic Tunnel. The effects of free-stream Mach number, angle-of-attack, angle of sideslip, and various vortex control devices on the local flow values were studied. The model was tested at Mach numbers of 0.6, 0.9, and 1.2 and the angles of sideslip of 0 and +/- 5 deg; the model angle-of-attack was varied from -4 to 30 deg. Results are presented in terms of contour plots of local total pressure recovery. The dominant influence on the over-wing flow field was found to be the wing leading-edge vortex which first appears in the survey region at an angle-of-attack of 8 deg and increases in strength and influence with increasing angle-of-attack, finally dominating the entire survey region at very high angles-of-attack. I.S.

**A87-45183#**
**FLOW BEHIND SINGLE- AND DUAL-ROTATION PROPELLERS AT ANGLE OF ATTACK**
THOMAS TENEROWICZ (Boeing Commercial Airplane Co., Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1750)

The results from two wind tunnel tests, which were conducted to establish a data base to definee the local flowfield downstream of both single- and dual-rotation propellers, are presented here. The model used for both tests consisted of a nacelle containing a gearbox and a 29-hp electric motor that was used to drive an eight-bladed SR-2 propeller in the first and two counterrotating, four-bladed SR-2 propellers in the second test. The data were collected at two circumferential and four radial positions by using two split-film flow angularity probes attached to a rake slightly aft of the propellers. The data for both tests were collected at simulated takeoff conditions. The test results show that the top inlet location is best for a single-rotation configuration and that either top or bottom inlet location is appropriate for a dual-rotation configuration. The data also show that the dual-rotation propellers produce lower levels of swirl and radial flow angles at all locations. Author

**A87-45184#**
**TWO-DIMENSIONAL NUMERICAL ANALYSIS FOR INLETS AT SUBSONIC THROUGH HYPERSONIC SPEEDS**
R. H. BUSH, P. G. VOGEL, W. P. NORBY, and B. A. HAEFFELE (McDonnell Aircraft Co., St. Louis, MO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1751)

FANSI (factored algorithm for Navier-Stokes, inlets) is a two-dimensional flowfield analysis code for inlet flowfield studies which is valid for subsonic through hypersonic speeds. Examples are presented which reveal the code's applicability over a wide range of conditions with attached and separated boundary layers. The code can accurately predict the loss mechanisms (flow separation shock formation) occurring at subsonic maneuver conditions for a traditional two-ramp external-compression outlet. In addition, it is capable of obtaining hypersonic separated solutions in high contraction ratio diffusers. K.K.

**A87-45185#**
**NAVIER-STOKES SIMULATIONS OF SUPERSONIC FIGHTER INTAKE FLOWFIELDS**
JOSEPH VADYAK, MARILYN J. SMITH, and DAVID M. SCHUSTER (Lockheed-Georgia Co., Advanced Flight Sciences Dept., Marietta) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 17 p. Research supported by Lockheed Independent Research and Development Programs. refs
(AIAA PAPER 87-1752)

An analysis is presented for calculating steady (or unsteady) three-dimensional supersonic fighter intake flowfields. This algorithm can compute the flowfield about forebody, inlet, and diffuser configurations at zero or nonzero incidence. The algorithm can solve either the Euler momentum equations for inviscid flow, the thin- and shear-layer Navier-Stokes equations for viscous flow, or the full Navier-Stokes equations for viscous flow. The flowfield is determined on a body-fitted numerically-generated computational grid. A fully-implicit alternating-direction-implicit algorithm is employed for solution of the finite-difference equations. Viscous flow results are presented to illustrate application of the analysis for cases at supersonic free-stream speeds. Author

**A87-45238*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**PARAMETRIC STUDY OF SINGLE EXPANSION RAMP NOZZLES AT SUBSONIC/TRANSONIC SPEEDS**
F. J. CAPONE, R. J. RE, E. A. BARE (NASA, Langley Research Center, Hampton, VA), and M. K. MACLEAN (General Electric Co., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987.—12 p. refs
(AIAA PAPER 87-1836)

The Langley Research Center has conducted a parametric investigation to determine the aeropropulsive characteristics of single expansion ramp nozzles (SERN). The SERN is a nonaxisymmetric, variable-area, internal/external expansion exhaust nozzle. Internal nozzle parameters that were varied included upper ramp length, ramp chordal angle, lower flap length, flap angle and the axial and vertical locations of nozzle throat. Convergent-divergent and convergent nozzles were included in this investigation which was conducted in the Langley 16-Foot Transonic Tunnel at Mach numbers from 0.6 to 1.2 and at nozzle pressure ratios up to 12.0. Author

**A87-45278#**
**PERFORMANCE CALCULATION OF COUNTER ROTATION PROPELLER**
S. SAITO, H. KOBAYASHI (National Aerospace Laboratory, Tokyo, Japan), K. NASU (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), and Y. NAKAMURA AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1889)

A newly developed aerodynamic code, named Local Circulation Method (LCM), was applied to high-speed counterrotation propellers (CRPs) to investigate the potentials of these highly skewed/swept blade systems operating in high subsonic or transonic range. The calculations of CRP performance in a wide range of geometrical and operational rotor variables provided the design data base for CRPs, including efficiency maps parametered by blade pitch angles of front and rear rotor. It was shown that, compared with SRP, the CRP has a potential of higher efficiency with several percentage points. I.S.

**A87-45280#**
**EXTENSION OF LOCAL CIRCULATION METHOD TO COUNTER ROTATION PROPELLER**
SHIGERU SAITO, HORISHI KOBAYASHI (National Aerospace Laboratory, Tokyo, Japan), YOSHIYA NAKAMURA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), and KENICHI NASU AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-1891)

A computational method for rotary wing airloading calculation called the local circulation method (LCM) has been extended to a counter rotation propeller (CRP). The new method is a combination of LCM for single rotor and a coaxial helicopter rotor model used in the local momentum theory (LMT) with some modifications. The interaction of two rotors via swirl velocity is introduced in addition to axial induced velocity. Results are compared with those of experiment for subsonic CRP performance and showed a good agreement. It is applied to transonic propeller employing experimental two-dimensional lift slope data at high Mach number. It also resulted in a good agreement with Euler calculation in single rotation advanced turbo-prop (ATP). Some results of calculation are given both for performance and time dependent airloading. Author

**A87-45281*#** Lockheed-Georgia Co., Marietta.
**WIND TUNNEL TESTS ON A ONE-FOOT DIAMETER SR-7L PROPFAN MODEL**
ABDULLAH S. ALJABRI (Lockheed-Georgia Co., Marietta) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p.
(Contract NAS3-24339)
(AIAA PAPER 87-1892)

Wind tunnel tests have been conducted on a one-foot diameter model of the SR-7L propfan in the Langley 16-Foot and 4 x 7 Meter Wind Tunnels as part of the Propfan Test Assessment (PTA) Program. The model propfan was sized to be used on a 1/9-scale model of the PTA testbed aircraft. The model propeller was tested in isolation and wing-mounted on the aircraft configuration at various Mach numbers and blade pitch angles. Agreement between data obtained from these tests and data from Hamilton Standard validate that the 1/9-scale propeller accurately simulates the aerodynamics of the SR-7L propfan. Predictions from an analytical computer program are presented and show good agreement with the experimental data. Author

**A87-45283#**
**NUMERICAL ANALYSIS OF PEAK HEAT TRANSFER RATES FOR HYPERSONIC FLOW OVER A COWL LEADING EDGE**
JEFFREY A. WHITE (Pratt and Whitney, West Palm Beach, FL) and CHEA M. RHIE (Pratt and Whitney, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-1895)

The complex viscous shock interaction phenomenon present when an oblique shock impinges on a blunt body bow shock, and the peak heat transfer rates representative of the flow field near the inlet cowl leading edge of a hypersonic vehicle are computed. A pressure based implicit finite volume method is used to solve the steady state Reynolds averaged Navier-Stokes equations for the flow field. Steady state solutions are obtained for the complete bow-oblique shock flow field with all shocks, shear layers, jets, and boundary layers being captured by the computational procedure. Computed results are presented for two dimensional blunt body flows with and without shock impingement and are compared with data. Computed peak heat transfer and stagnation pressure augmentation are presented and compared with experimental data. Author

**A87-45284*#** PEDA Corp., Palo Alto, Calif.
**AERODYNAMIC DESIGN MODIFICATION OF A HYPERSONIC WIND TUNNEL NOZZLE BY CSCM WITH HIGH ORDER ACCURACY**
J. Y. YANG, C. K. LOMBARD, R. C.-C. LUH, N. NAGARAJ, and W. H. CODDING (PEDA Corp., Palo Alto, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(Contract NAS2-12243)
(AIAA PAPER 87-1896)

An improved version of the CSCM implicit Navier-Stokes solver with a flexible data structure has been applied, in conjunction with a sophisticated patched grid system, to the aerodynamic analysis of hypersonic axisymmetric contoured nozzles of the NASA-Ames 3.5-foot hypersonic wind tunnel. The results obtained are found to be in good agreement with experiment. Based on the analysis, a newly designed throat contour for the Mach 14 nozzle has been recommended. V.L.

**A87-45332*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**THREE-DIMENSIONAL NUMERICAL PREDICTIONS OF THE FLOW BEHIND A REARWARD-FACING-STEP IN A SUPERSONIC COMBUSTOR**
K. UENISHI (NASA, Langley Research Center; Vigyan Research Associates, Inc., Hampton, VA), R. C. ROGERS, and G. B. NORTHAM (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1962)

A CFD code was developed to compute the mixing and combustion of hydrogen fuel in the turbulent flow fields of scramjets. The code is based on the complete Reynold's time-averaged three-dimensional Navier-Stokes equations, and chemical species equations. The code includes a global finite rate hydrogen-air chemical reaction model and the Baldwin-Lomax (1978) turbulence model. The validity of this CFD code was demonstrated by comparing computed results from the code with existing data for three configurations, each containing an important feature of the scramjet combustor flow. The code was then applied to the reacting flow field in a complex combustor model in which hydrogen fuel was injected transversely into a supersonic hot airstream through several fuel injectors. I.S.

**A87-45334#**
**FORCE ACCOUNTING FOR AIRFRAME INTEGRATED ENGINES**
GARY A. SULLINS and FREDERICK S. BILLIG (Johns Hopkins University, Laurel, MD) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1965)

This paper is intended to clarify some of the issues concerning force accounting methods for systems employing air breathing propulsion. A detailed derivation of the thrust equation is presented for a somewhat simplified vehicle configuration using the freestream as the upstream reference plane. In doing so, forces on the forebody were considered as aerodynamic forces. The method was then extended to a more complicated vehicle in which the engine is integrated into a vehicle airframe. Since this is but one of the possible methods of force accounting, it was compared to another in which the inlet cowl plane is used as the upstream reference plane. Whereas, this alternative method and others are valid, as long as all forces are properly accounted for, to obtain the same degree of accuracy requires considerably more rigor. Author

**A87-45386*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**UNSTEADY THREE-DIMENSIONAL NAVIER-STOKES SIMULATIONS OF TURBINE ROTOR-STATOR INTERACTION**
MAN MOHAN RAI (NASA, Ames Research Center, Moffett Field, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 29 p. NASA-supported research. refs
(AIAA PAPER 87-2058)

Fluid flows within turbomachinery tend to be extremely complex. Understanding such flows is crucial to efforts to improve current turbomachinery designs, and the computational approach can be used to great advantage in this regard. This study presents a finite-difference, unsteady, thin-layer Navier-Stokes approach to calculating the flow within an axial turbine stage. The relative motion between the stator and rotor airfoils is made possible with the use of patched grids that move relative to each other. The calculation includes end-wall and tip-leakage effects. Results in the form of time-averaged surface pressures, pressure amplitudes (corresponding to the pressure fluctuation in time), near-surface velocity vectors, and pressure contours in the passage areas are presented. The numerical results are compared with experimental data wherever possible, and the agreement between the two is found to be good. Author

**A87-45394#**
**THE INFLUENCE OF FLOW NON-UNIFORMITIES IN AIR-BREATHING HYPERSONIC PROPULSION SYSTEMS**
MARK J. LEWIS and DANIEL E. HASTINGS (MIT, Cambridge, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 15 p. Research supported by the Charles Stark Draper Laboratory. refs
(AIAA PAPER 87-2079)

The generation of inlet nonuniformities and their influence on the flowfield of a supersonic combustion ramjet, or scramjet, is examined. In particular, the problem of inlet Mach number and mass flux stratification through the formation of a thick forebody boundary layer is considered, along with the effect that the boundary layer flow will have on the inviscid core region inside the scramjet. Estimates are made of the expected thickness of the hypersonic boundary layer at various flight conditions that are applicable to a trans-atmospheric vehicle trajectory, and these are related to the position of the vehicle bow shock. It is found that an engine designed for uniform flow cannot tolerate large inlet gradients in Mach number and mass flux. It is suggested that, in order to reduce the thickness of the forebody boundary layer, an aerospace plane may operate more effectively at lower altitudes than those which optimize lift-to-drag. Such a vehicle would also be restricted to a narrow range of angles of attack because of the sensitivity of the hypersonic boundary layer thickness to deflection angle. Author

**A87-45397#**
**A STAGE-BY-STAGE POST-STALL COMPRESSION SYSTEM MODELING TECHNIQUE**
M. W. DAVIS, JR. (Sverdrup Technology, Inc., Arnold Air Force Station, TN) and W. F. O'BRIEN (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 15 p. refs
(AIAA PAPER 87-2088)

A one-dimensional, stage-by-stage axial compression system mathematical model has been constructed which can describe system behavior during post-stall events such as surge and rotating stall. The model uses a numerical technique to solve the nonlinear conservation equations of mass, momentum, and energy. Inputs for blade forces and shaft work are provided by a set of quasi-steady stage characteristics modified by a first-order lagging equation to simulate dynamic stage characteristics. The model was validated with experimental results for a three-stage, low-speed compressor and a nine-stage, high-pressure compressor. Using the model, a parametric study was conducted to determine the effect on post-stall system behavior of inlet resistance, combustor performance, heat transfer, and stage characteristic changes. Results demonstrate a new capability for the analysis of design options and operating conditions on compression system post-stall behavior. Author

**A87-45413*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**TWO-DIMENSIONAL NOZZLE PLUME CHARACTERISTICS**
UWE H. VON GLAHN (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 20 p. Previously announced in STAR as N87-18540. refs
(AIAA PAPER 87-2111)

Future high performance aircraft will likely feature asymmetric or two-dimensional nozzles with or without ejectors. In order to design two-dimensional nozzle/ejector systems of minimum size and weight, the plume decay and spreading characteristics of basic two-dimensional nozzles must first be established. The present work deals with the experimental analyses of these plume characteristics and includes the effects of nozzle aspect ratio and flow conditions (jet Mach number and temperature) on the plume decay and spreading of two-dimensional nozzles. Correlations including these variables are developed in a manner similar to those previously developed successfully for conic and dual-flow plumes. Author

**A87-45414*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**SECONDARY STREAM AND EXCITATION EFFECTS ON TWO-DIMENSIONAL NOZZLE PLUME CHARACTERISTICS**
UWE H. VON GLAHN (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. Previously announced in STAR as N87-18539. refs
(AIAA PAPER 87-2112)

In order to design two-dimensional nozzle/ejector systems for future high performance aircraft, the basic engine exhaust plume velocity and temperature decay as effected by the secondary stream (ejector) and decay augmentation means must be assessed. Included in the assessment of the plume decay characteristics are the effects of nozzle aspect ratio and nozzle/ejector flow conditions. Nozzle/ejector plume decay can be enhanced by suitable excitation of the plume shear layers. Correlations of these factors are developed in a manner similar to those previously developed for conic and dual-flow nozzle plumes. Author

**A87-45435#**
**DEVELOPMENT OF A VISCOUS CASCADE CODE BASED ON SCALAR IMPLICIT FACTORIZATION**
C. J. KNIGHT and D. CHOI (Avco Everett Research Laboratory, Inc., MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 18 p. Research sponsored by the Avco Lycoming Independent Research and Development Program. refs
(AIAA PAPER 87-2150)

A viscous cascade code has been developed, first for 2D configurations and then extended to 3D linear cascades with flat, parallel endwalls. It employs scalar implicit approximate factorization, a finite volume formulation, second order upwind differencing, and a two-equation q-omega turbulence model based on integration to the wall. A special form of the thin layer approximation for the compressible Navier-Stokes equations is used which gives accurate skin friction predictions on highly skewed meshes, now based on sheared H-grids. The 2D code has been validated by considering testcases for NASA Energy Efficient Engine blade and vane cascade geometries. The turbulence model displays proper boundary layer transition behavior. The 3D E(3) vane cascade has also been considered with straight endwalls. Agreement with experiment is quite good. Author

**A87-45436#**
**NAVIER-STOKES SOLUTIONS FOR HIGHLY LOADED TURBINE CASCADES**
B. N. SRIVASTAVA (Avco Everett Research Laboratory, Inc., Everett, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. Research supported by the Avco Everett Research Laboratory Independent Research and Development Funds. refs
(AIAA PAPER 87-2151)

This paper deals with computation of 2-D turbulent thin-layer Navier-Stokes equations in a highly loaded turbine cascade geometry at subsonic and transonic conditions. MacCormack's explicit scheme has been utilized for overall cascade flow predictions which have been favorably compared with flow visualizations for bulk flow behavior and with surface pressure data, outflow angles and outflow Mach numbers for both C- and H-grid topologies. Author

**A87-45779**
**WAKE MEASUREMENTS OF AN OSCILLATING AIRFOIL**
S. O. PARK and J. S. KIM (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) IN: Turbulence measurements and flow modeling; Proceedings of the International Symposium, Iowa City, IA, Sept. 16-18, 1985 . Washington, DC, Hemisphere Publishing Corp., 1987, p. 127-136. Research supported by the Korea Advanced Institute of Science and Technology and Korea Science Foundation. refs

Wake flow fields of NACA 0012 airfoil oscillating sinusoidally about 25 percent chord axis are investigated using hot wire deg anemometry and flow visualization. Measurements are performed at 0 deg mean incidence angle with oscillation amplitude of 7.4 deg, for three values of reduced frequency K = 0.09, 0.13 and 0.20. Velocity and turbulence intensity profiles, determined by ensemble average technique, are reported and compared. A peculiar flow pattern with 'turbulent blobs' is observed during the period of oscillation, of which the visualization picture is included. Author

**A87-45792**
**UNSTEADY VISCOUS FLOWS ROUND MOVING CIRCULAR CYLINDERS AND AIRFOILS. II**
Y. LECOINTE and J. PIQUET (Ecole Nationale Superieure de Mecanique, Nantes, France) IN: Turbulence measurements and flow modeling; Proceedings of the International Symposium, Iowa City, IA, Sept. 16-18, 1985 . Washington, DC, Hemisphere Publishing Corp., 1987, p. 675-684. refs
(Contract DRET-83/215)

High Reynolds number laminar flow around circular cylinders and airfoils, with or without superimposed motions of high reduced amplitude, are presently addressed by the solution of unsteady, two-dimensional Navier-Stokes equations that are written in their vorticity streamfunction formulation and then solved numerically by means of compact schemes. The procedure presented for the interpretation of harmonic results is shown to be useful. Attention is given to the cases of a pitching elliptic cylinder and a surging NACA 0012 airfoil. O.C.

**A87-46094**
**AERODYNAMIC CHARACTERISTICS OF WAVE RIDERS [AERODINAMICHESKIE KHARAKTERISTIKI VOLNOLETOV]**
A. I. SHVETS PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Mar.-Apr. 1987, p. 62-68. In Russian. refs

The lifting force, aerodynamic efficiency, and shock wave forms are investigated for several lifting configurations with a sharp bend in the transverse profile, including caret wings, triangular wings with a conical bend, winged pyramidal bodies, and rectangular-planform caret wings. In the Mach number range 2-6, the triangular-planform wings with a bend in the transverse profile investigated here are shown to have a higher aerodynamic efficiency than equivalent plane triangular wings. V.L.

**A87-46184#**
**A COMPUTATIONAL METHOD FOR DETERMINING FLOWFIELD PROPERTIES WHEN THE PITOT PRESSURE IS THE ONLY MEASURED INSTREAM PROPERTY**
R. D. STOCKBRIDGE (Johns Hopkins University, Laurel, MD) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 77-83. refs

A computational procedure has been developed for the calculation of all in-stream flow properties in a ducted supersonic flow where viscous effects are important. Experimental measurements of pitot pressures, wall pressures and temperature, and upstream plenum conditions are the input data. The method has been designed for use when reliable measurements for a second instream flowfield property are unavailable. The experimental flowfields for which the procedure was developed were Mach 1.66, 2.35 and 2.89 flows through an annular duct with a length to height ratio of 18.6. The computational procedure divides the annular cross section into five zones and applies various standard theoretical constraints to the measured data to solve for the instream flow properties. Author

**A87-46189#**
**EFFICIENCY PARAMETERS FOR INLETS OPERATING AT HYPERSONIC SPEEDS**
FREDERICK S. BILLIG and DAVID M. VAN WIE (Johns Hopkins University, Laurel, MD) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 118-130. refs

A variety of parameters have been introduced to define the efficiency of the compression process in the intake of an airbreathing engine. In some regard, each of the previously introduced efficiency parameters is deficient when applied to the case of an inlet operating at high hypersonic speed with a compressed gas comprised of nonuniform flow. This paper will delineate these deficiencies and will introduce a new parameter that avoids most of the previous limitations and provides a simplified tool for indexing complex inlet flows. Author

**A87-46191#**
**3-D VISCOUS FLOW CALCULATIONS AT DESIGN AND OFF-DESIGN CONDITIONS FOR THE NACA 48-INCH RADIAL-INLET CENTRIFUGAL IMPELLER**
JOHN MOORE and JOAN G. MOORE (Virginia Polytechnic Institute and State University, Blacksburg) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 139-148. Research supported by the Rolls-Royce, PLC. refs

An elliptic flow calculation procedure has been used to model three-dimensional flow in the NACA 48-inch centrifugal impeller. The results demonstrate that fully elliptic steady turbulent flow calculations can be performed at design and off-design conditions. The calculations reproduce most of the features of the NACA study and they allow a quantitative assessemnt of the NACA results. They show an ability to handle complex three-dimensional flow with leading-edge separation and tip leakage, and the losses due to these effects are in good agreement with the NACA measurements. Author

**A87-46192#**
**INVESTIGATION OF THE THREE DIMENSIONAL FLOW NEAR THE EXIT OF TWO BACKSWEPT TRANSONIC CENTRIFUGAL IMPELLERS**
CH. FRADIN (ONERA, Chatillon-sous-Bagneux, France) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 149-155. refs

By employing hot wire probes, a detailed analysis of the flow field in the vicinity of the impeller outlet section for two transonic centrifugal compressors with backward leaned blades has been carried out. One of the rotors is equipped with splitter vanes. Using coordinates within the relative frames linked to the rotor, the test results give the velocity distribution at the impeller outlet. Effect of the splitter vanes on flow distribution is clearly shown. Tests were made at several radii at the outlet of the rotor in the vaneless diffuser. The increase in amplitude of the axial heterogeneities and the decay of the blade to blade ones are shown. Using mean values of the impeller outlet flow parameters, the effect of rotor geometry on diffuser performance can be measured. Author

**A87-46195#**
**TRANSONIC STREAM FUNCTION SOLUTION ON S(2) STREAMSURFACE FOR A HIGH PRESSURE RATIO CENTRIFUGAL COMPRESSOR**
XIAOLU ZHAO (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 168-174. refs

In this paper, the conservative stream function equation expressed with respect to a curvilinear stream surface coordinate system is used to calculate the transonic flow field along S(2) stream surface of a centrifugal impeller. The problem of mixed flow can be solved by the use of artificial compressibility method, and the shock within the inducer can be captured automatically. The distribution of the fluid velocity from hub to shroud can be obtained directly by integrating the velocity gradient equation, after knowing the streamline pattern. A computer program has been coded which can be used in the S(1)-S(2) iteration procedure in order to get the three-dimensional analysis solution for a high pressure ratio centrifugal compressor. It can also be used as a component in a transonic means of CAD method, by which the designer can design a transonic centrifugal compressor more efficiently. The transonic flow field on a mean S(2) stream surface of an 8:1 pressure ratio centrifugal compressor impeller has been computed using this computer program. A comparison of computed results with experimental data shows fairly good agreement. Author

**A87-46204#**
**APPLICATION OF A 3D INVISCID ROTATIONAL DESIGN PROCEDURE FOR TURBOMACHINERY BLADINGS**
MAURO VARETTI and FRANCESCO LAROCCA (FIAT Aviazione S.p.A., Turin, Italy) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 246-252. refs

A method for solving cascade design problem for compressible inviscid three-dimensional flow is considered. The Euler equations are solved by using a time-marching procedure with one sided differences approximations. The method provides the geometry of the cascade corresponding to a given pressure jump distribution across the blade surfaces. The closure condition is directly ensured by prescribing blade thickness distribution. Examples are presented for inviscid rotational transonic shockless stator blades and some checks on the accuracy of the computations are discussed. Author

**A87-46206#**
**NUMERICAL SIMULATION OF TRANSONIC THREE-DIMENSIONAL FLOWS IN TURBINE BLADE PASSAGES**
M. IA. IVANOV IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 261-270. refs

There are presented the modern numerical methods of the transonic three-dimensional flow analysis widely used to turbine design of the airbreathing engines. Principal consideration is given to effective flow calculation procedures for the approximation of the ideal gas. Developed calculation methods are based on different flow models including potential approximation and full multi-dimensional models for vortex flows. Characteristic calculation examples of the transonic flows past turbine blade passages are given. Author

**A87-46208#**
**TIP CLEARANCE FLOWS. I - EXPERIMENTAL INVESTIGATION OF AN ISOLATED ROTOR. II - STUDY OF VARIOUS MODELS AND COMPARISON WITH TEST RESULTS**
M. J. P. SCHMIDT (Instituto Tecnologico de Aeronautica, Sao Jose dos Campos, Sao Paulo, Brazil), B. AGNEW (Newcastle-upon-Tyne, University, England), and R. L. ELDER (Cranfield Institute of Technology, Bedford, England) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 291-306. refs

Experiments have been undertaken to define the effect of tip clearance on a low-speed, isolated rotor over a range of tip clearances, with attention to the spanwise distribution of blade losses. The first part of this study notes that spanwise loss distribution is strongly dependent on tip clearance and stage loading values. The second part compares these results to predictions of various models, including those of Hesslegreaves (1969), Lewis (1977), Lakshminarayana (1970), and Robinson (1982). This last

model, which is the simplest one employed, also yielded the closest approximations to experimental results. O.C.

**A87-46211#**
**A STUDY OF SOME FACTORS AFFECTING THE PERFORMANCE OF A CONTRA-ROTATING AXIAL COMPRESSOR STAGE**
P. B. SHARMA, Y. P. JAIN, and D. S. PUNDHIR (Indian Institute of Technology, New Delhi, India) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeroanutics and Astronautics, 1987, p. 324-330. Research supported by the Aero R&D Board of India. refs

An experimental investigation of the performance of a contra-rotating stage is reported. The influence of factors such as speed ratio of the two rotors, rotor stagger, pitch-chord ratio and axial spacing between the rotors is examined from tests on a 0.66 hub-tip ratio compressor. The study reveals that the performance of a contra-rotating stage is affected by all these factors. Axial spacing between the rotors and the speed ratio of the rotors both exhibit a strong influence on the stalling behavior of the stage. It has been found that in a stage with close axial gap, rotating stall on the first rotor is suppressed if the second rotor is contra-rotated at a speed 50 percent faster than the first rotor. This unique advantage of contra-rotation is not obtained if the axial gap is large. Measurements of sound pressure level are also reported to highlight the high noise problems associated with a contra-rotating stage. Author

**A87-46215#**
**AN IMPROVED APPROACH FOR TRANSONIC FLOW**
F. MARTELLI (Firenze, Universita, Florence, Italy) and A. BORETTI IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 362-370. refs

An efficient explicit algorithm is presented for solving compressible time-dependent Navier-Stokes equations for mass, momentum, and energy in the transonic flow field of plane turbine cascades. The flow equations are written in dimensionless integral form, and then discretized by means of a classical explicit, dissipative, pseudounsteady finite-area technique. A simple algebraic eddy viscosity model is employed, and the results of coarse grid computations for two transonic turbine blade sections are found to be in good agreement with experimental data. O.C.

**A87-46216#**
**IMPROVEMENT OF AERODYNAMIC CALCULATION ON S(2)M STREAM SURFACE OF AXIAL COMPRESSOR BY USING OF ANNULUS WALL BOUNDARY LAYER CALCULATION**
WANG QINGHUAN and SU JIAN (Chinese Academy of Sciences, Institute of Engineering Thermophysics, People's Republic of China) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 371-377. refs

This paper presents an approach to improve the aerodynamic calculations on S(2)m (mean S(2) stream surface) by employing the annulus wall boundary layer (AWBL) calculation technique. A simplified formula of transforming the displacement thickness of AWBL into the mass flow blockage coefficient conventionally used in S(2)m calculation has been proposed. The inviscid-viscid iterative calculations using three different schemes have been carried out to investigate the blockage effects of AWBL on the S(2)m calculation. The results of improved S(2) calculations for both of a single-stage and a ten-stage axial compressor were compared with that measured by laser two-focus velocimeter in the compressor rotor. Author

**A87-46223#**
**FLOW PHENOMENA IN TRANSONIC TURBINE CASCADES DETAILED EXPERIMENTAL AND NUMERICAL INVESTIGATION**
H.-J. DIETRICHS, J. HOURMOUZIADIS, F. MALZACHER (MTU Motoren- und Turbine-Union Muenchen GmbH, Munich, West Germany), and W. BRAEUNLING (DFVLR, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 425-435. refs

The reduction of the number of turbine stages in order to reduce the weight, the complexity and the cooling air requirement of aircraft engines causes a considerable increase of the aerodynamic loading of the turbomachinery components. The resulting transonic flow fields within the vanes and blades of highly loaded turbines is dominated by the intensity of compression shocks and their interaction with the suction side boundary layer. The shock structures, their intensity and the interaction mechanism are discussed using schlieren photography, static pressures and wake measurements as well as numerical analysis. The contour of the separation bubble in the visious interaction zone could be modelled satisfactorily by means of the method of characteristics. An inviscid time marching computer code was used for the computation of the surface-Mach-number distributions and the transonic flow fields. Author

**A87-46232#**
**UNDEREXPANDED JET-FREE STREAM INTERACTIONS ON AN AXISYMMETRIC AFTERBODY CONFIGURATION**
N. B. MATHUR and K. S. YAJNIK (National Aeronautical Laboratory, Bangalore, India) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 507-512. refs

The exhaust jet-freestream interactions of an axisymmetric afterbody configuration have been studied experimentally, using an equivalent body-of-revolution representative of an actual combat aircraft configuration. Attention is given to the effects of jet pressure ratio and freestream Mach number on boattail, base, and afterbody pressure drag, for Mach numbers of 0.6-1.1 and Reynolds numbers from 20 million/m to 35 million/m, at zero-deg incidence. Jet pressure ratio was varied over 1-6. The underexpanded jet plume primarily affects the afterbody pressure distribution, and therefore the afterbody pressure drag. O.C.

**A87-46238#**
**A METHOD FOR THE CALCULATION OF THE INTERACTION OF A TURBULENT BOUNDARY LAYER WITH A SHOCK WAVE**
J. KALLAS and K. D. PAPAILIOU (National Technical University, Athens, Greece) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 551-560. refs

A two equation energy integral shear layer·method is presented and used for the calculation of the normal shock/turbulent boundary layer interaction. The effect of wall curvature and normal fluctuation terms is taken into account. The interaction is computed using the approximate method of Mason, Inger and Panaras. Comparisons with experiment give good results, both for attached and detached situations. Author

**A87-46264**
**THE AIR-INJECTION METHOD OF FIXING BOUNDARY-LAYER TRANSITION AND INVESTIGATING SCALE EFFECTS**
P. R. ASHILL, J. L. FULKER, and D. J. WEEKS (Royal Aircraft Establishment, Bedford, England) Aeronautical Journal (ISSN 0001-9240), vol. 91, May 1987, p. 214-224. refs

The paper describes the air-injection method of fixing transition in wind-tunnel tests on a two-dimensional aerofoil and a swept panel at high subsonic free-stream speeds. The method is shown

to provide a repeatable level of disturbance which, for a given flow condition, may be generated without interrupting the test and which appears not to cause a significant excess drag. Examples are given illustrating the effectiveness of the technique in demonstrating scale-sensitive features of flows, and a correlation is presented which allows the minimum value of air-injection mass flow needed to fix transition to be estimated from a knowledge of the behavior of natural laminar flow on the wing. Author

**A87-46265**
**INVESTIGATION OF THE AERODYNAMIC PERFORMANCE AND NOISE CHARACTERISTICS OF A 1/5TH SCALE MODEL OF THE DOWTY ROTOL R212 PROPELLER**
W. J. G. TREBBLE Aeronautical Journal (ISSN 0001-9240), vol. 91, May 1987, p. 225-236.

An investigation of the four-bladed Dowty Rotol R212 propeller (NACA 16 sections) has been made at 1/5th scale (0.7 meter diameter) in the RAE 1.5 meter acoustic tunnel. Propeller power absorption and thrust have been measured over a range of rotational speeds up to 8000 rev/min at mainstream speeds fromm 15 m/s to 60 m/s for a range of blade settings. Slipstream wake surveys show outward movement of the position of the peak pressure as propeller loading is increased. Noise analysis demonstrates the predominance of multiple tones whose number and intensity increase with helical-tip Mach number. An empirical formula shows that the fundamental tone SPL varies with tip speed and power loading in an identical manner to that observed on a modern ARA-D section propeller. Author

**A87-46328#**
**AEROTHERMODYNAMIC COMPUTATIONS FOR SUPER-/HYPERSONIC FLIGHT**
BERNHARD WAGNER and HERBERT RIEGER Dornier-Post (English Edition) (ISSN 0012-5563), no. 2, 1987, p. 28-30.

Numerical methods for the aerodynamical evaluation of space transport and supersonic/hypersonic transport aircraft are described. Short and medium term problem sets for spaceflight aerodynamics for such vehicles as the Hermes/Ariane 5 are discussed. Typical flight regimes for reentry of spacecraft and transport aircraft are compared. The physical and mechanical effects during the reentry on space transport vehicles, and the need to stabilize the heat balance and limit the heating of the structure are studied. The solution of complete flow equations in hypersonic aerodynamic evaluation is considered. An example displaying the evaluation of a two-dimensional flow around a deflected flap at hypersonic speed is presented. The flow around the Hermes configuration is also examined. I.F.

**A87-46351#**
**CHANGES IN THE FREE FLOW IN THE INTAKE OF A TURBOJET ENGINE DURING THE AIRCRAFT TAKEOFF RUN [PRZEMIANA SWOBODNEGO PRZEPLYWU WLOTOWEGO SILNIKA ODRZUTOWEGO PODCZAS ROZBIEGU SAMOLOTU]**
TADEUSZ GAJEWSKI (Wyzsza Oficerska Szkola Lotnicza, Deblin, Poland) Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 42, Jan. 1987, p. 3-5, 10. In Polish. refs

**A87-46363**
**VALIDATION OF AERODYNAMIC MEASUREMENT TECHNIQUES AND CALCULATION METHODS FOR HIGH-LIFT SYSTEMS [ELEMENTS DE VALIDATION DES TECHNIQUES DE MESURE ET DES METHODES DE CALCUL EN AERODYNAMIQUE DES SYSTEMES HYPERSUSTENTES]**
P. CAPBERN (Aerospatiale, Division Avions, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 122, 1987, p. 26-34. In French. refs

Problems in the prediction of the coefficients of maximum lift and drag for high-lift aircraft are discussed for the cases of single slotted or double slotted flap systems. Following a treatment of the purely two-dimensional problem, the subsonic problem, where compressibility is negligible, is considered. Experimental drag measurements, obtained by wake sounding with the S10 wind tunnel, are compared with theoretical calculations obtained using an incompressible two-dimensional strong interaction method for multielement configurations. Improvements of the present calculation method are proposed, including the incorporation of a two-equation integral transport model for the prediction of strongly separated flow regions. R.R.

**A87-46504*** High Technology Corp., Hampton, Va.
**LINEAR STABILITY ANALYSIS OF THREE-DIMENSIONAL COMPRESSIBLE BOUNDARY LAYERS**
MUJEEB R. MALIK (High Technology, Inc., Hampton, VA) and STEVEN A. ORSZAG (Princeton University, NJ) Journal of Scientific Computing (ISSN 0885-7474), vol. 2, March 1987, p. 77-97. refs
(Contract NAS1-15604; NAS1-16977; NAS1-16237)

A compressible stability analysis computer code is developed. The code uses a matrix finite-difference method for local eigenvale solution when a good guess for the eigenvalue is available and is significantly more computationally efficient than the commonly used inital-value approach. The local eigenvalue search procedure also results in eigenfunctions and, at little extra work, group velocities. A globally convergent eigenvalue procedure is also developed that may be used when no guess for the eigenvalue is available. The global problem is formulated in such a way that no unstable spurious modes appear so that the method is suitable for use in a black-box stability code. Sample stability calculations are presented for the boundary layer profiles of an LFC swept wing. Author

**A87-46759#**
**UNSTEADY VISCOUS-INVISCID INTERACTION METHOD AND COMPUTATION OF BUFFETING OVER AIRFOILS**
P. GIRODROUX-LAVIGNE and J. C. LE BALLEUR (ONERA, Chatillon-sous-Bagneux, France) (Institute of Mathematics and its Applications and SMAI, Joint Conference on Computational Methods in Aeronautical Fluid Dynamics, University of Reading, England, Apr. 6-8, 1987) ONERA, TP, no. 1987-58, 1987, 28 p. Research supported by the Service Technique des Programmes Aeronautiques. refs
(ONERA, TP NO. 1987-58)

A time-consistent prediction of buffeting over airfoils is performed here for viscous-inviscid interaction using the semiimplicit numerical coupling technique where coupling is converged iteratively at each time step, permitting the treatment of unsteady separation. Viscous marching calculations are used to solve integral defect equations in a direct mode for attached flows and an inverse mode for separated flows. As an example, the method is applied to study two-dimensional buffeting flows numerically in the case of the RA16SC1 airfoil at lifting conditions. C.D.

**A87-46761#**
**STUDY OF THE AERODYNAMICS OF HIGH-SPEED PROPELLERS [ETUDE DE L'AERODYNAMIQUE DES HELICES POUR AVIONS RAPIDES]**
J. M. BOUSQUET (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Symposium on Technology for Advanced Aero Engine Components, Paris, France, May 4-8, 1987) ONERA, TP, no. 1987-61, 1987, 13 p. In French.
(ONERA, TP NO. 1987-61)

Calculation methods used in the development of the HT3 propeller are discussed, and comparison with experimental measurements shows the validity of the methods for the aerodynamic analysis of simple-rotation high-speed propellers. Good agreement is found between results for the HT3 propeller obtained in the S1 Modane wind tunnel and those obtained using the LPC program global method. Comparison with experimental pressure measurements shows the development of the transonic flow on the propeller blades to be well modeled by the three-dimensional Euler program. The present analysis is applied to the case of counterrotating coaxial propellers, and the performance benefits of these propellers in comparison with single rotating propellers are considered. R.R.

**A87-46776#**
**NUMERICAL SIMULATION OF FLOWS IN AXIAL AND RADIAL TURBOMACHINES USING EULER SOLVERS**
GEORGES MEAUZE and ANTOINE FOURMAUX (ONERA, Chatillon-sous-Bagneux, France) (Institut von Karman de Dynamique des Fluides, Cours, Rhode-Saint-Genese, Belgium, June 15-18, 1987) ONERA, TP, no. 1987-87, 1987, 57 p. refs
(ONERA, TP NO. 1987-87)

State of the art numerical methods for transonic flow simulation in turbomachines, in particular high-pressure-ratio turbines, using Euler solvers, are presented. Phenomena related to supersonic flows in turbomachines are described using one- or two-dimensional analysis. Euler equations are considered, and the treatment of the main boundary conditions in internal aerodynamics is addressed. The multidomain approach to treat complex problems in computational fluid dyanmics is examined, as is the discretization of the three-dimensional Euler equations by means of an explicit predictor-corrector scheme very similar to McCormack's scheme. Grid generation is discussed, and application examples are considered, including steady flow numerical applications, inverse-mode two-dimensional applications, viscous effects simulation, and unsteady flows. C.D.

**A87-46777#**
**ENTRAINMENT EFFECT OF A LEADING-EDGE VORTEX**
N. G. VERHAAGEN and A. C. H. KRUISBRINK (Delft, Technische Hogeschool, Netherlands) AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1025-1032. Previously cited in issue 19, p. 2738, Accession no. A85-40703. refs

**A87-46778*#** Notre Dame Univ., Ind.
**LAMINAR SEPARATION BUBBLE CHARACTERISTICS ON AN AIRFOIL AT LOW REYNOLDS NUMBERS**
M. M. O'MEARA and T. J. MUELLER (Notre Dame, University, IN) AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1033-1041. Research supported by the University of Notre Dame. Previously cited in issue 17, p. 2467, Accession no. A86-38433. refs
(Contract NSG-1419)

**A87-46779#**
**CONTROL OF THE DISCRETE VORTICES FROM A DELTA WING**
MOHAMED GAD-EL-HAK (Notre Dame University, IN) and RON F. BLACKWELDER (Southern California, University, Los Angeles, CA) AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1042-1049. Previously cited in issue 22, p. 3219, Accession no. A86-45411. refs
(Contract F49620-85-C-0131)

**A87-46922**
**COMPRESSIBLE FLOWS IN THE WAKES OF A SQUARE CYLINDER AND THICK SYMMETRICAL AIRFOIL ARRANGED IN TANDEM**
T. NAKAGAWA, G. E. A. MEIER, R. TIMM, and H.-M. LENT (Max-Planck-Institut fuer Stroemungsforschung, Goettingen, West Germany) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0080-4630), vol. 411, no. 1841, June 8, 1987, p. 379-394. refs

The two-dimensional compressible flow in the wake of a 20-mm-side square cylinder mounted 22.5-110 mm upstream of a 20-mm-chord-length NACA 0018 airfoil at freestream Mach numbers M = 0.15-0.91 and Re = 70,000-420,000 is investigated experimentally using the setup and flow-visualization techniques described by Nakagawa (1986). The results are presented in extensive graphs and photographs and characterized in detail. The effects of the spacing between the cylinder and the airfoil at M less than 0.63 are found to differ significantly from those in higher-velocity flows, especially when local flow regions become supersonic (at M = 0.7 or higher). T.K.

**A87-46951#**
**A PANEL METHOD FOR PREDICITING THE DYNAMIC STABILITY DERIVATIVES OF AN OSCILLATING WING IN HIGH SUBSONIC FLOW**
LIXIAN ZHUANG and BINGGANG TONG (University of Science and Technology of China, Hefei, People's Republic of China) 01Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 97-102. In Chinese, with abstract in English. refs

In this paper, the pitching and rolling damping derivatives of several different shape wings in high subsonic flow are calculated by using the so-called 'Locally Linearization-Transonic-Panel-Method' developed in an earlier paper. The calculated results are compared to the experimental data available and prove to be in good agreement with each other. The results of the present method are also compared to those of the purely linearized method, indicating that the nonlinear effect is not negligible in general for predicting the dynamic derivatives when the critical Mach number is approached. In this calculation, the necessary steady flow solutions are obtained from the authors' 'Iterative-Panel-Method' which was developed for predicting the steady pressure distribution on the wing surface in transonic/subsonic flow. The present method proved to be very cost-effective. Author

**A87-46956#**
**AN EXPERIMENTAL INVESTIGATION OF DELTA WINGS WITH LEADING-EDGE VORTEX SEPARATION**
JINGBAI LI and MENGBU QI (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 141-147. In Chinese, with abstract in English. refs

Low speed wind-tunnel tests have been carried out for five delta wings with leading-edge vortex separation. The effects of variations in leading-edge sweptback angle on vortex core trajectory, vortex burst point, vortex core circulation, and relative sink strength have been investigated using a seven-hole probe up to high angles of attack. The experimental results of the present paper have been compared with that of Mokry and Ohman (1980) by means of other measuring methods and showed fair agreement. Therefore, the seven-hole probe is a new, simple, convenient and accurate measuring tool for flow studies of separated vortices. Author

**A87-46962#**
**FAST METHODS APPLIED TO THE CALCULATION OF TRANSONIC AIRFOILS**
ZHENHUA XIAO and ZHONGYIN ZHANG (Northwestern Polytechnical University, Xian, People's Republic of China) Acata Aerodynamica Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 193-196. In Chinese, with abstract in English. refs

First, Bauer-Garabedian-Korn-Jameson's fast direct-solver/SLOR method and Holst's implicit approximate factorization algorithm (AF2) are described. Next, the subsonic and supercritical flows around the airfoil NACA 0012 are calculated using these two methods. Then, their convergent rates are compared. The result shows that the convergent rate of BGKJ's method is faster than AF2's. Author

**A87-47014#**
**AERODYNAMIC STUDY OF A HELICOPTER ROTOR IN HOVERING FLIGHT - THEORY VS. EXPERIMENT**
D. FAVIER, M. NSI MBA (Aix-Marseille II, Universite, Marseille, France), and A. VUILLET (Aerospatiale, Division Helicopteres, Marignane, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 1, 1987, p. 53-69. refs
(Contract DRET-82-432; DRET-84-009)

The present work aims to check the range of validity of two aerodynamic rotor calculation models by direct comparison with experiments performed in the hovering case. This hovering configuration is a first and challenging step in code validation before considering models predicting more complex configurations in the forward flight case. The first model applies the classical momentum theory to the rotating disk and the downstream wake.

The second is a vortex theory application based on a lifting line free wake analysis. In this second method, a new procedure for free wake analysis (based on an initial prescribed blade circulation) is proposed for the rotor performance prediction. To check the validity of these codes over a wide range, the calculation is compared with experiment at different levels: rotor performance, bounded circulation on the blade, tip vortex paths, induced velocity field, influence of the evolution blade tip geometry. These various comparisons provide a broad check of the code efficiency in predicting overall and local aerodynamic quantities typical of the hovering rotor cconfiguration. Author

**N87-25294*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**WIND TUNNEL PERFORMANCE RESULTS OF AN AEROELASTICALLY SCALED 2/9 MODEL OF THE PTA FLIGHT TEST PROP-FAN**
GEORGE L. STEFKO, GAYLE E. ROSE, and GARY G. PODBOY Jul. 1987 50 p Presented at the 23rd Joint Propulsion Conference, San Diego, Calif., 29 Jun. - 2 Jul. 1987; cosponsored by AIAA, SAE, ASME, and ASEE Prepared in cooperation with Sverdrup Technology, Inc., Cleveland, Ohio
(NASA-TM-89917; E-3610; NAS 1.15:89917; AIAA-87-1893)
Avail: NTIS HC A03/MF A01 CSCL 01A

High speed wind tunnel aerodynamic performance tests of the SR-7A advanced prop-fan have been completed in support of the Prop-Fan Test Assessment (PTA) flight test program. The test showed that the SR-7A model performed aerodynamically very well. At the cruise design condition, the SR-7A prop fan had a high measured net efficiency of 79.3 percent. R.J.F.

**N87-25295*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SUBSONIC WIND-TUNNEL MEASUREMENTS OF A SLENDER WING-BODY CONFIGURATION EMPLOYING A VORTEX FLAP**
NEAL T. FRINK Jul. 1987 313 p
(NASA-TM-89101; L-16265; NAS 1.15:89101) Avail: NTIS HC A14/MF A01 CSCL 01A

A wind tunnel study at Mach 0.4 was conducted for a slender wing-body configuration with a leading edge vortex flap of curved planform that is deflectable about a 74 degree swept hinge line. The basic data consist of a unique combination of longitudinal aerodynamic, surface pressure, and vortex flap hinge-moment measurements on a common model. The longitudinal aerodynamic, pressure and hinge-moment data are presented without analysis in tabular format. Plots of the tabulated pressure data are also given. Author

**N87-25296*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**PERFORMANCE AND LOADS DATA FROM A HOVER TEST OF A 0.658-SCALE V-22 ROTOR AND WING**
FORT F. FELKER, DAVID B. SIGNOR, LARRY A. YOUNG, and MARK D. BETZINA Apr. 1987 468 p
(NASA-TM-89419; A-87058; NAS 1.15:89419) Avail: NTIS HC A20/MF A01 CSCL 01A

A hover test of a 0.658-scale model of a V-22 rotor and wing was conducted at the Outdoor Aerodynamic Research Facility at Ames Research Center. The primary objectives of the test were to obtain accurate measurements of the hover performance of the rotor system, and to measure the aerodynamic interactions between the rotor and wing. Data were acquired for rotor tip Mach numbers ranging from 0.1 to 0.73. This report presents data on rotor performance, rotor-wake downwash velocities, rotor system loads, wing forces and moments, and wing surface pressures. Author

**N87-25297** Colorado Univ., Boulder.
**EXPERIMENTAL STUDIES ON THE DYNAMIC DEVELOPMENT AND CONTROL OF UNSTEADY SEPARATED FLOWS Ph.D. Thesis**
HENRY ELMER HELIN 1986 196 p
Avail: Univ. Microfilms Order No. DA8706426

Current research in unsteady aerodynamics revolves around the concept of enhancing aerodynamic performance through the energetic nature of vorticity dominated flowfields. It appears clear that substantial lift enhancement and stall delay are some of the beneficial consequences of certain unsteady aerodynamic conditions. However, the work in unsteady aerodynamics remains in its infancy and we cannot fully predict what the area may yield in useful consequences: but the possibilities appear promising. Before any useful scheme can be implemented a thorough understanding of the generation and control of unsteady phenomena must be obtained. Energetic vorticity dominated flows elicited through forced unsteady flow separation about a pitching airfoil were examined for a wide range of test conditions, including control oriented motion histories and model geometries. Phase locked high speed 16mm photography coupled with near-surface hot-wire anemometry and multi-port surface pressure measurements were used to quantify flowfield dynamics and the ensuing aerodynamic loading. The motion history employed as well as the model geometry had significant influences on the generation, coalescence, and convection of the vortical structures. Dissert. Abstr.

**N87-25298#** Aeronautical Research Inst. of Sweden, Stockholm. Aerodynamics Dept.
**THE AERONAUTICAL RESEARCH INSTITUE (FFA) WING BODY 85 COMPUTER PROGRAM. A PANEL METHOD FOR DETERMINATION OF AEROELASTIC CHARACTERISTICS APPLYING DIRECT BLOCK ITERATIVE SOLUTION TECHNIQUES**
PER KRANTZ Apr. 1986 15 p
(Contract FMV-F-K-82260-84260)
(FFA-TN-1986-28; ETN-87-99780) Avail: NTIS HC A02/MF A01

A panel program for calculations of aerodynamic characteristics of configurations with rigid or elastic wings was modified to handle a larger number of panels within a reasonable amount of computing time. A solution method for the equation systems is introduced and the number of operations required for solution is compared with the number needed for the old method. ESA

**N87-25299#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
**APPLICATION OF A THREE-DIMENSIONAL EULER CODE TO TRANSONIC BLADE TIP FLOW**
HEIDEMARIE STAHL Sep. 1986 21 p Presented at the Twelfth European Rotorcraft Forum, Garmisch-Partenkirchen, West Germany, 22-25 Sep. 1986 Sponsored by DGLR, Bonn, West Germany
(MBB-UD-482/86; ETN-87-99927) Avail: Issuing Activity

A three dimensional steady flow code for flows around fixed wings was modified for rotor flow. A method of step by step mesh refinement starting from the coarsest grid reduces the computation time usually associated with Euler codes, without reducing accuracy. A strong dependency between grid resolution and resolution of aerodynamic coefficients is shown. The grid must be large enough so that its outer boundaries can be considered to be in the undisturbed flow, so that far field conditions apply. ESA

**N87-25300#** Spectron Development Labs., Inc., Costa Mesa, Calif.
**TOMOGRAPHIC RECONSTRUCTION OF THREE-DIMENSIONAL FLOW OVER AIRFOILS Final Report, 15 Mar. 1983 - 14 Nov. 1986**
DARIUSH MODARRESS, HUNG TAN, and JAMES D. TROLINGER 18 Mar. 1987 31 p
(Contract DAAG29-83-C-0012)
(AD-A179976; SDL-87-2284-13F; ARO-19471.4-EG) Avail: NTIS HC A03/MF A01 CSCL 20D

Application of holographic tomography to the flow around the tip of a revolving airfoil is investigated. Data in the form of interferograms obtained at forty different angles obtained by AVRADCOM at NASA Ames were used to reconstruct the three-dimensional density field. An automated fringe analysis capability was developed to digitize, filter and repair the fringe patterns. The binary images of the interferograms were used as the input data to the reconstruction code. A new ART code based on the iterative refinement method of least squares solution was developed for tomographic reconstruction. Solutions were obtained for the density and velocity field at various heights above the blade. An important feature of the technique was found to be that with limited resolution (say 20 x 20), it was possible to repeatedly use the same code and zoom into regions surrounding important features of the flow and, hence, reconstruct the flow field in greater detail. This feature was used and the position of the shock wave over the wing was determined. Author (GRA)

**N87-25301*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**STUDY OF LEE-SIDE FLOWS OVER CONICALLY CAMBERED DELTA WINGS AT SUPERSONIC SPEEDS, PART 2**
RICHARD M. WOOD and CAROLYN B. WATSON Jul. 1987 404 p
(NASA-TP-2660-PT-2; L-16192; NAS 1.60:2660-PT-2) Avail: NTIS HC A18/MF A01 CSCL 01A

An experimental investigation was performed in which surface pressure data, flow visualization data, and force and moment data were obtained on four conical delta wing models which differed in leading edge camber only. Wing leading edge camber was achieved through a deflection of the outboard 30% of the local wing semispan of a reference 75 deg swept flat delta wing. The four wing models have leading edge deflection angles delta sub F of 0, 5, 10, and 15 deg measured streamwise. Data for the wings with delta sub F = 10 and 15 deg showed that hinge line separation dominated the lee-side wing loading and prohibited the development of leading edge separation on the deflected portion of wing leading edge. However, data for the wing with delta sub F = 5 deg showed that at an angle of attack of 5 deg, a vortex was positioned on the deflected leading edge with reattachment at the hinge line. Flow visualization results were presented which detail the influence of Mach number, angle of attack, and camber on the lee-side flow characteristics of conically cambered delta wings. Analysis of photographic data identified the existence of 12 distinctive lee-side flow types. Author

**N87-25302*#** Textron Bell Helicopter, Fort Worth, Tex.
**GROUND AND FLIGHT TEST RESULTS OF A TOTAL MAIN ROTOR ISOLATION SYSTEM Final Report**
DENNIS R. HALWES Washington NASA Jul. 1987 153 p Sponsored by Army Aerostructures Directorate
(Contract NAS1-16969)
(NASA-CR-4082; NAS 1.26:4082; REPT-699-099-055) Avail: NTIS HC A08/MF A01 CSCL 01B

A six degree-of-freedom (DOF) isolation system using six LIVE units has been installed under an Army/NASA contract on a Bell 206LM helicopter. This system has been named the Total Rotor Isolation System, or TRIS. To determine the effectiveness of TRIS in reducing helicopter vibration, a flight verification study was conducted at Bell's Flight Research Center in Arlington, Texas. The flight test data indicate that the 4/rev vibration level at the pilot's seat were suppressed below the 0.04g level throughout the transition envelope. Flight tests indicate over 95% suppression of vibration level from the rotor hub to the pilot's seat. The TRIS installation was designed with a decoupled control system and has shown a significant improvement in aircraft flying qualities, such that it permitted the trimmed aircraft to be flown hands-off for a significant period of time, over 90 seconds. The TRIS flight test program has demonstrated a system that greatly reduces vibration levels of a current-generation helicopter, while significantly improving the flying qualities to a point where stability augmentation is no longer a requirement. Author

**N87-25304*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EFFECT OF PLANFORM TAPER ON HOVER PERFORMANCE OF AN ADVANCED AH-64 MODEL ROTOR**
HENRY L. KELLEY Aug. 1987 13 p Prepared in cooperation with Army Aviation Research and Development Command, Hampton, Va.
(Contract DA PROJ. 1L1-61102-AH-45A)
(NASA-TM-89145; L-16267; NAS 1.15:89145; AVSCOM-TM-87-B-10) Avail: NTIS HC A02/MF A01 CSCL 01A

The hover performance of a 27 percent scale model baseline rotor and advanced rotor with a 3:1 tapered tip (TR3) for the AH-64 attack helicopter was investigated and compared. Hover results from a previously tested advanced rotor with a 5:1 tapered tip (TR5) were also compared. Rotor thrust was varied over a range for two tip Mach numbers. The results indicated that the TR3 blades had improved performance compared with the TR5 blades, and both the TR3 and TR5 blades were superior to the baseline rotor. The additional margin in performance for the TR3 blades was likely due to an increase in blade area and Reynolds number in the tip region of the blades. Author

**N87-25305*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**ON THE NONLINEAR AERODYNAMIC AND STABILITY CHARACTERISTICS OF A GENERIC CHINE-FOREBODY SLENDER-WING FIGHTER CONFIGURATION**
GARY E. ERICKSON and JAY M. BRANDON Jun. 1987 38 p Prepared in cooperation with NASA- Langley Research Center, Hampton, Va.
(NASA-TM-89447; A-87174; NAS 1.15:89447) Avail: NTIS HC A03/MF A01 CSCL 01A

An exploratory investigation was conducted of the nonlinear aerodynamic and stability characteristics of a tailless generic fighter configuration featuring a chine-shaped forebody coupled to a slender cropped delta wing in the NASA Langley Research Center's 12-Foot Low-Speed Wind Tunnel. Forebody and wing vortex flow mechanisms were identified through off-body flow visualizations to explain the trends in the longitudinal and lateral-directional characteristics at extreme attitudes (angles of attack and sideslip). The interactions of the vortical motions with centerline and wing-mounted vertical tail surfaces were studied and the flow phenomena were correlated with the configuration forces and moments. Single degree of freedom, free-to-roll tests were used to study the wing rock susceptibility of the generic fighter model. Modifications to the nose region of the chine forebody were examined and fluid mechanisms were established to account for their ineffectiveness in modulating the highly interactive forebody and wing vortex systems. Author

**N87-25306*#** National Aeronautics and Space Administration, Washington, D.C.
**RECENT PROGRESS IN THE MEASUREMENT OF THE DRAG COEFFICIENTS OF MODELS OF TRANSPORT AIRCRAFT IN A WIND TUNNEL**
C. ARMAND, P. HUGOUVIEUX, and R. SELVAGINNI Aug. 1987 57 p Transl. into ENGLISH of conference paper Progres Recents dans la Mesure en Soufflerie du Coefficient de Trainee de Maquettes d'Avion de Transport presented at the 23rd Symposium of Applied Aerodynamics, 1980 p 1-47 Symposium held in Aussois, France, 12-14 Nov. 1986 Original language document was announced in IAA as A87-21070 Transl. by Kanner (Leo) Associates, Redwood City, Calif.
(Contract NASW-4005)
(NASA-TT-20096; NAS 1.77:20096; ONERA-TP-1986-170) Avail: NTIS HC A04/MF A01 CSCL 01A

Techniques and apparatus employed by ONERA researchers at Mondane to obtain an accuracy of 0.0001 in drag measurements on scale models of transport aircraft are described. Emphasis is placed on cruise flight configurations for the Airbus, and on the computational methods applied to correct the data for scale models to account for wind tunnel effects, as opposed to aircraft in actual flight. Model design, the mounts used, calibration of the balances and the angle of attack, and the data acquisition and treatment systems are summarized. Methods used to offset the thermal friction, wall and support effects on the flowfield are discussed.
Author

**N87-25307*#** National Aeronautics and Space Administration, Washington, D.C.
**THE INTERFERENCE OF THE MODEL SUPPORT MAST WITH MEASUREMENTS OF THE LONGITUDINAL AND LATERAL AERODYNAMIC COEFFICIENTS**
C. VANDEKREEKE, J. VERRIERE, and G. QUEMARD Aug. 1987 32 p Transl. into ENGLISH of conference paper Interaction d'un Mat Support de Maquette sur les Mesures des Coefficients Aerodynamiques Longitudinaux presented at the 23rd Colloque d'Aerodynamique Appliquee, 1986 28 p Colloquium held in Aussois, France, 12-14 Nov. 1986 Original language document was announced in IAA as A87-21080 Transl. by Kanner (Leo) Associates, Redwood City, Calif.
(Contract NASW-4005)
(NASA-TT-20079; NAS 1.77:20079; ONERA-TP-1986-181) Avail: NTIS HC A03/MF A01 CSCL 01A

The effects the single-bottom support masts used in the ONERA S1 and S4 wind tunnels have on aerodynamic data collected with scale model aircraft were examined experimentally and analytically. Systematic studies were performed on the flow characteristics around different diameters for the mounts. Scaling methods used to make data from one wind tunnel correspond to data from the other are described. Airbus 320 models were introduced into the tests and mast-body flow interactions were observed. A summary is presented of restrictions on the mast diameters, relative to cylindrical model diameters, which will minimize the effects the masts have on longitudinal and lateral aerodynamic stability data.
Author

**N87-25993*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**DETAILED NEAR-WAKE FLOWFIELD SURVEYS WITH COMPARISON TO AN EULER METHOD OF AN ASPECT RATIO 4 RECTANGULAR WING**
M. D. KLINGE, S. O. KJELGAARD, and J. N. PERKINS (North Carolina State Univ., Raleigh.) 1986 29 p
(NASA-TM-89357; NAS 1.15:89357) Avail: NTIS HC A01/MF A01 CSCL 01A

An experimental investigation of the flowfield in the near-wake of an aspect ratio 4 rectangular wing was conducted, providing a complete detailed set of data for use in the validation of computational methods. An angle of attack of 8 degrees and two Reynolds numbers 530,000 and 391,000 were investigated using pitot and six-hole probes. In addition, two types of flow visualization were employed. The data presented includes contours of total pressure, mean velocity, flow angularity, and vorticity distribution data at five chordwise stations of the near-wake ranging from 0.167 to 5.00 chord lengths aft of the trailing edge. The experimental results were compared to the predicted results of a 2-D Euler numerical method. The results predicted by an Euler method failed to accurately define the flowfield. Tangential velocities remained relatively constant over the range of X/C considered though increased in angle of attack and Reynolds number did bring about corresponding increases. Axial velocities also increased with angle of attack and Reynolds number but showed greater sensitivity to increases in X/C. Graphic displays and contours of the total pressure data indicate that roll-up of the wing tip vortex is essentially complete one and one half chords downstream of the trailing edge.
Author

**N87-25997*#** Massachusetts Inst. of Tech., Cambridge. Aeronautical Systems Lab.
**AN EXPERIMENTAL LOW REYNOLDS NUMBER COMPARISON OF A WORTMANN FX67-K170 AIRFOIL, A NACA 0012 AIRFOIL AND A NACA 64-210 AIRFOIL IN SIMULATED HEAVY RAIN Final Report**
ANTHONY P. CRAIG and R. JOHN HANSMAN Jun. 1987 106 p
(Contract NAG1-568)
(NASA-CR-181119; NAS 1.26:181119; ASL-87-1) Avail: NTIS HC A06/MF A01 CSCL 01A

Wind tunnel experiments were conducted on Wortmann FX67-K170, NACA 0012, and NACA 64-210 airfoils at rain rates of 1000 mm/hr and Reynolds numbers of 310,000 to compare the aerodynamic performance degradation of the airfoils and to attempt to identify the various mechanisms which affect performance in heavy rain conditions. Lift and drag were measured in dry and wet conditions, a variety of flow visualization techniques were employed, and a computational code which predicted airfoil boundary layer behavior was used. At low angles of attack, the lift degradation in wet conditions varied significantly between the airfoils. The Wortmann section had the greatest overall lift degradation and the NACA 64-210 airfoil had the smallest. At high angles of attack, the NACA 64-210 and 0012 airfoils had improved aerodynamic performance in rain conditions due to an apparent reduction of the boundry layer separation. Performance degradation in heavy rain for all three airfoils at low angles of attack could be emulated by forced boundary layer transition near the leading edge. The secondary effect occurs at time scales consistent with top surface water runback times. The runback layer is thought to effectively alter the airfoil geometry. The severity of the performance degradation for the airfoils varied. The relative differences appeared to be related to the susceptibility of each airfoil to premature boundary layer transition.
Author

**N87-26005*#** Lockheed-California Co., Burbank.
**CFD APPLICATIONS: THE LOCKHEED PERSPECTIVE**
LUIS R. MIRANDA *In* NASA. Ames Research Center, Supercomputing in Aerospace p 77-85 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 01A

The Numerical Aerodynamic Simulator (NAS) epitomizes the coming of age of supercomputing and opens exciting horizons in the world of numerical simulation. An overview of supercomputing at Lockheed Corporation in the area of Computational Fluid Dynamics (CFD) is presented. This overview will focus on developments and applications of CFD as an aircraft design tool and will attempt to present an assessment, withing this context, of the state-of-the-art in CFD methodology.
B.G.

**N87-26019*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COMPUTATIONAL ANALYSIS OF HYPERSONIC AIRBREATHING AIRCRAFT FLOW FIELDS**
DOUGLAS L. DWOYER and AJAY KUMAR *In* NASA. Ames Research Center, Supercomputing in Aerocomputing p 239-255 Mar. 1987 Previously announced in IAA as A87-22531
Avail: NTIS HC A13/MF A01 CSCL 01A

The general problem of calculating the flow fields associated with hypersonic airbreathing aircraft is presented. Unique aspects of hypersonic aircraft aerodynamics are introduced and their demands on computational fluid dynamics are outlined. Example calculations associated with inlet/forebody integration and hypersonic nozzle design are presented to illustrate the nature of the problems considered. Author

**N87-26027#** Royal Aircraft Establishment, Farnborough (England).
**AERODYNAMICS OF UNMANNED AIRCRAFT AT FULL-SCALE IN THE RAE 24FT WIND-TUNNEL**
W. J. G. TREBBLE Jul. 1986 32 p
(RAE-TM-AERO-2081; BR100296; ETN-87-90092) Avail: NTIS HC A03/MF A01

Wind tunnel tests were made on full-scale models of the X-RAE 1 and X-RAE 2 unmanned aircraft (UMA) over a Reynolds number range from 500,000 to 1.2 million. The results show that substantial increases in lifting capability could be achieved by choosing a wing section (Wortmann FX63-137) more appropriate to the range of Reynolds number associated with the required airspeed range from 20 to 50 m/sec. The UMA stalls from the root trailing-edge so the 1 deg washout provided appears to be unnecessary. The UMAs have adequate stability margins and both have powerful nose-down moments at the stall. Lift/drag ratio increases as the Reynolds number is raised. ESA

**N87-26028** ESDU International Ltd., London (England).
**AEROFOIL MAXIMUM LIFT-COEFFICIENT FOR MACH NUMBERS UP TO 0.4**
Nov. 1984 16 p Supersedes ESDU-Aero-W.01.01.06
(ESDU-84026; ESDU-AERO-W.01.01.06; ISBN-0-85679-490-2; ISSN-0141-397X) Avail: ESDU

ESDU 84026 provides a simple empirically derived method for estimating maximum lift coefficient. The method predicts the increment in lift coefficient by which the maximum exceeds the value at zero incidence, and a prediction method for lift coefficient at zero incidence is included. Graphs of the increment show its variation with airfoil geometry and Reynolds nymber for airfoils with smooth or rough leading edges; rough here would cover ice formation while smooth includes the level of roughness required just to fix transition. A further empirical factor is provided to extend the method to apply to modern airfoils with rear loading. The accuracy is assessed in terms of standard deviation of prediction from experiment for nearly 500 points, subdivided by airfoil type, leading-edge condition and Reynolds number. The overall standard deviation was about 0.08. ESDU

**N87-26030** Georgia Inst. of Tech., Atlanta.
**VELOCITY MEASUREMENTS NEAR THE BLADE TIP AND IN THE TIP VORTEX CORE OF A HOVERING MODEL ROTOR Ph.D. Thesis**
THOMAS LEE THOMPSON 1986 156 p
Avail: Univ. Microfilms Order No. DA8707864

Detailed measurements with a laser Doppler velocimeter were performed in the tip region and in the tip vortex core of a single bladed model rotor. The rotor blade is untwisted and of constant chord with a NACA 0012 airfoil section and a square tip. The data from measurements near the blade tip were used to determine the tip vortex inception point and to study the subsequent growth of vortex during its passage over the upper surface of the blade. Velocity measurements at locations unaffected by a tip vortex passage were generally in good agreement with predictions from a hovering rotor lifting surface code developed at Georgia Tech. A flow visualization study verified the steadiness of the tip vortex trajectory in the near wake, in addition to supplying information necessary to construct a grid for measurement of the three components of velocity in the vortex core. Dissert. Abstr.

**N87-26031*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EFFECT OF REYNOLDS NUMBER VARIATION ON AERODYNAMICS OF A HYDROGEN-FUELED TRANSPORT CONCEPT AT MACH 6**
JIM A. PENLAND and DON C. MARCUM, JR. Aug. 1987 28 p
(NASA-TP-2728; L-16286; NAS 1.60:2728) Avail: NTIS HC A03/MF A01 CSCL 01A

Two separate tests have been made on the same blended wing-body hydrogen-fueled transport model at a Mach number of about 6 and a range of Reynolds number (based on theoretical body length) of 1.577 to 55.36 X 10 to the 6th power. The results of these tests, made in a conventional hypersonic blowdown tunnel and a hypersonic shock tunnel, are presented through a range of angle of attack from -1 to 8 deg, with an extended study at a constant angle of attack of 3 deg. The model boundary layer flow appeared to be predominately turbulent except for the low Reynolds number shock tunnel tests. Model wall temperatures varied considerably; the blowdown tunnel varied from about 255 F to 340 F, whereas the shock tunnel had a constant 70 F model wall temperature. The experimental normal-force coefficients were essentially independent of Reynolds number. A current theoretical computer program was used to study the effect of Reynolds number. Theoretical predictions of normal-force coefficients were good, particularly at anticipated cruise angles of attack, that is 2 to 5 deg. Axial-force coefficients were generally underestimated for the turbulent skin friction conditions, and pitching-moment coefficients could not be predicted reliably. Author

**N87-26032*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**STEADY AND UNSTEADY AERODYNAMIC FORCES FROM THE SOUSSA SURFACE-PANEL METHOD FOR A FIGHTER WING WITH TIP MISSILE AND COMPARISON WITH EXPERIMENT AND PANAIR**
HERBERT J. CUNNINGHAM Aug. 1987 29 p
(NASA-TP-2736; L-16262; NAS 1.60:2736) Avail: NTIS HC A03/MF A01 CSCL 01A

The body surface-panel method SOUSSA is applied to calculate steady and unsteady lift and pitching moment coefficients on a thin fighter-type wing model with and without a tip-mounted missile. Comparisons are presented with experimental results and with PANAIR and PANAIR-related calculations for Mach numbers from 0.6 to 0.9. In general the SOUSSA program, the experiments, and the PANAIR (and related) programs give lift and pitching-moment results which agree at least fairly well, except for the unsteady clean-wing experimental moment and the unsteady moment on the wing tip body calculated by a PANAIR-predecessor program at a Mach number of 0.8. Author

**N87-26033*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**LOW-SPEED WIND-TUNNEL RESULTS FOR SYMMETRICAL NASA LS(1)-0013 AIRFOIL**
JAMES C. FERRIS, ROBERT J. MCGHEE, and RICHARD W. BARNWELL Aug. 1987 38 p
(NASA-TM-4003; L-16279; NAS 1.15:4003) Avail: NTIS HC A03/MF A01 CSCL 01A

A wind-tunnel test has been conducted in the Langley Low-Turbulence Pressure Tunnel to evaluate the performance of a symmetrical NASA LS(1)-0013 airfoil which is a 13-percent-thick, low-speed airfoil. The airfoil contour was obtained from the thickness distribution of a 13-percent-thick, high-performance airfoil developed for general aviation airplanes. The tests were conducted at Mach numbers from 0.10 tp 0.37 over a Reynolds number range from about 0.6 to 12.0 X 10 to the 6th power. The angle of attack varied from about -8 to 20 degrees. The results indicate that the aerodynamic characteristics of the present airfoil are similar

to, but slightly better than, those of the NACA 0012 airfoil.
Author

# 03

# AIR TRANSPORTATION AND SAFETY

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

**A87-44701**
**HELICOPTER ROTOR ICING SYMPOSIUM, LONDON, ENGLAND, JAN. 14, 1986, PROCEEDINGS**
Symposium sponsored by the Royal Aeronautical Society. London, Royal Aeronautical Society, 1986, 111 p. For individual items see A87-44702 to A87-44707.

Papers are presented on when and where helicopter icing occurs, and the development of the Chinook helicopter fiberglass rotor blade deicing system. Attention is given to icing clearance criteria for UK military helicopters, rotor icing research, and icing clearances on civil helicopters. I.F.

**A87-44703**
**ROTOR ICING EXPERIENCE AT WESTLAND AND ITS APPLICATION TO CURRENT AND FUTURE HELICOPTERS**
R. L. FROST (Westland, PLC, Yeovil, England) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 24-45. Research supported by the Ministry of Defence (Procurement Executive).

The effects of ice on the W30 helicopter are examined, and an icing flight envelope for the helicopter is constructed. The equipment used to monitor icing during the flight testing of the helicopter is described. The flight tests were carried out at various altitudes, temperatures, and icing conditions; the stresses, performance, handling, and vibration of the helicopter were evaluated. It is observed that for the W30 the rotor performance limitations dominate the aircraft flight envelope and therefore the flight envelope must be restricted to ensure that the limitations are avoided. The performance of a Sea King helicopter with composite main rotor blades under icing conditions is analyzed. The data reveal that there is little difference in the operation of the helicopter with composite blades compared to one with metal blades. The design and development of an electrothermal rotor blade deicing system are examined. I.F.

**A87-44705**
**ICING CLEARANCE CRITERIA FOR UK MILITARY HELICOPTERS**
M. G. MATTERSBY and P. A. KNOWLES (Aeroplane and Armament Experimental Establishment, Boscombe Down, England) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 64-76.

The development of icing clearance criteria for UK military helicopters is discussed. The basic requirements for the evaluation of the aircraft performance in icing conditions are described. Flight testing techniques for the certification of a helicopter for flight in icing conditions are examined. Rotor deicing clearance data for the Chinook helicopter, obtained from a number of trials, are analyzed. I.F.

**A87-44706**
**ROTOR ICING RESEARCH AT RAE FARNBOROUGH**
R. W. GENT (Royal Aircraft Establishment, Farnborough, England) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 77-97.

Theoretical research at RAE into icing on helicopter rotors is reviewed. Mathematical models have been developed to predict accretion of ice on rotor blades for both the hover and forward flight cases. Theoretical results are compared with both icing wind tunnel and flight ice accretion measurements. Also described are both one- and two-dimensional models of an electrothermally deiced rotor, and results are shown to illustrate their capabilities. The planned future application of these models in both design and certification of helicopters for flight in icing is described.
Author

**A87-44707**
**ICING CLEARANCES ON CIVIL HELICOPTERS - UNHEATED AND HEATED BLADES**
D. W. BLACKALL (Civil Aviation Authority, London, England) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 98-103.

The need for ice flying capabilities for civil helicopters is discussed. Commercial and technical problems of establishing icing clearances for civil helicopters are studied. Examples of flight trials conductgd in order to gain icing clearance for certain aircraft are presented. I.F.

**A87-44748**
**FIRE, SMOKE, TOXICITY**
T. MADGWICK (British Aerospace, PLC, Civil Aircraft Div., Weybridge, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 395-423. refs

An account is given of fires experienced in airliner operations with a view to the characterization of the performance of the various materials used in airliner interiors. The results of these considerations are compared with data that have been produced by the laboratory test methods devised by the airliner manufacturing industry for cabin interior materials selection. The impact of new and impending airworthiness regulations on fire safety-related materials specifications is discussed. The difficulties posed by the fire/smoke toxicity problem are considered in the cases of epoxy, phenolic, polycarbonate, ABS, and PEEK-polyimide resins; of these, only PEEK-polyimide is found to be acceptable. O.C.

**A87-45635*#** Massachusetts Inst. of Tech., Cambridge.
**COMPARISON OF WET AND DRY GROWTH IN ARTIFICIAL AND FLIGHT ICING CONDITIONS**
R. JOHN HANSMAN, JR. and MARK S. KIRBY (MIT, Cambridge, MA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 1, July 1987, p. 215-221. FAA-supported research. Previously cited in issue 18, p. 2613, Accession no. A86-39948. refs
(Contract NGL-22-009-640; NAG3-6662)

**A87-46317**
**NUMERICAL SIMULATION OF CRUISER ON AIRCRAFT LIGHTNING**
M. MONAVON and M. LEROY (SEDACIP Sarl, Les Ulis, France) Electronics Letters (ISSN 0013-5194), vol. 23, June 4, 1987, p. 640-642. In French.

Ship and aircraft manufacture requires modern technologies based on composite materials, which increases the vulnerability of electronic equipment subjected to an electromagnetic pulse (EMP). The use of a 3D finite-difference method to simulate a natural EMP, such as lightning, is limited by excessive CPU time. Improvements are introduced to describe these phenomena using large computation time windows with reduced CPU cost. Numerical results are given when the hull of a cruiser is subjected to lightning. Author

**A87-46373**
**BURNING QUESTIONS**
J. M. RAMSDEN Flight International (ISSN 0015-3710), vol. 131, June 13, 1987, p. 121-125.

A study of over 150 survivable airliner impacts has concluded that postcrash fires were set off in some two-thirds of these, and

that over one-third of the deaths in these fire-involving crashes were due to fire-related rather than impact-related injuries. About 1300 people who might have survived the impacts are estimated to have burned to death. A broad evaluation is presently made of salient lessons to be learned from this and other studies bearing on the causes and consequences of cabin fires, with attention to the roles played by fuel characteristics, electrical wire insulation, escape systems, cabin furniture upholstery, and the extensive use of polymers in cabin structural elements. O.C.

**A87-46724#**
**THE AVSCOM FLIGHT SAFETY PART PROGRAM**
ANTHONY S. TORNATORE (U.S. Army, Aviation Systems Command, Saint Louis, MO) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 395-398.

This paper describes the procedural implementation of a management program designed to significantly curtail Army aviation major accidents caused by equipment induced problems. The program provides enhanced life cycle management, control, and surveillance of parts that are critical to the safe operation of the aircraft. Author

**N87-25282*#** Princeton Univ., N. J. Dept. of Mechanical and Aerospace Engineering.
**UNRESOLVED ISSUES IN WIND SHEAR ENCOUNTERS**
ROBERT F. STENGEL *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 197-204 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

Much remains to be learned about the hazards of low altitude wind shear to aviation. New research should be conducted on the nature of the atmospheric environment, on aircraft performance, and on guidance and control aids. In conducting this research, it is important to distinguish between near-term and far-term objectives, between basic and applied research, and between uses of results for aircraft design or for real-time implementation. Advances in on-board electronics can be applied to assuring that aircraft of all classes have near optimal protection against wind shear hazards. Author

**N87-25285*#** National Transportation Safety Board, Washington, D. C. Bureau of Technology.
**ACCIDENT INVESTIGATION**
WILLIAM G. BUD LAYNOR *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 217-220 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

The National Transportation Safety Board (NTSB) has attributed wind shear as a cause or contributing factor in 15 accidents involving transport-categroy airplanes since 1970. Nine of these were nonfatal; but the other six accounted for 440 lives. Five of the fatal accidents and seven of the nonfatal accidents involved encounters with convective downbursts or microbursts. Of other accidents, two which were nonfatal were encounters with a frontal system shear, and one which was fatal was the result of a terrain induced wind shear. These accidents are discussed with reference to helping the aircraft to avoid the wind shear or if impossible to help the pilot to get through the wind shear. E.R.

**N87-25287*#** United Air Lines, Inc., Denver, Colo.
**UNITED AIRLINES WIND SHEAR INCIDENT OF MAY 31, 1984**
DAVID A. SIMMON *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 233-234 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

An incident involving wind shear on 31 May 1984 is discussed by an airline employee. The specs of the plane are given, the weather conditions are listed, and the actions taken by the flight crew are discussed. E.R.

**N87-25288*#** National Center for Atmospheric Research, Boulder, Colo.
**UNITED AIRLINES WIND SHEAR INCIDENT OF MAY 31, 1984**
JOHN MCCARTHY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 235 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

An incident involving wind shear which occured on 31 May 1984 on a United Airlines aircraft is discussed by a member of the National Center for Atmospheric Research. The meteorological parameters important to this incident are detailed. E.R.

**N87-25308#** Lockheed-California Co., Burbank.
**KRASH ANALYSIS CORRELATION. TRANSPORT AIRPLANE CONTROLLED IMPACT DEMONSTRATION TEST Final Report, Feb. - Aug. 1985**
GIL WITTLIN Dec. 1986 125 p
(Contract DTFA03-84-C-00004)
(AD-A179906; LR-30916; DOT/FAA/CT-86-13) Avail: NTIS HC A06/MF A01 CSCL 01B

The analyses results of a transport airplane Controlled Impact Demonstration (CID) test using programs KRASH are described. Pre-CID analyses, presented in FAA technical report DOT/FAA/CT-85/9, are provided in summary form. The KRASH post CID correlation consists of modeling two sequences; a symmetrical impact of the fuselage with the ground (after engine-loss at initial air-to-ground impact) and the unsymmetrical air-to-ground including initial engine ground contact and subsequent fuselage impact with the ground. The analyses and test results are compared with regard to floor acceleration responses, fuselage shear and bending moment distribution, wing and engine acceleration responses, wing bending moment distribution, structural failures, fuselage underside crush, and sequence of events. GRA

**N87-25309#** Kentucky Univ., Lexington. Dept. of Mechanical Engineering.
**DETERMINATION OF THE LOCAL HEAT TRANSFER CHARACTERISTICS ON GLAZE ICE ACCRETIONS ON A CYLINDER AND A NACA 0012 AIRFOIL Final Report, May 1983 - Sep. 1986**
M. R. PAIS and S. N. SINGH Apr. 1987 74 p
(Contract F33615-83-C-3013)
(AD-A179931; AFWAL-TR-87-3001) Avail: NTIS HC A04/MF A01 CSCL 20D

In recent years, the problem of ice formation on aircraft has received considerable attention because of its influence on military aircraft capabilities. Military aircraft and helicopters may be required to operate under icing conditions which would effect their performance, maneuverability and impair the mechanical integrity of unprotected engines. Ice formation poses a hazard to flight in that it alters the aerodynamic characteristics of lifting surfaces, reducing the maximum lift and sharply increasing the drag. In addition the ice formation may lead to control problems and, if it sloughs off, damage structures downstream. The above situations can cause serious problems for military aircraft or missiles flying over the North Atlantic and North Sea. In Europe in winter it is possible to have the proper weather conditions for ice formation up to 30 percent of the time. The ice accretion process is of prime interest in aircraft design. In order to develop and then certify certain protection systems 11-16, it is necessary to be able to test engine intakes, aerofoils in simulated icing conditions. GRA

**N87-25310#** National Transportation Safety Board, Washington, D. C.
**AIRCRAFT ACCIDENT/INCIDENT SUMMARY REPORTS: UNALASKA, ALASKA, SEPTEMBER 25, 1985; JENKINSBURG, GEORGIA, SEPTEMBER 29, 1985; BOSTON, MASSACHUSETTS, DECEMBER 15, 1985; DEKALB, TEXAS, DECEMBER 31, 1985; ERIE, PENNSYLVANIA, FEBRUARY 21, 1986**
30 Jun. 1987 48 p
(PB87-910408; NTSB/AAR-87/02/SUM) Avail: NTIS HC A03/MF A01 CSCL 01C

A compilation of reports of aviation accidents investigated by the National Transportation Safety Board is presented. The accident locations and dates are: Unalaska, Alaska, September 25, 1985; Jenkinsburg, Georgia, September 29, 1985; Boston, Massachusetts, December 15, 1985; DeKalb, Texas, December 31, 1985; and Erie, Pennsylvania, February 21, 1986. Author

**N87-25311#** National Transportation Safety Board, Washington, D. C. Bureau of Safety Programs.
**ANNUAL REVIEW OF AIRCRAFT ACCIDENT DATA. US AIR CARRIER OPERATIONS CALENDAR YEAR 1983**
13 Feb. 1987 112 p
(PB87-160628; NTSB/ARC-87-01) Avail: NTIS HC A06/MF A01 CSCL 01C

The record of aviation accidents involving revenue operations of U.S. air carriers and on demand air taxis for calendar year 1983 is given. Tables are presented to describe the losses and characteristics of the 1983 accidents to enable comparisons with prior years. GRA

**N87-26034#** Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
**FUEL SAVING AND FUEL RELATED SUBJECTS WITHIN AN AIRLINE'S OPERATIONAL ENVIRONMENT**
J. BRUEGGEN 1 Apr. 1986 213 p Prepared in cooperation with KLM Royal Dutch Airlines, Amsterdam, Netherlands
(ETN-87-90148) Avail: NTIS HC A10/MF A01

Aircraft fuel level measuring magnetic sticks and their operation, the fuel used indicator and the corresponding fuel flow transmitter, the fuel quantity system, and the AIDS-equivalents of the fuel used and fuel quantity indication are described. The layout and operation of the horizontal tail and the trim unit are shown, and the variation of the elevator angle during flight, as a result of weight reduction and center of gravity shift (fuel burn) is analyzed. A unit which characterizes the fuel consumption of a Boeing 747 is presented. ESA

## 04

## AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

**A87-42779**
**REAL-TIME WIND ESTIMATION AND TRACKING WITH TRANSPONDER DOWNLINKED AIRSPEED AND HEADING DATA**
C. C. LEFAS (Nuclear Research Center Democritos, Attiki, Greece) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. AES-23, March 1987, p. 169-174. EUROCONTROL-supported research. refs

The use of magnetic heading and true air speed measurements made on board civil airplanes to assist in radar tracking is described. The data are telemetered via the air-ground data link of the mode S radar system. A new filter, similar to the first-order Kalman filter, is developed using velocity measurements to bias its prediction equations. This filter follows satisfactorily maneuvers, and estimates, in real time, the wind in the vicinity of the airplane. Finally a scheme is described to remove false data due to data-link corruption. Author

**A87-42786**
**GEOSTATIONARY SATELLITE NAVIGATION SYSTEMS**
TRI T. HA and R. CLARK ROBERTSON (Virginia Polytechnic Institute and State University, Blacksburg) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. AES-23, March 1987, p. 247-254. refs

The concept of position determination using geostationary satellites as an alternative to the global positioning system (GPS) is studied. The advantage of a geostationary system is that only three, or at most four, satellites are required to cover the continental United States. A total of twelve satellites are sufficient for global coverage (excluding polar regions), or eight if only longitude and latitude, but not altitude, are measured. The system involves the determination of the range to either four geostationary satellites or, if the altitude is not measured, three geostationary satellites. The accuracy of the proposed systems are evaluated to obtain the rms error associated with position determination, and the concept for the implementation of measurements required by the systems is presented. The accuracy of the systems are adequate for civilian use in the continental United States; however, there is a degradation in accuracy as the location of the user approaches the equator. Author

**A87-43455#**
**IRISH DAUPHIN HELICOPTER S.A.R. SYSTEM FLIGHT TESTS**
B. FOUQUES (Aerospatiale, Division Helicopteres, Marignane, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 10 p.

A system description, together with an evaluation of development tests and their revealed difficulties, are presented for the maritime search-and-rescue Dauphin helicopters developed for the Irish Air Corps and equipped in order to enable their quasi-autonomous operation in adverse weather conditions. Attention is given to the functions and integration of an automatic flight control system, Doppler, Omega and VOR/DME navigation, and flight data display systems. O.C.

**A87-43469#**
**AUTONOMOUS NAVIGATION SYSTEM FOR THE NEW GENERATION OF MILITARY HELICOPTERS AND ASSOCIATED FLIGHT TESTS**
M. BAEUMKER and W. HASSENPFLUG (Litton Technische Werke, Freiburg im Breisgau, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 22 p. refs

The paper describes an integrated autonomous strapdown inertial navigator, augmented by a Doppler velocity sensor and a magnetometer for helicopter application. To obtain height above ground, a radar altimeter is integrated into the navigation system. Accurate weapon delivery requirements and flight safety aspects while operating the helicopter under adverse weather conditions and at night demand the accurate determination of TAS throughout the entire speed regime. Next to position, velocity and attitude, the strapdown system provides all signals required for stability augmentation and to support autopilot functions. The system communicates with the other avionics on board the helicopter. Flight trials using three different types of helicopters have been performed to demonstrate the navigation capability and performance of a hybrid strapdown navigator, a new analytical true air speed system for the low speed regime, and the performance of a strapdown magnetometer. Author

**A87-44036**
**WORLDWIDE NAVIGATION INTO THE 21ST CENTURY - AN AIRLINE VIEW**
P. MOORE and D. M. PAGE (British Caledonian Airways, Ltd., Crawley, England) Journal of Navigation (ISSN 0020-3009), vol. 40, May 1987, p. 158-163.

The requirements for a future worldwide air navigation system, which combines navigation and air traffic control, are discussed. An integrated system of navigation and air traffic control is needed. The use of satellites for air navigation, control, and surveillance is examined. Consideration is given to the GPS, distance measuring equipment (DME)/DME fixing, and an automatic dependent surveillance system. Air traffic communications via data link transmission by satellites, operational control communications, and passenger communications are studied. The cost effectiveness of a control, navigation, and surveillance system based on satellites is evaluated. I.F.

**A87-44039**
**INTEGRATED NAVIGATION, COMMUNICATION AND SURVEILLANCE SYSTEMS BASED ON STANDARD DISTANCE MEASURING EQUIPMENT**
A. BECKER (DFVLR, Institut fuer Flugfuehrung, Brunswick, West Germany) Journal of Navigation (ISSN 0020-3009), vol. 40, May 1987, p. 194-205. refs

The use of standard distance measuring equipment (DME) to integrate communication/navigation/surveillance systems is studied. DME growth capabilities include the use of additional pulses, and the ability to accurately measure the angle of incidence of the received DME RF carrier wave. Various equipment has been developed based on the DME concept; the functions of the (1) three-way DME, (2) scanning three-way DME, (3) trilateration three-way DME, (4) ground azimuth direction finder, (5) ground elevation direction finders, (6) air-to-ground and ground-to-air selective datalinks, and (7) ground-to-air broadcast datalinks. Four methods for integrating communication/navigation/surveillance systems using DME elements are proposed. The bases of these systems are (1) three-way DME, (2) scanning three-way DME, (3) trilateration three-way DME, and (4) three-way DME with ground azimuth direction finder. These four systems are compared in terms of coverage, accuracy, integrity, frequency, utilization, installation, and costs. It is noted that system 2 is most applicable followed by systems 3, 1, and 4. I.F.

**A87-44040**
**COLOUR DEPENDENCE AND SURPLUS INFORMATION IN AIRPORT VISUAL AIDS DURING VFR OPERATIONS**
ROBERT K. MCKELVEY Journal of Navigation (ISSN 0020-3009), vol. 40, May 1987, p. 206-226. refs

Airport visual aids are investigated for failure to transfer from chromatic to achromatic viewing situations, and for their value during visual flight rule operations. Slide sequences of aircraft movements during taxi-out, take-off, approach, and landing operations under various meteorological conditions at night were prepared and evaluated by pilots. The responses of the 27 pilots are analyzed in terms of the proportions of color-linked response; the frequency of correct signal recognition responses within chroma categories; and the frequency of correct response within visual guidance categories. It is observed that only the signal light from the control tower is completely color dependent, and there is some contradiction between the complexity of the display system and the guidance values. I.F.

**A87-44231**
**AN AIRBORNE COLLISION AVOIDANCE SYSTEM - THE TCAS [UN SYSTEME ANTICOLLISION EMBARQUE - LE TCAS]**
JEAN LAMBERT (Direction Generale de l'Aviation Civile, Service Technique de la Navigation Aerienne, Paris, France Navigation (Paris) (ISSN 0028-1530), vol. 35, April 1987, p.

TCAS is a totally airborne system which uses the secondary radar signal formats to detect surrounding aircraft. It indicates their positions to the pilot and computes vertical avoidance maneuvers. This article describes the operation of the system and the conflict detection and resolution algorithms. A graphic interpretation of the algorithms is provided as well as a demonstration that it is not feasible to give the pilot an indication of the headings of surrounding aircraft in addition to their positions. Author

**A87-44312**
**ERRORS IN THE MEASUREMENT OF THE COURSE ANGLES OF RADAR REFERENCE POINTS DUE TO THE IMPRECISE STABILIZATION OF THE ANTENNA MOUNTING IN BANK AND PITCH [OSHIBKI IZMERENIIA KURSOVYKH UGLOV RADIOLOKATSIONNYKH ORIENTIROV IZ-ZA NETOCHNOI STABILIZATSII OSNOVANIIA ANTENNY PO KRENU I TANGAZHU]**
S. D. SUBOCHEV (Leningradskii Institut Aviatsionnogo Priborostroeniia, Leningrad, USSR) Priborostroenie (ISSN 0021-3454), vol. 30, April 1987, p. 49-52. In Russian.

A first-approximation analysis is made of the measurement error of the course angle of radar reference points according to the indicator of an airborne panoramic radar. It is shown that the error depends linearly on the stabilization errors of the antenna mounting in bank and pitch. B.J.

**A87-44845**
**TIME MODULATION. II - SCHEME CODES AVOIDANCE MANEUVERS FOR AIRCRAFT**
EDMOND R. GUNNY Microwaves & RF (ISSN 0745-2993), vol. 26, June 1987, p. 86, 88-90, 92, 93.

The operation of the reply encoder and decoder circuit and the intent generation of time-effective modulation avoidance scheme is described. In reply transmissions the reply message elements are sent out in separate range periods; the first reply pulse transmission is sent immediately upon detection and signal processing and the second is delayed by both the range listing time and encoded reply time. Reply message-time spacing is achieved by a random access memory module. The replies are then matched and sent to a computer to generate differential altitude data. The requirements for an air traffic control (ATC) transponder are examined. The limitations of the traffic alert and collision avoidance systems currently utilized are discussed. A data link for pilots and ATC on a common radio spectrum needs to use a modulation system such as the one proposed. A diagram of the pulse-pair matching of signature modulation system is presented. I.F.

**A87-45722#**
**AIRBORNE LASER COMMUNICATIONS SCINTILLATION MEASUREMENTS**
ROBERT J. FELDMANN, LINDEN B. MERCER (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH), and STEVEN K. ROGERS (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: MILCOM '86 - Military Communications Conference, Monterey, CA, Oct. 5-9, 1986, Conference Record. Volume 3 . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 45.5.1-45.5.5. refs

The effects of scintillation on air-to-air laser communication performance are investigated using optical scintillation data collected during the Laser Airborne Communications Experiment (LACE). The objectives of and experimental procedures for LACE are described. The collected scintillation data are compared to data derived from terrestrial atmospheric turbulence models. It is observed that the ground scintillation data correlate with this prediction, and the initial flight test results agree with a log normal distribution. I.F.

**A87-45878**
**THE QUALITY OF RADAR DATA AND ITS DETERMINATION AT THE RADAR INSTALLATIONS OF THE BUNDESANSTALT FUER FLUGSICHERUNG [RADARDATENQUALITAET UND IHRE BESTIMMUNG AN DEN RADARANLAGEN DER BUNDESANSTALT FUER FLUGSICHERUNG]**
BOR B. CLOOS (Bundesanstalt fuer Flugsicherung, Frankfurt am Main, West Germany) IN: Radar Technology 1986; Symposium, 6th, Bremen, West Germany, Nov. 4-6, 1986, Reports . Duesseldorf, Deutsche Gesellschaft fuer Ortung und Navigation, 1986, p. C2.1-C2.21. In German. refs

The procedures used by the West German federal flight-safety agency to evaluate the quality of radar data are reviewed. The parameters used to define quality are introduced; the importance of the interface between the radar sensor and the display is indicated; problems related to target classification, reproducibility, and statistical significance are discussed; and the design concept of an integrated radar evaluation system is presented. Diagrams, drawings, graphs, and photographs are provided. T.K.

**A87-46415**
**TERRAIN MODELLING OF GLIDESLOPE FOR INSTRUMENT LANDING SYSTEM**
M. M. POULOSE, P. R. MAHAPATRA, and N. BALAKRISHNAN (Indian Institute of Science, Bangalore, India) IEE Proceedings, Part H - Microwaves, Antennas and Propagation (ISSN 0950-107X), vol. 134, pt. H, no. 3, June 1987, p. 275-279. refs

The paper makes a contribution to the evaluation of irregularities introduced in electronically defined glideslopes of UHF instrument landing systems (ILS) by the unevenness of the terrain around the glideslope antenna. Various methods of physical and geometric optics have been applied in recent years to model and estimate the glideslope aberration at given locations prior to actual installation. A systematic study of various methods is made in the paper. A general treatment is evolved, which is capable of exhaustively handling arbitrary ray order effects and topography. The uniform asymptotic theory has been applied to the ILS problem and results compared with the uniform theory of diffraction. The results of actual case studies are presented. Author

**A87-46861**
**APPLICATION OF WEDGE DIFFRACTION THEORY TO ESTIMATING POWER DENSITY AT AIRPORT HUMPED RUNWAYS**
ALFRED R. LOPEZ (Hazeltine Corp., Commack, NY) IEEE Transactions on Antennas and Propagation (ISSN 0018-926X), vol. AP-35, June 1987, p. 708-714. refs

Shadowing caused by humped runways at some airports significantly attenuates the guidance signals of the microwave landing system as the aircraft approaches the touchdown point. Application of wedge diffraction theory provides an estimate of this effect. A wedge diffraction factor is presented which relates the signal strength in the shadow to that for line-of-sight on a flat runway. Computations are confirmed by measurements at two airports. Author

**N87-25312#** Federal Aviation Agency, Atlantic City, N.J.
**HELIPORT VISUAL APPROACH SURFACE TESTING TEST PLAN**
ROSANNE M. WEISS and JOHN R. SACKETT Feb. 1987 31 p (AD-A179897; DOT/FAA/CT-TN86/61) Avail: NTIS HC A03/MF A01 CSCL 01D

This Technical Note identifies procedures to be used during tests to be conducted at the Federal Aviation Administration Technical Center. These tests are designed to test the applicability of existing heliport approach and departure surface criteria. Three different types of aircraft will be used. GRA

**N87-25313#** Test Wing (4950th), Wright-Patterson AFB, Ohio.
**TACAN/INS PERFORMANCE EVALUATION (TIPE) FLIGHT TEST REPORT Report, 29 Apr. - 24 May 1986**
CHRISTOPHER J. MCCORMACK 22 Jan. 1987 43 p (AD-A180138; REPT-4950/FTR-86-10) Avail: NTIS HC A03/MF A01 CSCL 17G

The TACAN/INS Performance Evaluation test program investigated the feasibility of test missions requiring aircraft position information without using dedicated ground based tracking radars. This test examined the accuracy of the aircraft's TACAN receiver and on board inertial navigation system by comparing data from these airborne systems with information from a ground based precision laser tracker. Data analysis concentrated on the distance measuring equipment information from the TACAN transceiver. The report contains a summary of the data collected as well as a description of the data reduction techniques, including dual DME position fixing and three dimensional coordinate transformations. The results indicate that a dual TACAN positioning system can provide accurate position fixing. GRA

## 05

## AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

**A87-42855**
**FRACTURE OF AN AIRCRAFT HORIZONTAL STABILIZER**
IAN C. HOWARD (Sheffield, University, England) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 259-276.

An analysis is presented on the data of the accident report on a Boeing 707 crash, the origin of which was found to be a fatigue failure of the top chord of the stabilizer. This fracture had eventually propagated, severing the stabilizer from the body of the aircraft during a flap maneuver. In the present study, linear elastic fracture mechanics (LEFM) is used to investigate the first static jump of the crack; in addition, use was made of published data on stress intensity factor in a bar weakened by a corner crack. The results made it possible to predict the fracture toughness of the material from which the cracked component was made and to estimate the load transferred within the stabilizer by the arrest of this crack. I.S.

**A87-42856**
**FATIGUE LIFE ANALYSIS OF FUEL TANK SKINS UNDER COMBINED LOADS**
CHARLES R. SAFF and M. A. FERMAN (McDonnell Aircraft Co., St.Louis, MO) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 277-290.

The superposition of high- and low-frequency loadings has caused numerous fatigue crack problems throughout the history of metal airframes. Fighter aircraft fuel tanks are subjected to the superposition of low-frequency (0.1 to 1 Hz) maneuver loads and high frequency (50 to 300 Hz) vibrations to panel flutter and fuel slosh. This loading can lead to cracks, and leaks, in shorter times than can be predicted by using either load condition alone. This paper examines two methods for predicting fatigue lives under combined high- and low-frequency loadings. Tests of beam element specimens and a simulated fuel tank were used to examine prediction accuracy of both techniques. Results show that both techniques accurately predict the effects of combined load frequencies on life when adjusted to correlate predictions with the extreme (high- and low-) frequency data. Author

**A87-43402#**
**FEL - A NEW MAIN ROTOR SYSTEM**
DIETER BRAUN, HUBERT FROMMLET, and ALOIS SCHWARZ (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p.

A new hingeless main rotor system, the fiber-elastomeric bearing rotor (FEL) for a 4-5-ton helicopter is under development. Its main features are elastomeric bearings and composite materials for the blades and hub. Flapping and lead lag motions are made in the flexible neck of the blades; pitch change is accomplished by the elastomeric bearings. The design goals for this new rotor type are low weight, simple and robust construction, low parts count, minimal maintenance, reduced vulnerability, and excellent maneuverability by high control power. Stress calculations, stiffness optimization, and component testing have been performed, and the new rotor system has been verified on the whirl tower. Author

**A87-43403#**
**NEW AERODYNAMIC DESIGN OF THE FENESTRON FOR IMPROVED PERFORMANCE**
A. VUILLET and F. MORELLI (Aerospatiale, Division Helicopteres, Marignane, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 12 p. refs

An evaluation is made of the performance advantages and prospective design improvements for the 'fenestron' type of helicopter tail rotor. Attention is given to the results of recent fenestron flow analyses conducted with both scale models and full scale aircraft, as well as to the methods employed to obtain these experimental data. Tests of a fenestron incorporating stator blades behind the rotor, within the diffuser structure, have indicated significant efficiency and maximum thrust improvements for a given rotor solidity. O.C.

**A87-43406#**
**OPTIMUM DESIGN OF A HELICOPTER ROTOR BLADE**
S. HANAGUD, ADITI CHATTOPADHYAY, Y. K. YILLIKCI, D. SCHRAGE (Georgia Institute of Technology, Atlanta), and G. REICHERT (Braunschweig, Technische Universitaet, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 26 p. refs

The problem of minimum weight design of a helicopter rotor blade subject to a constraint on its coupled flap-lag-torsional natural frequency has been studied in this paper. Modern structural optimization technique based on optimality criteria approach has been applied for optimizing the weight of the blade. Optimum designs are presented for a typical soft-in-plane hingeless rotor configuration. The results indicate that the application of structural optimization techniques leads to benefits in rotor blade design not only through substantial reduction in weight but a considerable reduction in the vibratory hub shears and moments at the blade root due to proper placement of blade natural frequency. Author

**A87-43407#**
**EXPANDING TILT ROTOR CAPABILITIES**
J. M. DREES (Bell Helicopter Textron, Fort Worth, TX) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p. refs

The XV-15 tilt-rotor aircraft is the culmination of over 50 years of research, development, and testing. It has proven the practicality of the tilt rotor concept and led directly to implementation of the V-22 Osprey program. The time has now come to project the full potential of the tilt rotor in the future. In this paper, possibilities for weight reduction and performance improvement are discussed that could lead to significant enhancements in payload and operational speeds. In particular, control system configurations, wing download reductions, wing forward sweep, and canard concepts are suggested as candidates offering potential improvements for the next generation of tilt-rotor aircraft. To achieve forward velocities beyond what is feasible with the tilt rotor, its derivative, the tilt-fold rotor, could become attractive for high transonic and perhaps supersonic performance, provided that suitable convertible engines become available. Author

**A87-43408*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**CALCULATED PERFORMANCE, STABILITY, AND MANEUVERABILITY OF HIGH-SPEED TILTING-PROP-ROTOR AIRCRAFT**
WAYNE JOHNSON, BENTON H. LAU, and JEFFREY V. BOWLES (NASA, Ames Research Center, Moffett Field, CA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 43 p. Previously announced in STAR as N87-17695. refs

The feasability of operating tilting-prop-rotor aircraft at high speeds is examined by calculating the performance, stability, and maneuverability of representative configurations. The rotor performance is examined in high-speed cruise and in hover. The whirl-flutter stability of the coupled-wing and rotor motion is calculated in the cruise mode. Maneuverability is examined in terms of the rotor-thrust limit during turns in helicopter configuration. Rotor airfoils, rotor-hub configuration, wing airfoil, and airframe structural weights representing demonstrated advanced technology are discussed. Key rotor and airframe parameters are optimized for high-speed performance and stability. The basic aircraft-design parameters are optimized for minimum gross weight. To provide a focus for the calculations, two high-speed tilt-rotor aircraft are considered: a 46-passenger, civil transport and an air-combat/escort fighter, both with design speeds of about 400 knots. It is concluded that such high-speed tilt-rotor aircraft are quite practical. Author

**A87-43409#**
**RSRA/X-WING - A STATUS REPORT**
ARTHUR W. LINDEN (United Technologies Corp., Sikorsky Aircraft Div., Stratford, CT) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 15 p.

A development history and status report is presented for the Rotor System Research Aircraft; this is an 'X-wing' helicopter able to bring its main rotor to a full halt in order to employ it as a wing during high speed flight, and vice versa. Attention is given to this rotary-to-fixed wing conversion mode. The flight test phase for this experimental vehicle began in the Fall of 1986. Rotor mechanical design details and control system organization are discussed. O.C.

**A87-43410*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**MEASUREMENT OF SIDE FORCES OF A H-FORCE ROTOR**
HENRY R. VELKOFF (NASA, Ames Research Center; U.S. Army, Advanced Research Technology Activity, Moffett Field, CA), CHRISTIAN PETERSILGE, and CURTIS COWAN (Ohio State University, Columbus) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p. refs

Study of the use of tip vanes has been underway to investigate both the impact of the vanes on hover performance and on their potential use as force generators. It is the aim of this paper to report on progress made to determine the forces that can be generated. Model tests were run using a 6-ft-diameter rotor with tip vanes pivoted below the blade tips. Data were taken on the thrust, torque, and side force. The results obtained were in substantial agreement with the side force predicted by using a simple wing model. Author

**A87-43411#**
**PREDICTION OF BLADE AIRLOADS IN HOVERING AND FORWARD FLIGHT USING FREE WAKES**
R. H. MILLER and S. C. ELLIS (MIT, Cambridge, MA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 11 p. refs

Recent advances in the determination of rotor airloads and performance in hovering and forward flight, including autorotation,

are discussed. The ability to predict the spatial and temporal variation of blade airloads in forward flight is particularly important, since the higher harmonic components of these loads are the primary source of helicopter vibration. Flight regimes and rotor configurations are identified that require the use of free-wake analytical techniques, as opposed to those regimes for which the simpler rigid wake or momentum balance techniques are adequate. Author

**A87-43423#**
**MEASUREMENTS OF THE PERFORMANCE OF A HELICOPTER SWEPT TIP ROTOR IN FLIGHT**
M. J. RILEY (Royal Aircraft Establishment, Bedford, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 14 p.

Swept and rectangular planforms have been flight tested simultaneously on a single rotor. Surface pressure distributions have shown the swept tip to perform well on the retreating blade and in the highly loaded areas at the front and rear of the rotor disk as well as on the advancing blade. Blade dynamic response measurements have demonstrated the effectiveness of the chosen planform in controlling aerodynamic pitching moments and overall power measurements indicate a reduction of the power required by the swept tip rotor. Author

**A87-43427#**
**AN ANALYSIS OF IN-FIN TAIL ROTOR NOISE**
M. ROGER and F. FOURNIER (Lyon, Ecole Centrale, Ecully, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 15 p. refs
(Contract DRET-83-025; DRET-84-368)

This paper is concerned with some aspects of sound generation and sound propagation from a fenestron in-fin tail rotor. The study includes the three following parts: (1) a prediction of rotor-noise sources using calculations based on unsteady aerodynamics theory; (2) an experimental investigation of the diffraction caused by the casing; and (3) the definition of an acoustic testing procedure on a real complete version of a fenestron-type tail rotor. Each part was performed independently. All the results given here are therefore only preliminary results, which must be considered as a first attempt at understanding the noise generated by an in-fin tail rotor. Author

**A87-43431*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**ROTOR DESIGN FOR MANEUVER PERFORMANCE**
JOHN D. BERRY (NASA, Langley Research Center; U.S. Army, Aerostructures Directorate, Hampton, VA) and DANIEL SCHRAGE (Georgia Institute of Technology, Atlanta) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 12 p.

A method of determining the sensitivity of helicopter maneuver performance to changes in basic rotor design parameters is developed. Maneuver performance is measured by the time required, based on a simplified rotor/helicopter performance model, to perform a series of specified maneuvers. This method identifies parameter values which result in minimum time quickly because of the inherent simplicity of the rotor performance model used. For the specific case studied, this method predicts that the minimum time required is obtained with a low disk loading and a relatively high rotor solidity. The method was developed as part of the winning design effort for the American Helicopter Society student design competition for 1984/1985. Author

**A87-43434#**
**HELICOPTER MODELLING FOR PERFORMANCE CALCULATION**
KARL LIESE (Braunschweig, Technische Universitaet, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 19 p. BMFT-sponsored research. refs

Methods for helicopter performance calculations are brought into line with the specific job in each case. Modern calculation techniques used in science and industry generally include analytical, empirical, and experimental parts, computing exact results within short time. Essential parts of the helicopter physical model are studied (such as downwash, blade-tip loss, hub geometry, and blade motions, as well as blade and fuselage aerodynamics), and their influence on the power required and trim settings is described. The high variety of results based on different modeling techniques makes it possible to adapt existing calculation methods to a new task or to bring about a new efficient method by combining suitable parts. Author

**A87-43442*#** California Univ., Los Angeles.
**RECENT TRENDS IN ROTARY-WING AEROELASTICITY**
PERETZ P. FRIEDMANN (California, University, Los Angeles) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 46 p. refs
(Contract NAG2-209; NAG2-226)

The purpose of this paper is to survey the principal developments which have occurred in the field of rotary-wing aeroelasticity during the past five year period. This period has been one of considerable activity and approximately one hundred papers have been published on this topic. To facilitate this review the field has been divided into a number of areas in which concentrated research activity has taken place. The main areas in which recent research is reviewed are: (1) structural modeling; (2) aerodynamic modeling; (3) aeroelastic problem formulation using automated or computerized methods; (4) aeroelastic analyses in forward flight; (5) coupled rotor/fuselage analyses; (6) active controls and their application to aeroelastic response and stability; (7) application of structural optimization to vibration reduction; and (8) aeroelastic analysis and testing of special configurations. These areas are reviewed with different levels of detail and some useful observations regarding potentially rewarding areas of future research are made. Author

**A87-43443#**
**AEROELASTIC STABILITY OF A BEARINGLESS CIRCULATION CONTROL ROTOR IN FORWARD FLIGHT**
INDERJIT CHOPRA and CHANG-HO HONG (Maryland, University, College Park) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p. refs

The aeroelastic stability of flap bending, lag bending and torsion of a bearingless circulation control rotor blade in forward flight is examined using a finite element formulation. The flexbeam, the torque tube and the outboard blade are all discretized into beam elements, and the displacement compatibility conditions are introduced in assembled matrices. Quasisteady strip theory is used to evaluate aerodynamic forces, and the airfoil characteristics are taken from data tables. The effects of pneumodynamics and centrifugal pumping in the pressure duct are included to calculate jet momentum coefficient as a radial station. Two types of vehicle trim, propulsive and auxiliary power, are calculated from vehicle and rotor equilibrium equations through numerical integration of element forces in azimuth as well as in radial directions. The nonlinear periodic blade response is calculated using a finite element in time method in normal mode equations. The periodic linearized perturbation equations in modal space are analyzed for stability, using Floquet transition matrix theory. The effects of several parameters on blade stability are examined, including advance ratio, collective pitch, shaft tilt, propulsive and auxiliary power trim. Author

**A87-43444#**
**INVESTIGATION OF GROUND AND AIR RESONANCE USING A COMBINATION OF MULTIBLADE COORDINATES AND FLOQUET THEORY**
J. EWALD (Braunschweig, Technische Universitaet, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 15 p. refs
(Contract BMFT-LFF-84318)

The description of the dynamic behavior of helicopters often leads to differential equations with periodically varying coefficients. The solution of these differential equations can be obtained by different mathematical methods. An efficient procedure results from the combination of multiblade coordinates and Floquet theory. Using this method, investigations of ground and air resonance are carried out. By plotting the eigensolutions and eigenvector functions it is shown that the transformation using multiblade coordinates does not eliminate the periodicity of the coefficients. This is due not only to the different dynamic behavior of rotor blades, but also to special frequencies contained in the system matrices. Author

**A87-43445#**
**AN IMPROVED ASSUMED MODE METHOD FOR ESTIMATING THE MOTION OF A NONUNIFORM ROTOR BLADE**
H. AZZAM and P. TAYLOR (Southampton, University, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 13 p. Research supported by the Ministry of Defence (Procurement Executive). refs

The uncoupled flapwise and torsional motion of a rotating blade is considered in order to demonstrate that the Galerkin method is also applicable to the case of a nonuniform blade whose structural properties vary sharply along its length. Then, a finite element-like-technique of the assumed modes is presented to provide a consistent relation between the deflection and the moment of the nonuniform blade. The concept of the equivalent flapping hinge offset for hingeless blades is reassessed in an attempt to make the flapping equation more representative. Finally, an equivalent elastic twist is proposed in order to partially compensate for the absence of the torsional analysis in the simple rotor programs. Author

**A87-43449#**
**DAMAGE TOLERANCE CONCEPTS FOR MODERN HELICOPTERS**
M. TAPAVICZA (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 21 p. refs

Damage-tolerant methods have found much interest in the helicopter community in the past years. The aim of damage tolerance is that structures may withstand reasonable static and dynamic loads despite the occurrence of defects as a consequence of fatigue, wear, impact, etc. Damage tolerance may be achieved by slow defect growth or fail-safe capability of the structure. In the first case, it is assured that defects propagate slowly and that early detection is guaranteed. In the second case, defects are absorbed by redundant load paths or defect-arresting structures. Tolerating defects is necessarily connected with the availability of adequate inspection methods and maintenance intervals, which have to be approved during the certification procedure. Although designed to the hitherto accepted safe-life philosophy, many helicopters already incorporate a bundle of damage-tolerant features (e.g., the application of composite material or redundant-load-path design). The qualification of entire helicopters solely according to the damage-tolerant approach seems premature; rather, a combined safe-life/damage-tolerance philosphy is adequate at the present time. Author

**A87-43450#**
**DETERMINATION OF THE STRUCTURAL PROPERTIES OF HELICOPTER ROTOR BLADES BY THEORETICAL AND EXPERIMENTAL METHODS**
C. HATCH and A. R. LEE (Royal Aircraft Establishment, Farnborough, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 20 p.

The use of a theoretical method for determining equivalent beam extensional, bending, and torsional stiffnesses for helicopter rotor blades fabricated from anisotropic material with arbitrary cross-sectional geometry is discussed, and results presented. The method, which uses the NASTRAN finite-element package, also determines all stiffness coupling terms and predicts the position of the elastic axis and shear center. Experimental data, derived from simple section beams and model rotor blades manufactured from composite materials, are used for comparison with the theoretically derived stiffnesses. An experimental method used for determining the beam bending stiffness, torsional stiffness, and shear center is also presented. This technique uses a number of +/- 1 g servo accelerometers mounted on the blade and used as inclinometers to measure angular deflections for known loads. This method enables shear-center positions to be determined to an accuracy better than 1 percent of the blade chord, and bending and torsional stiffnesses to within 2 percent. Author

**A87-43451#**
**COMPOSITE VITAL PARTS OPTIMISATION FOR EH 101 ROTOR HUB**
E. ANAMATEROS, L. CARONI, M. FARIOLI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Gollarate, Italy), and C. ROTONDI DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 27 p. refs

This paper is aimed to present the optimization of the design, manufacturing, and controllability of composite loop-windings. These loop-windings are parts of the EH 101 main rotor hub. The material used for the construction of the loop-windings is graphite-epoxy composite material. The target of the program was to optimize the manufacturing process, minimize defects, and choose the graphite-epoxy material with the characteristics more compatible with this application. To attain this target, manufacturing and structural tests were carried out, correlations with analytical models, and structural tests were performed. Research for the nondestructive tests were done in order to assume the quality of the loop-windings. Author

**A87-43456*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**CORRELATION OF SA349/2 HELICOPTER FLIGHT-TEST DATA WITH A COMPREHENSIVE ROTORCRAFT MODEL**
GLORIA K. YAMAUCHI, RUTH M. HEFFERNAN (NASA, Ames Research Center, Moffett Field, CA), and MICHEL GAUBERT (Aerospatiale, Division Helicopteres, Marignane, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 52 p. Previously announced in STAR as N87-17692. refs

A comprehensive rotorcraft analysis model was used to predict blade aerodynamic and structural loads for comparison with flight test data. The data were obtained from an SA349/2 helicopter with an advanced geometry rotor. Sensitivity of the correlation to wake geometry, blade dynamics, and blade aerodynamic effects was investigated. Blade chordwise pressure coefficients were predicted for the blade transonic regimes using the model coupled with two finite-difference codes. Author

**A87-43459#**
**EXPERIMENTAL APPLICATION OF STRAIN PATTERN ANALYSIS (SPA) - WIND TUNNEL AND FLIGHT TEST RESULTS**
A. R. WALKER and D. B. PAYEN (Royal Aircraft Establishment, Farnborough, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 25 p.

Further experimental application of Strain Pattern Analysis (SPA) to derive rotor blade deformation is described. The SPA technique has now been extended to derive not only the vibration mode shapes of a rotating blade, but also the instantaneous deformation shape at consecutive azimuth stations around the rotor disc. This technique has been successfully applied to both a dynamically scaled rotor model tested in the RAE 24 ft Wind Tunnel, and a Puma helicopter used in flight research at RAE Bedford. Instantaneous blade deformations around the rotor disc are presented for both the model and helicopter rotor blades. These results are compared with corresponding calculated deflections. Author

**A87-43463#**
**SUBSTANTIATION OF THE ANALYTICAL PREDICTION OF GROUND AND AIR RESONANCE STABILITY OF A BEARINGLESS ROTOR, USING MODEL SCALE TESTS**
P. T. W. JUGGINS (Westland, PLC, Helicopter Div., Yeovil, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 19 p. Research supported by the Ministry of Defence (Procurement Executive). refs

Prediction of the ground and air resonance stability of a bearingless main rotor demands the use of analytical techniques which adequately address the particular characteristics associated with this type of rotor. The approach adopted in such an analytical procedure is described and the substantiation of analysis by testing of a scale model bearingless main rotor is reported. Substantiation is achieved, from generally good agreement between measured and theoretical data, although parameters are identified which hindered clear evaluation of some stability margins by the Moving Block technique. The effects of pitch-lag coupling on stability are discussed, from measured results and from a theoretical study. Implications for added damping requirements on a full scale rotor are identified. Author

**A87-43471#**
**LIGHTNING PROTECTION ACTIVITY IN THE DEVELOPMENT OF A NEW HELICOPTER**
GIUSEPPE MESCHI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Cascina Costa, Italy) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p.

The design and test procedures used to minimize the effects of lightning on helicopters (especially those with many composite structures) are discussed. The division of an aircraft surface into zones on the basis of lightning susceptibility called for by MIL-STD-1757 is reviewed and illustrated with a drawing; the peak, intermediate, continuing, and restrike currents to be survived are presented in tables; protective techniques against direct effects (metallic meshes, coatings, or laminae) and against indirect effects (shielding, terminal protection devices, and grounding) are described; and high-voltage and current-flow test procedures for components and complete aircraft are outlined. T.K.

**A87-43472#**
**AIR CYCLE ENVIRONMENTAL CONTROL SYSTEM FOR HELICOPTERS - A TRADE-OFF STUDY**
A. MANNINI, G. SARRI (Microtecnica-Torino, Turin, Italy), and V. MARCHIS (Torino, Politecnico, Turin, Italy) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p.

In the present comparative analysis of air-cycle helicopter environmental control systems (ECSs), an attempt is made to define the most suitable system configuration on the basis of aircraft and mission parameters; trade-offs involve choices among simple, 'bootstrap', and combined simple/bootstrap cycles in view of system weight-saving, energy-saving, overall dimensions, reliability, and maintainability criteria. The behavior of complete ECSs encompassing heat exchangers, valves, water separators and pipes is simulated by a well-tested computer program. The effects of weight and power savings obtainable by the optimum configuration are elaborated through evaluation of consequent fuel saving as a function of mission length. The sample case of the EH 101 helicopter is presented. O.C.

**A87-43473#**
**AIR CONDITIONING SYSTEMS FOR HELICOPTERS**
FRANCIS COUGNENC (Toulouse, Centre d'Essais Aeronautique, France) and MARCEL LESCAUDRON (ABG-Semca, S.A., Toulouse, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 11 p.

The cooling of helicopter avionics as well as cabins requires air conditioning systems whose basing on air or vapor cycles must be evaluated in light of the full range of technological and economic criteria. Attention is presently given to the certification tests that must be undertaken for such air conditioning systems and the facilities in which they can be conducted, with a view to plans for next-generation facility designs. Illustrative examples of the testing process are given for current helicopter cooling systems. O.C.

**A87-43474#**
**THE TILT-ROTOR AIRCRAFT - A RESPONSE TO THE FUTURE? FROM EUROPEAN INTERROGATIONS TO EUROFAR ACTIONS**
HELMUT HUBER (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany), J. ANDRES, and J. RENAUD (Aerospatiale, Division Helicopteres, Marignane, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 51 p. refs
(MBB-UD-485-86-PUB)

The European Future Advanced Rotorcraft (Eurofar) program, concerned with the development of a tilt-rotor aircraft by a group of European aircraft manufacturers,, is examined. The advantages and limitations of helicopters, and methods for extending these limitations and increasing the operational efficiencies of the helicopter are discussed. The manufacturers propose to design a 10-ton-class tilt-rotor aircraft that consists of an aircraft fuselage with a fixed wing having a low aspect ratio and wing-tip mounted tilting rotor. The aircraft is to weigh 10,200 kg, have a useful load of 4,010 kg, an empty-to-gross weight ratio of 0.607, and a take-off weight of 13,000 kg. Diagrams of the proposed tilt-rotor aircraft and its operating modes, and graphs explaining the expected performance of the aircraft are presented. I.F.

**A87-44256**
**HELICOPTER ROTOR ICING PROTECTION METHODS**
H. J. COFFMAN, JR. (Bell Helicopter Textron, Inc., Fort Worth, TX) American Helicopter Society, Journal (ISSN 0002-8711), vol. 32, April 1987, p. 34-39. refs

Current production helicopter rotor icing protection systems and most systems now under development use electrothermal deicing. This paper reviews other types of rotor icing protection systems for which interest has been shown. In searching for icing protection systems that weigh and cost less than the electrothermal deicing method, investigators have looked at fluid anti-icing, pneumatic deicing, electro-impulse deicing, and electro-vibratory deicing methods. Several of these alternative blade icing protection systems show promise for future development. Author

**A87-44577**
**PROSPECTS FOR THE USE OF COMPOSITES IN CIVIL AIRCRAFT**
A. W. KITCHENSIDE (British Aerospace, PLC, Weybridge, England) IN: High tech - The way into the nineties; Proceedings of the Seventh International SAMPE Conference, European Chapter, Munich, West Germany, June 10-12, 1986 . Amsterdam and New York, Elsevier Science Publishers, 1986, p. 15-28.

The civil-aircraft primary-structure use of carbon-fiber-reinforced composites is presently assessed on the basis of a technology demonstration program concerned with the production of a BAe 125 commuter-airliner wing structure. At the structural loading levels that exist in small civil-aircraft wings and in empennage structures, which are of the order of 1.0 MN/m, these composites can furnish worthwhile weight savings relative to aluminum alloys. At the higher loadings that are characteristic of larger aircraft wing structures, cost-effectiveness relative to emerging Al-Li alloy structures will require the use of higher-modulus fibers. O.C.

**A87-44594**
**A310-300 CFRP FIN - DAMAGE TOLERANCE DEMONSTRATION**
O. GOEKGOEL (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) IN: High tech - The way into the nineties; Proceedings of the Seventh International SAMPE Conference, European Chapter, Munich, West Germany, June 10-12, 1986 . Amsterdam and New York, Elsevier Science Publishers, 1986, p. 273-286. refs

An account is given of the damage-tolerance philosophy applied to the certification process of an airliner's CFRP empennage structure box, with a view to general requirements encountered in the A310-300 aircraft, design principles and allowables, structural test methods, damage and defect types, and inspection and repair philosophies. Impact, bird-strike, APU-rotor-failure, and lightning-strike damage consequences for the structure have been tested in the course of certification. Four categories of defect and delamination size have been established for various elements of the structure. O.C.

**A87-44704**
**DEVELOPMENT OF THE CHINOOK HELICOPTER ROTOR BLADE DE-ICING SYSTEM**
KENNETH LUNN (Boeing Vertol Co., Philadelphia, PA) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 46-63.

The design and development of a rotor deicing system for composite rotor blade equipped Chinook helicopters are described. Spanwise electrothermal deicing mats arranged in a 12-wire system form the basis of the deicing system for the composite rotor blades. Diagrams of the location of the heaters on the rotor blade are presented. The system consists of an ice detector unit, the deicer controller, two distributors, a pilot control panel, a development test panel, and an outside air temperature sensor; the operation of these components is discussed. A prototype of the deicing system was subjected to thermodynamic modeling, bench testing, flight and support tests, and thermal fatigue testing. The test data reveal that the electrothermal deicing system will allow composite rotor blade helicopters to operate effectively in all levels of icing severity. I.F.

**A87-45158#**
**STOVL ENGINE/AIRFRAME INTEGRATION**
R. L. BUCKNELL (Pratt and Whitney, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-1711)

Considerations for engine/airframe integration are examined with reference to four single-engine, advanced short takeoff, vertical landing supersonic aircraft concepts (vectored thrust, remote augmentor lift system, tandem fan, and ejector lift). In particular, attention is given to typical propulsion considerations, engine cycle selection trades, fore and aft combustor nozzle integration, and engine operability and integrated controls. It is noted that the selection of the preferred approach to engine/airframe integration depends largely on the installation to minimize supersonic drag and on the achievement of reliable operation for required operating modes, including transition of engine and aircraft, ground effects, and all flight maneuvers. V.L.

**A87-45237#**
**STOL CHARACTERISTICS OF A TACTICAL AIRCRAFT WITH THRUST VECTORING NOZZLES**
ROBERT F. TAPE (Rolls-Royce, Inc., Atlanta, GA), RONALD J. GLIDEWELL (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH), and DAVID E. BERNDT (Rockwell International Corp., Los Angeles, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1835)

An evaluation has been made of tactical aircraft exhaust system thrust vectoring concepts capable of improving short field operational capabilities in next-generation fighters. An advanced STOL combat aircraft, configured on the basis of study results, exhibits field length requirements of less than 1000 feet, using the vectored bypass flow from an unmixed turbofan engine as a source of propulsive lift. The nozzles are located close to the center of gravity, minimizing the effect of thrust vectoring on pitch characteristics. Two exhaust nozzle concepts are selected for detailed study in wind-tunnel tests. O.C.

**A87-45300*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INTEGRATION EFFECTS OF PYLON GEOMETRY AND REARWARD MOUNTED NACELLES FOR A HIGH-WING TRANSPORT**
JOHN R. CARLSON and MILTON LAMB (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(AIAA PAPER 87-1920)

Results of a wind-tunnel study of the effect of pylon cross-sectional shape and tow angle on airplane drag and an aft-mounted nacelle are presented. The 1/24-scale wide-body high-wing transport model was tested in the Langley 16-Foot Transonic Tunnel at free-stream Mach 0.7-0.8 and angles of attack from -3 to 4 degrees. A compression-type pylon is found to have the lowest drag at both Mach 0.7 and 0.8 and to be capable of suppressing the velocities in the inboard region of the pylon-wing junction, reducing the extent of supersonic flow and the probability of flow separation. It is also shown that the D-shaped aft-mounted nacelle has a low interference drag, as do previously tested circular nacelles in the same position. V.L.

**A87-45302#**
**ADVANCED FIGHTER THRUST REVERSER INTEGRATION FOR MINIMUM LANDING DISTANCE**
CHRISTOPHER J. ANDERSON and MARTY K. BRADLEY (Northrop Corp., Hawthorne, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-1923)

Thrust reversers are an effective means of reducing landing groundroll distance, but their use and effectiveness are limited by the problem of exhaust plume reingestion into the inlet which causes undesirable thermal distortion for the engine. Canting the reverser discharge away from the inlet allows the reverser to be used longer before reingestion, but it also reduces the effective reverse thrust. This paper investigates the effect of varying reverser discharge angles on landing groundroll distance for an advanced fighter configuration in the 30,000-40,000 lb landing weight class. Utilizing the results of water tunnel testing, along with full and partial reverse engine data, landing groundroll distances are predicted for various reverser discharge angles. The analysis indicates that uncanted thrust reversers can reduce the landing groundroll from 5,000 feet to approximately 2,000 feet and that canting the reversers outboard away from the vertical axis allows

them to be used for a longer portion of the groundroll and can further reduce the landing groundroll to distances as short as 1,000 feet. Author

**A87-45335#**
**THRUST/DRAG ACCOUNTING FOR AEROSPACE PLANE VEHICLES**
R. P. C. LEHRACH (United Technologies Research Center, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p.
(AIAA PAPER 87-1966)

Three approaches for representing the net axial force of highly integrated hypersonic engine/vehicle configurations, such as the Aerospace Plane, in terms of engine thrust and vehicle drag are discussed. Two approaches are found to be preferable, one in which engine performance is generated from the local inlet flow field conditions and the entire vehicle forebody is treated as vehicle drag, and one in which engine performance is generated from the free-stream conditions and the inlet-flow-wetted surface of the forebody is subtracted from vehicle drag considerations. Other than field forces, only the pressure-area and shear as applied to the surfaces of the system act to produce system motion. It is suggested that the two portions of the total system surface constituting the vehicle and propulsion system must be defined, and that the selected engine control volume should bound the defined engine surface. R.R.

**A87-45400#**
**FLIGHT TEST AND EVALUATION OF PROPULSION SYSTEM OPERABILITY CHARACTERISTICS**
GARY P. MOE, RONALD M. DAVINO (USAF, Flight Test Center, Edwards AFB, CA), and ED GRAHAM (ED Graham and Associates, Lancaster, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p.
(AIAA PAPER 87-2092)

Propulsion system test methodologies are examined with emphasis on the testing of the afterburning turbofan engine. In particular, attention is given to instrumentation, data acquisition and display, flight test maneuvers, analysis, and coordination with other facilities. The discussion also covers investigations of compressor stall, gas generator aerodynamic instabilities, internal acoustic disturbances, and digital control strategies. V.L.

**A87-45452#**
**HALE THERMAL BALANCE**
EDWARD P. PETKUS and ROGER W. GALLINGTON (Science Applications International Corp., Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(AIAA PAPER 87-2172)

This paper describes some of the unique challenges in balancing the thermal loads in High Altitude Long Endurance (HALE) aircraft. HALE aircraft operate in a low density and a low velocity environment making heat rejection difficult. HALE aircraft must also operate through several diurnal cycles, each creating a unique thermal environment. An optimal HALE aircraft's thermal system requires several novel concepts to overcome these challenges. The paper describes some concepts of minimizing heat loads and of rejecting waste heat effectively. Heat rejection concepts such as; surface heat exchangers, fuel tank heat sinks, and conventional radiators, are discussed relative to their respective merits and weaknesses. Heat sources such as; reciprocating engines, turbochargers, and avionics, are discussed relative to their impact on vehicle performance. Some relative measures of performance are derived that allow HALE system designers to describe sensible integrated concepts. Author

**A87-45647**
**FOKKER 50 - PEDIGREE WITH POWER**
HARRY HOPKINS Flight International (ISSN 0015-3710), vol. 131, June 1987, p. 23-27.

The Fokker 50 commuter aircraft is a follow-on development of the highly successful F.27-500, incorporating the more technologically advanced and powerful PW125B engines of 2500 shp maximum power. Attention is presently given to the design features and flight handling qualities of the aircraft. Power increases with the throttle are noted to have greater effect on longitudinal stability with the more efficient propellers now used. For the same fuel capacity as the F.27, the range of the Fokker 50 at economic cruise speed is more than 30 percent greater, due to the economy of the new engines. O.C.

**A87-45648**
**SEASTAR - GLASS, PLASTIC, AND TRADITION**
ALAN POSTLETHWAITE and JANICE LOWE Flight International (ISSN 0015-3710), vol. 131, June 1987, p. 38-41.

The traditional amphibious aircraft-design problems posed by production start-up costs and airframe corrosion are addressed in the CD.2 aircraft presently discussed through the employment of GFRP throughout the airframe. The primary structure is built up by means of simple and comparatively inexpensive hand lay-up methods developed by the sailplane construction industry. The result is a near-$5 million 13-passenger aircraft employing two turboprop engines in tandem configuration above the fuselage, for which sales of 250 units over a 10-year period are projected. The fuselage features a flat belly for aquaplaning, in marked contrast to the more conventional v-section hull of other amphibious designs. O.C.

**A87-46312**
**THE NEW SOVIET FIGHTERS - HOW GOOD ARE THEY?**
BILL SWEETMAN Interavia (ISSN 0020-5168), vol. 42, June 1987, p. 577-580.

Performance capability projections, industrial production level evaluations, and weapons effectiveness assessments are presented for the Soviet MiG-29, MiG-31, Su-27, and Su-25 fighter aircraft. Twin-turbofan propulsion systems, large radar antennas, and two-stage, long-range interception missiles, typified by the AA-10 that will be used by both the Su-27 long-range escort/air superiority fighter and the MiG-29 frontal aviation/multirole fighter, are characteristic of this entire generation of Soviet fighter design. The MiG-31 is an interceptor capable of carrying four AA-9 missiles, which are comparable in size and range to the F-14's AIM-54 long-range radar-guided missiles. The AA-11, an IR-guided dogfighting missile comparable to the Sidewinder, will soon become available. Although unprecedented yearly production rate reductions have been observed for these aircraft, the MiG-29 is expected to reach mass production rates of 300 aircraft/year in the near future. O.C.

**A87-46313**
**FLYING THE CF-18 HORNET**
MARK LAMBERT Interavia (ISSN 0020-5168), vol. 42, June 1987, p. 595-598, 600.

A cockpit-systems, flight-handling qualities, and maneuvering performance evaluation is presented for the RCAF's CF-18 version of the F/A-18 U.S. Navy fighter. Attention is given to the fly-by-wire control augmentation and stabilization system, which encompasses autopilot and autothrottle functions. The fighter can be flown and maneuvered in level flight at up to 35-deg angle-of-attack without afterburner, and, although electronically limited to 7.33 g at low weight conditions, has been flown at 11 g during an emergency maneuver. During air-to-air combat, sufficient flight-related information appears on the radar screen to allow the pilot to handle the aircraft without additional reference to the HUD. O.C.

**A87-46314**
**PROVING THAT AVANTI STANDS FOR PROGRESS**
MARC GRANGIER Interavia (ISSN 0020-5168), vol. 42, June 1987, p. 645-647.

A large part of the P-180 Avanti twin-turboprop aircraft's flight envelope has been explored, and the prototype is currently flying without weight restrictions in actual certification conditions. The prototype is noted to have broken the 700 km/hr barrier, reaching 722 km/hr in level flight at 35,000 ft. Fuel consumption measurements have indicated that the Avanti will have a 3700-km

range when cruising at 590 km/hr at 41,000 ft with four passengers on the basis of 2510 lb of fuel. On the strength of these encouraging flight test program results, the manufacturer has decided to proceed with the manufacture of an initial batch of 12 aircraft. O.C.

**A87-46326#**
**DORNIER 328 - CONCEPT FOR A NEW-GENERATION REGIONAL AIRLINER**
FRIEDHELM ZIMMER Dornier-Post (English Edition) (ISSN 0012-5563), no. 2, 1987, p. 12-17.

The design of the Do 328 is described. The requirements for the aircraft include high operation economy and an optimum price/performance ratio; the aircraft is in the 11-ton class and has an engine performance requirement of about 2 x 1,700 shp. The basic configuration of the aircraft is high wing, which has the potential to increase the fuel capacity by about 500 kg, and the tail unit has a T configuration. The pressurized fuselage consists of a cylindrical pipe in the cabin area, a conical fuselage front section with the cockpit, and a conical fuselage tail section with a stepped, large volume baggage compartment. Consideration is given to reducing cabin noise, the use of CRFP composites and AlLi for aircraft parts, the avionics system of the aircraft, and the cabin design. Diagrams of the aircraft are presented. I.F.

**A87-46327#**
**TECHNOLOGICAL ASPECTS IN PREPARING THE DEVELOPMENT OF REGIONAL AIRLINERS**
KARL-HEINZ DOST Dornier-Post (English Edition) (ISSN 0012-5563), no. 2, 1987, p. 18-21.

The development of an optimum aerodynamic fuselage design and the application of the fiber composite construction method to the development of the fuselage are examined during the new fuselage technology program for the Do 328. Two fuselage configurations, C2 and D2, were developed. The C2 has wing/fuselage transition section design and the D2 configuration is wing and landing gear integrated into the pressurized fuselage; these two configurations are analyzed, tested, and compared. It is determined that the D2 configuration is the better design. The use of fiber composites in the primary structures of the pressurized fuselage is studied, testing various fiber/resin (epoxy) systems. Configuration studies of trade-offs between aerodynamics and structure are discussed. Future research in the areas of acoustical efficiency, power plant configurations, and wing designs is planned. I.F.

**A87-46362**
**TRENDS IN THE AEROELASTIC ANALYSIS OF COMBAT AIRCRAFT [TENDANCES ACTUELLES DE L'ANALYSE AEROELASTIQUE DES AVIONS MILITAIRES]**
C. PETIAU and S. BRUN (Avions Marcel Dassault Breguet Aviation, Saint-Cloud, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 122, 1987, p. 10-25. In French. refs

Following a discussion of the general principles of the structural finite element analysis of aeroelastic coupling and the simplifying assumptions leading to static aeroelasticity, the ELFINI program of aircraft structural analysis is considered. The data management approach relies on the load-basis and aerodynamic form basis principles, and permits computation of the finite element solutions and the theoretical aerodynamic analysis independently of the less costly aeroelastic and flight maneuver computations. The present approach deals effectively with flight-measurement model adjustments and the optimization and differentiation of the aerodynamic coefficients, while it is less able to treat the static and dynamic nonlinear effects. R.R.

**A87-46371**
**EH.101 - THE HELICOPTER MATURES**
GRAHAM WARWICK Flight International (ISSN 0015-3710), vol. 131, June 13, 1987, p. 83-86, 88, 90.

The three-engined EH-101 state-of-the-art helicopter is the result of a British-Italian collaborative effort, and will be marketed in the forms of three distinct variants for troop transport, ASW, and offshore oil rig-servicing/civilian commuting. Commonality among the three versions extends to engines, transmissions, rotors, most of the airframes, and numerous systems; the turboshaft engines are T700/CT7s. The main rotors employ wide-chord tips in order to increase lift, reduce drag, and delay stall, on the basis of a combination of sweep, thickness, area, and vortex effects. The commercial version will accomodate 30 passengers. The primary structure employed is almost entirely metallic. O.C.

**A87-46735**
**SOVIET HELICOPTER DEVELOPMENT**
ELFAN AP REES Aerospace (ISSN 0305-0831), vol. 14, June 1987, p. 9-18.

A development history and performance trend evaluation is presented for Soviet helicopters produced by the Mil and Kamov design bureaus. Attention is given to the Mi-6 and Mi-26 cargo helicopters, the Mi-8 passenger helicopter, and the Mi-24 'Hind' troop transport/helicopter gunship, which has come to be considered the most effective combat helicopter of the counterinsurgency and antiarmor type. The Mi-24 will be supplemented in current service by the smaller Mi-28 'Havoc'. Kamov designs are of the contrarotating rotor type, which obviates a tail rotor, and have appeared in both civil-aviation and naval variants. The gathering of Western helicopter design-related information, the development of Soviet helicopter turboshaft powerplant gearboxes, and the emphasis placed on attack helicopter development, are also discussed. O.C.

**A87-46870#**
**FLYING WING COULD STEALTHILY REAPPEAR**
WILLIAM R. SEARS (Arizona, University, Tucson) Aerospace America (ISSN 0740-722X), vol. 25, July 1987, p. 16-19.

The development of the flying-wing aircraft, in particular the XB-35 bomber that needed to carry a 10,000 lb bomb load and have a range of 10,000 miles, is discussed. The span-loading theory for distributing the weight and inertia loading along the span, which is the major advantage of the flying wing, is described. The methods used to obtain high lift and momentum equilibrium during landing and takeoff of the XB-35 are examined. Consideration is given to the testing of a flying-wing model and the XB-35. The testing revealed the good stability and controllability of a flying-wing aircraft. I.F.

**A87-47009*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INTERDISCIPLINARY OPTIMUM DESIGN**
JAROSLAW SOBIESZCZANSKI-SOBIESKI (NASA, Langley Research Center, Hampton, VA) and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg, VA) NATO Advanced Study Institute on Computer Aided Optimal Design, Troia, Portugal, June 29-July 11, 1986. 36 p. refs

Problems related to interdisciplinary interactions in the design of a complex engineering systems are examined with reference to aerospace applications. The interdisciplinary optimization problems examined include those dealing with controls and structures, materials and structures, control and stability, structure and aerodynamics, and structure and thermodynamics. The discussion is illustrated by the following specific applications: integrated aerodynamic/structural optimization of glider wing; optimization of an antenna parabolic dish structure for minimum weight and prescribed emitted signal gain; and a multilevel optimization study of a transport aircraft. V.L.

**N87-25276*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**B-57B GUST GRADIENT PROGRAM**
DENNIS W. CAMP *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 117-124 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

The NASA B-57B Gust Gradient Program (GGP) is a NASA multicenter program. The program objectives are presented. The primary objective is to get wind gust data which can be used in new design criteria for aeronautical systems. The GGP data could

also be used to provide turbulence information for use in simulation programs. This program is outlined. Author

**N87-25281*#** Calspan Corp., Buffalo, N. Y.
**MILITARY SPECIFICATIONS**
PHILIP REYNOLDS *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 181-195 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

The current situation relative to the military specification is that there is not one specific model of turbulence which people are using. Particular disagreement exists on how turbulence levels will vary with qualitative analysis. It does not tie one down to specifics. When it comes to flying quality specifications, many feel that one should stay with the definitions of the Cooper-Harper rating scale but allow the levels to shift depending on the level of turbulence. There is a ride quality specification in the MIL-SPEC having to do with flight control systems design that is related to a turbulence model. This spec (MIL-F8785C) and others are discussed. Author

**N87-25284*#** Alabama Univ., University. Dept. of Aerospace Engineering.
**HELICOPTER-V/STOL DYNAMIC WIND AND TURBULENCE DESIGN METHODOLOGY**
J. EARL BAILEY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 209-216 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

Aircraft and helicopter accidents due to severe dynamic wind and turbulence continue to present challenging design problems. The development of the current set of design analysis tools for a aircraft wind and turbulence design began in the 1940's and 1950's. The areas of helicopter dynamic wind and turbulence modeling and vehicle response to severe dynamic wind inputs (microburst type phenomena) during takeoff and landing remain as major unsolved design problems from a lack of both environmental data and computational methodology. The development of helicopter and V/STOL dynamic wind and turbulence response computation methology is reviewed, the current state of the design art in industry is outlined, and comments on design methodology are made which may serve to improve future flight vehicle design. Author

**N87-25314** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Space Div.
**A MODEL TEST VEHICLE FOR HYPERSONIC AEROSPACE SYSTEMS DEVELOPMENT**
H. GRALLERT, G. CUCINELLI, and M. RIGAULT 1986 13 p Presented at the 37th International Astronautical Federation Congress on Space: New Opportunities for All People, Innsbruck, Austria, 4-11 Oct. 1986 Previously announced in IAA as A87-15882 Submitted for publication
(MBB-UR-875/86; IAF-86-125; ETN-87-99937) Avail: Issuing Activity

The use of a hypersonic test vehicle in the Hermes space shuttle development program is proposed. The technical, safety, and cost justifications of such an approach are outlined. The MAIA 1:3 scale model of Hermes is described. ESA

**N87-25315#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Helicopter Div.
**DESIGN FOR REPAIRABILITY OF HELICOPTER ROTOR BLADES**
M. HAHN 1986 17 p Presented at the 62nd AGARD Meeting of the Structures and Materials Panels Specialists' Meeting, Oslo, Norway, 14-18 Apr. 1986
(MBB-UD-491/86; ETN-87-99931) Avail: Issuing Activity

Repairability criteria for helicopter main rotors are described, and repair procedures are outlined. Service experience with main and tail rotors is reviewed. ESA

**N87-25316#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany).
**DESIGN OF A COMPOSITE TAIL FOR THE AIRBUS A-320**
H. BRENNEIS 1986 24 p Presented at the 15th International Council of the Aeronautical Sciences (ICAS) Congress, London, England, 7-12 Sep. 1986
(MBB-UT-12-86; ICAS-86-4.3.5; ETN-87-99958) Avail: Issuing Activity

A CFRP tail was built for the A-320 aircraft. The modular design involves wrapping the CFRP fabric around metallic cores, pressed together to obtain the desired geometry. The required thicknesses are obtained by different thermal expansion between the metal cores and the bonding tool made from CFRP-prepreg during the cure cycle at 125 C and 10 bar. No repairs caused by cracks or delaminations are reported after 120,000 life cycle tests, i.e., the equivalent of 3 aircraft life cycles. ESA

**N87-25317#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany).
**A310-300 CFRP FIN DAMAGE TOLERANCE DEMONSTRATION**
O. GOEKGOEL 1986 23 p Presented at the 7th International Conference SAMPE European Chapter, Munich, West Germany
(MBB-UT-015/86; ETN-87-99959) Avail: Issuing Activity

An approach for the determination of appropriate validation loads for given inspection intervals to demonstrate acceptable low level of risk in service of CFRP fin is outlined. The inspection intervals for metal fins are applied to the CFRP fin. ESA

**N87-25318#** Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
**CORRELATION OF B-1 FLIGHT TEST SUBJECTIVE ASSESSMENTS AND SOME RIDE QUALITY/VIBRATION EXPOSURE CRITERIA Final Report, Mar. 1982 - Jun. 1985**
JOHN W. RUSTENBURG May 1986 103 p
(AD-A179844; ASD-TR-85-5015) Avail: NTIS HC A06/MF A01 CSCL 01C

This study reviews several methods for describing the intensity of a vibration of ride-quality environment and its effect and comfort, proficiency and fatigue. These methods are applied to vibration environments encountered during B-1 low-altitude, high-speed flight tests. The resulting vibration environment/ride quality descriptions are correlated with qualitative assessments of turbulence levels and impact on performance and discomfort obtained from the crew. This correlation provides an evaluation of the sensitivity of the methods in predicting the effects of variation in the vibration environment. To evaluate the precision of the methods in predicting ride quality ratings for a high-speed low-altitude environment, the qualitative assessments of the crew are compared to ratings, boundaries or limits established by the different methods. GRA

**N87-25320*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A MULTI-BODY AIRCRAFT WITH AN ALL-MOVABLE CENTER FUSELAGE ACTIVELY CONTROLLING FUSELAGE PRESSURE DRAG Patent Application**
RICHARD M. WOOD, inventor (to NASA) 12 Feb. 1987 16 p
(NASA-CASE-LAR-13511-1; US-PATENT-APPL-SN-013801)
Avail: NTIS HC A02/MF A01 CSCL 01C

A multi-body aircraft with an all-movable center fuselage which translates relative to two side fuselages is described. At subsonic and transonic flight the center fuselage is in a forward position. At supersonic speeds the center fuselage moves aft so as to ensure optimum aerodynamic interference at particular Mach numbers. This provides an increased shock strength and greater surface areas so the significant reductions in zero-lift wave drag can be achieved. This concept allows for a significant increase in the wing aspect ratio which would improve high-lift performance at all speeds without incurring a significant supersonic zero-lift wave drag penalty. In additions, an improved low-fineness ratio, high-speed performance is achieved at all speeds and for all flight conditions. NASA

**N87-25321*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INTEGRALLY-STIFFENED CRASH ENERGY-ABSORBING SUBFLOOR BEAM STRUCTURE Patent Application**
GARY L. FARLEY, inventor (to NASA) 19 May 1987 12 p
(NASA-CASE-LAR-13697-1; US-PATENT-APPL-SN-051426)
Avail: NTIS HC A02/MF A01

An integrally-stiffened crash energy-absorbing subfloor beam is disclosed which provides increased energy absorption efficiency and ease of fabrication while uncoupling the design parameters for energy absorption and structural stiffness. The invention comprehends a beam web integrally stiffened by an assembly of vertically oriented tubular stiffeners, interconnected by vertical flat plates and top and bottom beam caps. The tubular stiffeners are of arbitrary cross-sectional shape. Typical materials for the beam are any ductile metallic (aluminum) or non-metallic materials or fiber reinforced composite material (Graphite/Epoxy and Kevlar/Epoxy). A subfloor structure is built by arranging the beams into a grid or latticework configuration such that the flat plates between the tubular stiffeners are oriented vertically. A rigid floor surface is attached over this grid of beams to complete a lower fuselage structure. NASA

**N87-26035*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
**SINGULAR TRAJECTORIES IN AIRPLANE CRUISE-DASH OPTIMIZATION**
KARL D. BILIMORIA and EUGENE M. CLIFF Jan. 1987 124 p
(Contract NAG1-203)
(NASA-CR-180636; NAS 1.26:180636) Avail: NTIS HC A06/MF A01 CSCL 01C

The problem of determining cruise-dash trajectories is examined for the case of time-fuel optimization using a linear combination of time and fuel as the performance index. The trajectories consist of a transient arc followed by a steady-state arc. For cases where the steady-state arc is flown with full throttle the associated skeletal transient trajectories are also flow with full throttle, and the cruise-dash points are approached monotonically in an asymptotic fashion. When the steady-state arc is flown at an intermediate throttle setting, the transient trajectories follow a singular control law and exhibit a complex structure that is different from the full-throttle transients. Addressing the question of optimality of the steady-state arc, it was found that although steady-state cruise fails a Jacobi-type condition, steady-state cruise-dash can satisfy this condition if the emphasis on time is sufficiently large. The outcome of the Jacobi test appears to be connected with the eigenstructure of the linearized state-adjoint system. Author

**N87-26036*#** Kansas Univ. Center for Research, Inc., Lawrence. Flight Research Lab.
**AN EXPERIMENTAL INVESTIGATION OF DYNAMIC GROUND EFFECT Final Report**
PAI HUNG LEE, C. EDWARD LAN, and VINCENT U. MUIRHEAD Jan. 1987 83 p
(Contract NAG1-616)
(NASA-CR-180560; NAS 1.26:180560; CRINC-FRL-717-1) Avail: NTIS HC A05/MF A01 CSCL 01C

Sixty degree delta wing, F-106B, and XB-70 models with and without flap deflections were tested in static and dynamic ground effect in the 36 by 51 inch subsonic wind tunnel at the University of Kansas. Dynamic ground effect was measured with movable sting support. For flow visualization, a tufted wire grid was mounted on the movable sting behind the model. Tests results showed that the lift and drag increments in dynamic ground effect were always lower than the static values. Effect of the trailing-edge flap deflections on lift increments was slight. The fuselage reduced the lift increments at a given ground height. From flow visualization under static conditions, the vortex core was seen to enlarge as the ground approached. Author

**N87-26037*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Chemistry.
**FACTORS AFFECTING THE STICKING OF INSECTS ON MODIFIED AIRCRAFT WINGS Semiannual Report, 15 Jun. - 30 Dec. 1986**
O. YI, M. R. CHITSAZ-Z, N. S. EISS, and J. P. WIGHTMAN 3 Jun. 1987 32 p
(Contract NAG1-300)
(NASA-CR-180957; NAS 1.26:180957) Avail: NTIS HC A03/MF A01 CSCL 01C

Past studies have shown that the surface energy of a polymer coating has an important effect on the sticking of insects to the surface. However, mechanical properties of polymer coatings such as elasticity may also be important. A further study is suggested using polymer coatings of known surface energy and modulus so that a better understanding of the mechanism of the sticking of insects to surfaces can be achieved. As the first step for the study, surface analysis and road tests were performed using elastomers having different energies and different moduli. The number of insects sticking to each elastomer was counted and compared from sample to sample and with a control (aluminum). An average height moment was also calculated and comparisons made between samples. Author

**N87-26039#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und raumfahrt, Stuttgart (West Germany). Forschungsbereichs Werkstoffe und Bauweisen.
**CANARD CONFIGURATIONS [ENTEN - FLUGZEUGE]**
M. MAILAENDER, M. DEGENER, H. DOEKER, H. HALD, H. P. SCHMIDT, and D. WETZEL 21 Feb. 1986 41 p In GERMAN
(ETN-87-99914) Avail: NTIS HC A03/MF A01

Canard configurations were compared with conventional configurations. The static lateral stability and the directional stability of canard and conventional configurations are summarized. Aerodynamic characteristics, such as the interactions between control surfaces and wings, sweep, sideslip, profile, load distribution, center-of-gravity range, trim, propulsion arrangement, and stalling behavior, are discussed for both configurations. The problems of a canard delta configuration are given. The performances and maneuverability of the canard and conventional configurations are compared. Development measures for military aircraft in active control, aeroelastic tailoring, conformal stores carriage, mission adaptive wings, and thrust vectoring, are given. ESA

**N87-26040** Stanford Univ., Calif.
**IDENTIFICATION OF A DYNAMIC MODEL OF A HELICOPTER FROM FLIGHT TESTS Ph.D. Thesis**
GARTH WILLIAM MILNE 1987 301 p
Avail: Univ. Microfilms Order No. DA8707707

Techniques for identifying continuous models of dynamic systems were applied to the unstable longitudinal hover dynamics of a CH-47B Chinook helicopter. The equation error method with carefully filtered 7.18 Hz data produced good pitch transfer function models. Frequency response plots for increasing order models were used to determine the model order. The linear inter-sample equivalent produced better continuous models from identified ARMA models than the zero order hold assumption. Dissert. Abstr.

**N87-26041*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EVALUATION OF INSTALLED PERFORMANCE OF A WING-TIP-MOUNTED PUSHER TURBOPROP ON A SEMISPAN WING**
JAMES C. PATTERSON, JR. and GLYNN R. BARTLETT Aug. 1987 30 p
(NASA-TP-2739; L-16252; NAS 1.60:2739) Avail: NTIS HC A03/MF A01 CSCL 01C

An exploratory investigation has been conducted at the Langley Research Center to determine the effect of a wing-tip-mounted pusher turboprop on the aerodynamic characteristics of a semispan wing. Tests were conducted on a semispan model with an upswept,

untapered wing and an airdriven motor that powered an SR-2 high-speed propeller located on the tip of the wing as a pusher propeller. All tests were conducted at a Mach number of 0.70 over an angle-of-attack range from approximately -2 to 4 deg at a Reynolds number of 3.82 x 10 to the 6th based on the wing reference chord of 13 in. The data indicate that, as a result of locating the propeller behind the wing trailing edge at the wing tip in the crossflow of the wing-tip vortex, it is possible to improve propeller performance and simultaneously reduce the lift-induced drag. Author

**N87-26042*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**OPTIMIZATION METHODS APPLIED TO THE AERODYNAMIC DESIGN OF HELICOPTER ROTOR BLADES**
JOANNE L. WALSH, GENE J. BINGHAM, and MICHAEL F. RILEY (PRC Kentron, Inc., Hampton, Va.) May 1987 27 p Presented at the 26th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Materials Conference, Orlando, Fla., 15-17 Apr. 1985 Previously announced in IAA as A85-30245
(NASA-TM-89155; NAS 1.15:89155; AIAA-85-0644) Avail: NTIS HC A03/MF A01 CSCL 01C

Described is a formal optimization procedure for helicopter rotor blade design which minimizes hover horsepower while assuring satisfactory forward flight performance. The approach is to couple hover and forward flight analysis programs with a general-purpose optimization procedure. The resulting optimization system provides a systematic evaluation of the rotor blade design variables and their interaction, thus reducing the time and cost of designing advanced rotor blades. The paper discusses the basis for and details of the overall procedure, describes the generation of advanced blade designs for representative Army helicopters, and compares design and design effort with those from the conventional approach which is based on parametric studies and extensive cross-plots. Author

**N87-26247#** City Univ., London (England). Dept. of Mechanical Engineering.
**HELICOPTER VIBRATION CONTROL: RECENT ADVANCES**
G. T. S. DONE *In* Vibration Inst., The Shock and Vibration Digest, volume 18, no. 8 p 13-17 Aug. 1986
Avail: NTIS HC A05/MF A01

Recent advances in the control of helicopter vibration are described and associated literature is reviewed. Vibration absorbers and isolators, direct rotor control, structural design and modification, and vibration studies are considered. Author

**N87-26833** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
**EULER SOLUTION FOR A COMPLETE FIGHTER AIRCRAFT AT SUB- AND SUPERSONIC SPEED**
ALBRECHT EBERLE and KENT P. MISEGADES (Cray Research, Inc., Mendota Heights, Minn.) *In its* Research and Development. Technical-Scientific Publications 1986 p 73-82 1986 Presented at the AGARD Symposium on Applications of Computational Fluid Dynamics in Aeronautics, Aix-en-Provence, France, 7-10 Apr. 1986
(MBB-LKE-122-S/PUB/234) Avail: Issuing Activity

A high resolution Euler code applied to air-flow calculations behind a fighter-type aircraft is described. It features a Godunov-type averaging procedure based on the eigenvalue analysis of the Euler equations, by means of which the fluxes are evaluated at the finite volume faces separating constant sets of flow variables on either side. The procedure is third-order accurate and locally preserve monotonic, thus avoiding the drawbacks of global total-variation-diminishing schemes. The grid generation for complex configurations is performed from solutions of linear biharmonic equations with only one parameter, prescribed by the program user. The vector computer performance of the explicit and implicit program versions is discussed. ESA

**N87-26834** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.
**AIRCRAFT TECHNOLOGY OF THE NINETIES IN MBB PASSENGER AIRCRAFT PROJECTS [FLUGZEUG-TECHNOLOGIE DER 90ER JAHRE IN VERKEHRSFLUGZEUG-PROJEKTEN VON MBB]**
UWE GANZER *In its* Research and Development. Technical-Scientific Publications 1986 p 83-90 1986 In GERMAN Presented at the DGLR-Jahrestagung, Munich, West Germany, 8-10 Oct. 1986
(MBB-UT-0021/86; DGLR-86-108) Avail: Issuing Activity

Problems arising in the application of propfan propulsion systems are treated. Methods for the design of laminar wings, and the development of a wing made of carbon fiber reinforced plastics are discussed. The research program for the development of cockpits and flight control is presented. ESA

## 06

## AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

**A87-42812**
**SCAN STABILIZATION AND JITTER CONTROL FOR AN AIRBORNE TELESCOPE**
M. A. FLOYD, C. A. LIN, and M. G. LYONS (Integrated Systems, Inc., Palo Alto, CA) IN: Acquisition, tracking, and pointing; Proceedings of the Meeting, Orlando, FL, Apr. 3, 4, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 102-120.

An evaluation is made of the primary considerations in the development of high fidelity performance models for airborne scanning telescopes, using a generic example to illustrate the principles involved in such modeling. Due to the scan's ability to reject low frequency sources of image jitter, the scan motion itself is rarely the cause of low system performance; instead, acoustic and base motion power spectra in an open aircraft cavity create large image jitter amplitudes that are only partially attenuated by the scan and subsequent TDI signal processing. The modification of TDI intervals, or the number of pixels, can improve jitter rejection if changes in sensitivity and/or range can be accommodated. O.C.

**A87-43375**
**TESTING AUTOMATED GROUND COLLISION AVOIDANCE SYSTEMS ON THE AFTI/F-16**
JOHN D. HOWARD and MARK A. SKOOG (USAF, Flight Test Center, Edwards AFB, CA) Cockpit (ISSN 0742-1508), Jan.-Mar. 1987, p. 5-13.

The testing of an automated ground collision avoidance (GCA) system, consisting of air-to-air and air-to-surface autorecovery, on the AFTI/F-16 is described. The AFTI/F-16 GCA system is composed of a G-induced loss-of-consciousness and spatial-disorientation autorecovery system applicable to medium and high altitudes and a low-altitude GCA system based on pilot selected above ground-level-altitudes. The effects of dive angle, airspeed, bank angle, roll rate, and load factor on the performance of the systems are investigated. It is determined that sensor performance varies with altitude, and the best performance is possible at the lowest altitudes. Various uses of future GCA systems, such as low-altitude manual maneuvering and an advanced automated maneuvering attack system are discussed. The use of incremental run-by-run analysis, remotely piloted vehicles, or remote real-time modeling for future testing of GCA systems is proposed. I.F.

**A87-43404#**
**EH101 COCKPIT DESIGN**
G. BARTON, J. REVELL, and G. WEBSTER (Westland Helicopters, Ltd., Yeovil, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p.

This paper describes the work undertaken on the EH101 'all CRT' cockpit design from initial conception through to system design, detailed format development and proposed certification programme covering the approach to the many topical issues such as power systems formats, integrity, reversion, software certification and the problems of three engine instrumentation. Described are the trade-off studies on weight, screen size, configuration and flexibility. The resulting selected system is described, including architecture, interfaces and modes of operation including reversion. The work undertaken on format development particularly the power system displays with the problems of instrumentation for three engines, torque margin and hover formats is covered. The proposed certification programme is described before finally drawing conclusions from the work undertaken to date and discussing possible future enhancements to the EH101 Cockpit Electronics Display System. Author

**A87-43437#**
**A PROMISING LOW SPEED AIR DATA SYSTEM FOR HELICOPTERS**
J. MANDLE (Crouzet, S.A., Division Aerospatiale, Valence, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 21 p.

The principle of operation, instrumentation, and performance of CLASS, a set of algorithms and hardware developed for the French defense department to calculate the (low) bidirectional airspeed of a helicopter using data from conventional pneumatic sensors, are discussed and illustrated with diagrams, drawings, and graphs. Calibration is performed using the truck-mounted anemometer scheme proposed by Mandle and Weiss. In flight tests performed at Bretigny during 1984, the CLASS equipment was shown to give accurate results in stabilized flights (standard deviation below 3 kts) and transient maneuvers. T.K.

**A87-43439#**
**A NEW METHOD OF ANALYTICAL EVALUATION OF HELICOPTER TRUE AIRSPEED**
W. HASSENPFLUG (Litton Technische Werke, Freiburg, West Germany) and R. SCHWAEBLE (Krupp Atlas Elektronik GmbH, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 21 p. refs

Due to rotor-induced downwash and limited resolution, the classical air-data computation utilizing pressure-differential and temperature measurements is not applicable to the helicopter low-airspeed range (below 20 m/s). In order to overcome this problem, several approaches have been made in the past resulting in systems with external sensors (like LASSIE and LORAS) and without external sensors (the so-called analytical systems like VIMI). As VIMI (Durand, 1974) was not designed to meet the accuracy requirement of 2 m/s, 95-percent probability, a new analytical method for the generation of military helicopters (Hassenpflug and Schwaeble, 1985) has been developed using specific helicopter-control features. The validity and accuracy of this new analytical method has been verified by a series of flight trials. Author

**A87-43468#**
**STANDARDIZATION AND LOGISTIC SUPPORT COST EFFECTIVENESS OF ADVANCED AVIONICS SYSTEMS**
V. BUONTEMPO (Selenia S.p.A., Pomezia, Italy) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p. refs

Modular standardization which has already been adopted within avionic systems can also be used to optimize the logistic support in terms of performance (such as operative availability, maintainability, system reliability, and testing) and costs (purchasing, maintenance, spare parts, technical documentation, training, and ground support equipment). After a short description of the status of technological integration, hardware, and software standardization available to date on avionic systems, a demonstration of the effectiveness of the new maintenance philosophy and concepts (elimination of the second maintenance level) is given. The results derived can be extended to naval and ground defense systems. Author

**A87-43470#**
**EMI-FAULT PREVENTION AND SELF RECOVERY OF DIGITAL FLIGHT CONTROL SYSTEMS**
MICHAEL STOCK (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 20 p.

It is the aim of this paper to show ways to achieve system reliability and survivability for microcomputers in complex flight critical applications. Microcomputer systems failures caused by EMI and their impact on flight control systems is addressed. Also addressed are ways to maintain system reliability in electromagnetic contaminated environment and ways to ensure self recovery after EMI-caused faults. In conclusion, a digital flight-control system, designed with respect to EMI problems and flight-tested on a BK 117, is presented. Author

**A87-44727**
**ENGINEERING AND HUMAN VISUAL CONSIDERATIONS IN DEVELOPMENT OF A FIBRE OPTIC HELMET MOUNTED DISPLAY**
B. L. WELCH and R. KRUK (CAE Electronics, Ltd., Montreal, Canada) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 295-313.

The design requirements and development of a fiber optic helmet-mounted display (FOHMD) are described. The FOHMD is applicable in ground-based and airborne operational and training devices. Methods for developing a helmet display that has a field of view of 100 deg horizontal x 60 deg vertical, with separate eyepieces which have an overlap of 25-40 deg, and a resolution of about 1 arcmin/pixel are discussed. The FOV and resolution requirements determine the hardware characteristics. Luminance levels close to normal daylight levels are determined by combining optical characteristics of display devices, relay optics between display and fiber optic cables, the transmission of fiber optic cables, and the transmission of helmet optics. Various devices for the color CRTs are examined. Consideration is given to factors which affect performance: the exit pupil, image stability, and eye tracking of the FOHMD. I.F.

**A87-45115**
**FIBER OPTIC CONTROL OF JET AIRCRAFT ENGINES**
GLEN E. MILLER (Boeing Photonics Laboratory, Bellevue, WA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 269-282.

The paper describes an experimental drop-in fiber optic system developed to replace the primary electrical throttle level angle sensor and electrical wiring used for control and monitoring of a commercial jet engine. The modification involved the replacement of the electrical throttle control sensor with a functionally-equivalent electrically-passive optical sensor. During the B 757 flight test, the fiber optic interfaces performed in a manner indistinguishable from that of the normal electrical interfaces, and the tracking and dynamic response of the optical throttle lever angle (TLA) were identical to those of the secondary electrical TLA resolver. K.K.

**A87-45126**
**ONBOARD INSTRUMENTATION FOR FLIGHT TEST TAKEOFF PERFORMANCE**
HAROLD K. CHENEY (Douglas Aircraft Co., Long Beach, CA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 539-543.

By using an inertial navigation system (INS) for space position data, a method has been developed to obtain velocity, distance, height, wind, and ambient temperature for takeoff performance using only instrumentation on board a test aircraft. No external instrumentation is required. The flight path component of wind at the aircraft is determined using pitot total pressure, tracking altitude, and tracking velocity. Ambient runway temperature is determined using measured total temperature prior to rotation. The only external information required is the runway slope. The resulting performance data are equivalent or superior to similar data obtained using external systems. The recent improvement of INS height values obtained using the Litton LTN-96 INS with longer baro-inertial loop time constant values is presented. Author

**A87-45732**
**AN AIRBORNE LASER AIR MOTION SENSING SYSTEM. I - CONCEPT AND PRELIMINARY EXPERIMENT**
R. J. KEELER, R. J. SERAFIN, R. L. SCHWIESOW, D. H. LENSCHOW (National Center for Atmospheric Research, Boulder, CO), J. M. VAUGHAN (Royal Signals and Radar Establishment, Malvern, England) et al. Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572), vol. 4, March 1987, p. 113-127. refs

This paper presents a concept for a laser air motion sensing system using a conically scanned optical Doppler technique that senses air motions remote from the aircraft. The advantages of the technique include calibration based on physical constants rather than experiment for an accurate measurement of mean wind, freedom from flow distortion effects on turbulence measurements, all-weather performance, reduction in error from mechanical vibrations, and ability to measure vertical wind shear. An experiment comparing a single-component laser velocimeter and a differential pressure gust probe shows that the optical approach measures the turbulence spectrum accurately at frequencies up to 10 Hz and that the SNR is not a limiting factor. The effect of spectral skewing caused by airflow distortion in cloud is observed. C.D.

**A87-45733**
**AN AIRBORNE LASER AIR MOTION SENSING SYSTEM. II - DESIGN CRITERIA AND MEASUREMENT POSSIBILITIES**
LEIF KRISTENSEN (Forsoganlaeg Riso, Roskilde, Denmark) and DONALD H. LENSCHOW (National Center for Atmospheric Research, Boulder, CO) Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572), vol. 4, March 1987, p. 128-138. refs

A conically scanning Doppler lidar technique for measuring air motions from an aircraft is proposed in the companion paper (Keeler et al.). A theoretical analysis of this technique shows that, assuming isotropic turbulence, the technique is feasible for measuring air motions to scales small enough that the velocity spectra in a convective atmospheric boundary layer can be resolved well into the inertial subrange, and most of the turbulent motions that contribute to the vertical fluxes can be resolved. A scanning beam range of 10 m was selected to ensure that flow distortion induced by the aircraft will not significantly affect the velocity measurement. Thus, the technique offers improved accuracy over presently used immersion air motion sensors. An additional feature is the possibility of measuring mean vertical wind shear. Author

**A87-45879**
**RADAR REQUIREMENTS FOR FUTURE AVIONICS SYSTEMS [ANFORDERUNGEN AN RADARGERAETE IN ZUKUENFTIGEN AVIONIKSYSTEMEN]**
W. HETZNER and W. KOHL (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) IN: Radar Technology 1986; Symposium, 6th, Bremen, West Germany, Nov. 4-6, 1986, Reports . Duesseldorf, Deutsche Gesellschaft fuer Ortung und Navigation, 1986, p. C3.-C3.15. In German.

The performance demands on radar equipment for future aircraft are reviewed. General requirements include integrability in advanced avionics architectures with VHSIC components, high-speed data buses, speech-recognition and synthesis devices, and AI features; low probability of intercept; polarization agility; advanced conformal or phased-array antennas; automatic correction for radome-induced boresight errors; light weight; and reduced cooling and power demands. These requirements are discussed in detail for combat aircraft (air-air and air-ground operation), early-warning aircraft, and maritime patrol aircraft. T.K.

**A87-46727**
**CULPRITS CAUSING AVIONIC EQUIPMENT FAILURES**
KAM L. WONG, IRVING QUART (Kambea Industries, Inc., Manhattan Beach, CA), JAMES M. KALLIS (Hughes Aircraft Co., El Segundo, CA), and ALAN H. BURKHARD (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 416-421.

An examination of industrial and military failure data is performed to determine the major locations and types of defects causing avionics field failures. Field failures were found to occur primarily in devices containing semiconductors, with discrete capacitors and discrete resistors being less frequent locations of failures. Connectors, relays, filters, and magnetic devices were found to be insignificant contributors to failures, while solder joints and printed circuit boards are believed to have a significant number of failures. More than a dozen types of defects, each contributing to a small fraction of the failures, have been identified. R.R.

**N87-26838** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.
**AVIONICS SYSTEMS FOR FUTURE CIVIL HELICOPTERS [AVIONIKSYSTEME FUER KUENFTIGE ZIVILHUBSCHRAUBER]**
ANTON INGELSPERGER *In its* Research and Development. Technical-Scientific Publications 1986 p 167-174 1986 In GERMAN Presented at the 4th BMFT-Statusseminar, Munich, West Germany, 28-30 Apr. 1986 Original language document announced in IAA as A87-14005
(MBB-UD-473/86) Avail: Issuing Activity

Civil helicopter cockpit instrumentation using color displays, and the testing of color displays are explained. The central control unit principles are discussed. The main fields in cockpit instrumentation and central control unit which need further development for use in future helicopters are discussed. The use of development simulators, signal standardization and bus system, and software for display systems are presented. ESA

# 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.

**A87-43464#**
**T700/CT7 DERIVATIVE GROWTH ENGINE RELIABILITY - CONSISTENT WITH LONGSTANDING INDUSTRY TRADITIONS**
H. G. DONOHIE and W. W. ROSTRON (General Electric Co., Aircraft Engine Business Group, Lynn, MA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 25 p. refs

The current family of T700/CT7 step 2 growth derivative engines, which encompass civil and military turboshafts as well as a civil turboprop, has high commonality with predecessor engines; in addition, all technology improvements have undergone demonstration in previous programs. A further development program is underway which will conduct design verification tests needed for the substantiation of engine level performance, as well as durability testing to achieve an early design maturity. O.C.

**A87-43465#**
**DEVELOPMENT PROGRAM OF A FULL AUTHORITY DIGITAL ELECTRONIC CONTROL SYSTEM FOR THE T55-L-712E TURBOSHAFT ENGINE**
DAVID PETRO (Textron, Inc., Avco Lycoming Textron Div., Stratford, CT) and ANTHONY J. GENTILE (Chandler Evans, Inc., West Hartford, CT) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 20 p.

An evaluation is made of the primary requirements for the incorporation of a full authority digital electronic control system on a twin-engine military helicopter; the component configuration employed is discussed in light of such criteria as maintainability, diagnostics, performance history recording, environmental capabilities, engine installation, and aircraft integration. Closed-loop computer simulations are used in order to evaluate and optimize engine control modes. O.C.

**A87-43466#**
**DEVELOPMENT OF A FLEXIBLE AND ECONOMIC HELICOPTER ENGINE MONITORING SYSTEM**
A. A. TEN HAVE (Nationaal Lucht- en Ruimtevaartlaboratorium, Emmeloord, Netherlands) and C. R. TJALSMA (Royal Netherlands Navy, The Hague, Netherlands) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 12 p. refs

Lynx helicopter engine loading is the subject of a research program aimed at investigating the possibility of continuous and automated monitoring of engine fatigue damage accumulation based on the Rolls-Royce Cycle Life Control concept. A pilot flight test program has been carried out, the results of which are being used for the development of a usable Lynx engine in-flight data processor. Such a device will provide valuable information on Lynx engine service loading, and may be the basis of computerized Cyclic Life Control within the RNLN in the future. This paper will generally describe major topics of the above program. Author

**A87-43467#**
**HELICOPTER TURBOSHAFT ENGINE ACOUSTIC AND INFRARED STUDIES AND TESTS**
A. FARRANDO (Turbomeca, S.A., Bordes, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 9 p.

The following statement concerns the field of the acoustic and infrared detection of helicopter turbushaft engines. Test facilities in use and main research being carried out at present at Turbomeca are described. A few significant results in the acoustic signature reduction are shown. Author

**A87-43605**
**SELECTION OF ADMISSIBLE CONTACT STRESSES FOR TOOTHED GEARS OF AIRCRAFT ENGINES [K VOPROSU O VYBORE DOPUSKAEMYKH KONTAKTNYKH NAPRIAZHENII DLIA ZUBCHATYKHH PEREDACH AVIADVIGATELEI]**
IU. I. VOLOSHIN Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 18-20. In Russian.

The paper proposes a method for determining coefficients which refine values of admissible stresses in the calculation of the contact endurance of the active surfaces of toothed gears in aircraft engines. A calculation example confirms the effectiveness of the proposed method. B.J.

**A87-43606**
**APPROXIMATION OF THE CHARACTERISTICS OF THE TURBINE OF A GAS TURBINE ENGINE IN A WIDE RANGE OF OPERATING MODES [APPROKSIMATSIIA KHARAKTERISTIK TURBINY GAZOTURBINNOGO DVIGATELIA V SHIROKOM DIAPAZONE REZHIMOV RABOTY]**
V. P. GERASIMENKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 20-24. In Russian. refs

Polynomial approximations of turbine characteristics have been obtained from factor planning of experiments, which makes it possible to refine them during turbine operation with a minimum of empirical data. The approximations can be included in various mathematical models of gas turbine engines, and are particularly suitable for the development of adaptive models in connection with optimal engine control. B.J.

**A87-43607**
**THE LOW-ASPECT-RATIO PARAMETER OF BLADES [PARAMETR MALOGO UDLINENIIA LOPATOK]**
A. D. GRIGA Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 24-26. In Russian.

It is proposed that the low-aspect-ratio parameter of turbine blades be determined from the condition of the equality of profile losses to the sum of end losses and secondary-vortex losses. It is concluded that the characteristics of turbine stages with low-aspect-ratio blades can be improved by choosing values of kinematic and geometric characteristics in such a way as to obtain minimum values of the aspect ratio. B.J.

**A87-43609**
**OPTIMIZATION OF THE DURATION OF ULTRASONICALLY ACTIVATED IMPACT SURFACE TREATMENT OF GAS-TURBINE-ENGINE BLADES [OPTIMIZATSIIA DLITEL'NOSTI UL'TRAZVUKOVOGO UPROCHNENIIA LOPATOK GTD]**
V. G. KAZANSKII and V. M. ANISHCHENKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 28-30. In Russian.

Consideration is given to the ultrasonically activated impact surface treatment (via small steel balls) of turbine blades in the finishing stage of treatment. Eddy-current monitoring was used in order to exclude the effect of the initial stage of the material on the final results of the treatment. Fatigue and nondestructive tests were used to determine the optimal duration of the surface treatment. B.J.

**A87-43614**
**NUMERICAL STUDY OF THE GASDYNAMIC PROCESS IN A PULSEJET ENGINE [CHISLENNOE ISSLEDOVANIE GAZODINAMICHESKOGO PROTSESSA V PUL'SIRUIUSHCHEM VOZDUSHNO-REAKTIVNOM DVIGATELE]**
V. M. LAPOTKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 51-56. In Russian.

The effect of the combustion-chamber parameters on the gasdynamic process in a pulsejet engine is assessed using a mathematical model based on the conservation laws of mass, momentum, and energy. It is found that the parameters of existing

pulsejet engines are far from optimal. It is concluded that the characteristics of these engines can be improved by increasing the amount of energy supplied to the gas, by increasing the rate of energy supply, by lengthening the zone of energy supply, and by optimizing the engine geometry. B.J.

**A87-43616**
**CALCULATION OF THE RELIABILITY OF AIRCRAFT-ENGINE PARTS UNDER REPEATED STATIC LOADING [RASCHET NADEZHNOSTI DETALEI AVIATSIONNYKH DVIGATELEI PRI POVTORNO-STATICHESKOM NAGRUZHENII]**
A. S. MOSKALENKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 60-62. In Russian.

The paper describes a mathematical model for the reliability of aircraft-engine parts which takes into account the gradual accumulation of damage. This model, based on the linear theory of damage accumulation, identifies the influence of structural, fabrication, and operational factors, and indicates ways to increase reliability. B.J.

**A87-43620**
**ENGINEERING AND COST PRINCIPLES FOR INCREASING THE PRODUCTION EFFICIENCY AND MAINTAINABILITY OF AIRCRAFT ENGINES [TEKHNIKO-EKONOMICHESKOE OBOSNOVANIE POVYSHENIIA UROVNIA TEKHNOLOGICHNOSTI AVIATSIONNYKH DVIGATELEI]**
S. A. NIKITIN and V. V. DOBRIAKOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 81-86. In Russian.

The problem of increasing the production efficiency and maintainability of aircraft engines is examined. A formula for the cost justification of the selection of a modular version of a structure is proposed on the basis of an engineering and cost analysis. A system of primary and secondary indices is presented for evaluating the production efficiency and maintainability of engine designs. B.J.

**A87-43621**
**OPTIMIZATION OF SYSTEMS FOR THE AUTOMATIC TESTING OF AIRCRAFT ENGINES ACCORDING TO COST CRITERIA [OPTIMIZATSIIA AVTOMATIZIROVANNYKH SISTEM ISPYTANII AVIATSIONNYKH DVIGATELEI PO EKONOMICHESKIM KRITERIIAM]**
V. A. PIL'SHCHIKOV and IA. V. SAFRONOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 86-90. In Russian.

Five optimization models for automatic test systems for aircraft engines are described. All the models provide for minimization of costs over the service life of the systems. B.J.

**A87-43640**
**A STUDY OF THE THERMAL-STRESS STATE OF GAS TURBINE ENGINE BLADES WITH PROTECTIVE COATINGS [ISSLEDOVANIE TERMONAPRIAZHENNOGO SOSTOIANIIA MODELEI LOPATOK GTD S ZASHCHITNYMI POKRYTIIAMI]**
G. N. TERT'IACHENKO, K. P. BUISKIKH, L. V. KRAVCHUK, and G. R. SEMENOV (AN USSR, Institut Problem Prochnosti, Kiev, Ukrainian SSR) Problemy Prochnosti (ISSN 0556-171X), no. 5, May 1987, p. 67-70. In Russian. refs

Thermal stress analysis is carried out for wedge-shaped blade models of ZhS6U nickel alloy of three different sizes with heat-resistant electron-beam coatings of three different compositions (Ni-Co-Cr-Al-Y, Co-Cr-Al-Y, and Ni-Cr-Al-Y). It is shown that, in addition to protecting the blade surface against corrosion and erosion, the protective coatings are also capable of reducing thermal stresses in the surface layers of a structural element. V.L.

**A87-43701#**
**EVALUATING AND TESTING OF TURBOFAN ENGINES**
THERESE M. MILLER (General Electric Co., Aircraft Engine Business Group, Evendale, OH) ASME, Winter Annual Meeting, Anaheim, CA, Dec. 7-12, 1986. 7 p.
(ASME PAPER 86-WA/DE-3)

The tasks of the engineering evaluation specialist in planning, conducting, and interpreting ground tests of turbofan aircraft engines are reviewed. Consideration is given to the DOD and FAA requirements for qualification and certification tests, the test instrumentation, data acquisition procedures, endurance testing, performance testing, ingestion testing, blade-out testing, verification testing, and test interruptions. Photographs of test facilities and test-damaged engine components and graphs of typical results are provided. T.K.

**A87-43702#**
**FINITE ELEMENT ANALYSIS AND REDESIGN OF JET ENGINE STARTER BREECH CHAMBER**
ALFRED G. STRIZ (Oklahoma, University, Norman) and FRANK P. BRUECKNER (Hughes Aircraft Co., Tucson, AZ) ASME, Winter Annual Meeting, Anaheim, CA, Dec. 7-12, 1986. 6 p. refs
(Contract F34601-83-C-3448)
(ASME PAPER 86-WA/DE-20)

A stress analysis by the finite element method of failure prone jet engine starter breech chambers is presented. The chambers are modelled as axisymmetric and as three-dimensional structures. The static analysis is performed by two finite element codes, SAP IV and MSC/NASTRAN. The maximum stresses are found on the inside surface of the chamber dome and are due to large bending stresses resulting from a considerable change in curvature and thickness in the merger region of the spherical chamber dome and the stiffer cylindrical side wall. Reductions of these high stresses are possible by decreasing the chamber wall thickness just below the failure area and/or by increasing the dome wall thickness by Atterbury and Bert's thin-shell reinforcement method. The effects of high burn temperatures on the chamber stresses are presented as are those of a modelled corrosion pit. All results are compared to data obtained experimentally by Khan. Author

**A87-44253**
**HEAT EXCHANGERS FOR TURBOSHAFT ENGINES**
PETER PLETSCHACHER Interavia (ISSN 0020-5168), vol. 42, May 1987, p. 503.

The decisive factor in the design of a heat exchanger for aircraft turboshaft and turboprop engines, in order to obtain fuel consumption improvements through the recuperation of exhaust heat, is the ability to withstand high inlet temperatures and large pressure differentials while maintaining suitably small volume and weight increases to the powerplant installation. Attention is given to initial test results from a heat exchanger for a 1000 kW-class turboshaft engine; exchanger inlet temperatures are of the order of 1000 K at full load. Heat exchanger internal airflow patterns were investigated in detail for the case of subassemblies. A fuel saving of 25-35 percent is projected for airliners that cruise at 60-70 percent of rated power. O.C.

**A87-44272**
**COUNTDOWN TO THE PROPFAN**
KEN FULTON Air International (ISSN 0306-5634), vol. 32, June 1987, p. 316-321.

A development history, current development status, and relative performance advantage assessment is made of the candidate turbomachine designs for 'propfan' propulsion systems that are to be used by next-generation commercial aircraft in order to further reduce specific fuel consumption. Attention is given to the progress made by the Unducted Fan (UDF), which is currently undergoing flight testing and appears to exhibit substantial intrinsic advantages over both single-rotation and contrarotation propfan systems employing a gearbox (rather than the UDF's contrarotating low pressure turbine stages) for transfer of engine bypass power. O.C.

**A87-44582**
**THE ART OF RETICULATION AND APPLICABLE ADHESIVES**
SID QUICK (Dexter Corp., Hysol Aerospace and Industrial Products Div., Pittsburg, CA) IN: High tech - The way into the nineties; Proceedings of the Seventh International SAMPE Conference, European Chapter, Munich, West Germany, June 10-12, 1986 . Amsterdam and New York, Elsevier Science Publishers, 1986, p. 103-115.

A development status evaluation is made of engine nacelles that have been acoustically treated for compliance with FAA requirements and regulations; most of these nacelle designs in some fashion employ a perforated aluminum face sheet that is bonded to a reticulated honeycomb core. Attention is presently given to the unique properties required in reticulable adhesive films, as well as the equipment and procedures required to perform such film reticulations, as found in the state-of-the-art 'DynaRohr' sound-attenuating hardware system. O.C.

**A87-45156#**
**ADVANTAGES OF THRUST VECTORING FOR STOVL**
B. D. WARD (Rolls-Royce, Inc., Atlanta, GA) and W. J. LEWIS (Rolls-Royce, PLC, Bristol, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(AIAA PAPER 87-1708)

The advantages of concepts capable of full thrust vectoring over other STOVL and conventional aircraft concepts are examined in terms of the takeoff ground roll (as a function of the takeoff gross weight), efficiency of transition to fully wingborne flight, and overall aircraft safety. In particular, it is shown that full vectoring concepts (advanced vector thrust and hybrid fan vectored thrust) have two important advantages over part vectoring concepts (RALS, ejectors, lift, and lift/cruise): (1) for a given engine size, the vectored thrust resultant is greater and (2) there are no changes to the engine configuration or rating required during STO or transition to wingborne flight. V.L.

**A87-45157#**
**IMPACT OF ENGINE TECHNOLOGY ON SUPERSONIC STOVL**
DONALD W. ELLIOTT and JOHN R. SIMMONS (General Electric Co., Technologies Dept., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(AIAA PAPER 87-1709)

The effect of advanced engine technologies on the supersonic STOVL aircraft is evaluated in terms of the takeoff gross weight (TOGW) for a single-engine aircraft flying a typical STOVL supersonic mission. The far-term engine technology applied to the generic single-engine STOVL aircraft with 80-percent composite utilization is predicted to have a 30-percent improvement in TOGW for the STOVL mission. For the intermediate-term technology with 60-percent utilization of composites, the predicted improvement in TOGW is 22 percent. The SLIDE (short landing integrated deflected exhaust) concept would have a 15-percent lower TOGW than the same technology STOVL aircraft for the STOVL mission. V.L.

**A87-45161#**
**COMBUSTION-GENERATED TURBULENCE IN PRACTICAL COMBUSTORS**
D. R. BALLAL (Dayton, University, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(Contract F33615-82-C-2255)
(AIAA PAPER 87-1721)

Combustion-generated turbulence in practical combustors is examined with reference to experimental data for gas turbine combustors, dump combustors, bluff body stabilized combustors, and flames stabilized by a rearward facing step. Four different mechanisms that either affect or are affected by the combustion-generated turbulence are identified: combustion zone structure, reaction rates, recirculation and swirling motion, and two-phase combustion. Measurements indicate a dominating influence of small-scale random turbulence, consistent with mean gradient transport modeling. Due to the contribution of small-scale turbulent diffusion, turbulent flame in practical combustors is thick, and the mean reaction rate in such a thick flame is found to be at least 50 percent higher than that in a thin laboratory flame. V.L.

**A87-45168#**
**PROPFAN PROPULSION SYSTEMS FOR THE 1990'S**
C. N. REYNOLDS (Pratt and Whitney, Engineering Div., East Hartford, CT), R. E. RIFFEL (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and S. LUDEMANN (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p.
(AIAA PAPER 87-1729)

PW-Allison Engines with subcontractor Hamilton Standard are designing a Propfan Propulsion System for commercial and military transport aircraft. These companies are targeting for an early 1990's certification of a pusher system for the Douglas MD91X and the Boeing 7J7 airliners. The paper describes the Model 578 Propfan Propulsion System design considerations. Included are discussions on core engine selection, comparing new versus derivative; cycle definition; configuration and installation studies including gear system concepts; and propfan propulsor configurations. Engine selection studies will highlight fuel burn, economic, and acoustic criteria. Author

**A87-45169#**
**ENGINE DESIGN AND SYSTEMS INTEGRATION FOR PROPFAN AND HIGH BYPASS TURBOFAN ENGINES**
N. J. PEACOCK (Rolls-Royce, PLC, Derby, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p.
(AIAA PAPER 87-1730)

The effects of engine configuration geometry on alternative courses to the provision of such aircraft services as cabin pressurization, air conditioning, and electricity (through engine air bleed and accessory power trains) are presently examined for a propfan and a high bypass ratio turbofan employing the technology features anticipated for the next generation of high-speed, long-range airliner propulsion systems. The projected trends in cabin comfort level requirements lead, notwithstanding increasing engine efficiency, to specific fuel consumption penalties; where these are currently 1-2 percent, they will rise to over 4 percent for the best engine-offtake systems. By using the engine solely as a provider of electrical power, this fuel consumption penalty may be reduced by up to 2 percent. O.C.

**A87-45170**
**PREPARING A PROPFAN PROPULSION SYSTEM FOR FLIGHT TEST**
D. C. CHAPMAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), G. J. SEVICH (Pratt and Whitney, Engineering Div., East Hartford, CT), and D. E. SMITH (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p.
(AIAA PAPER 87-1731)

The PW-Allison 578-DX Propfan Demonstrator Propulsion System is being prepared for flight test by the Pratt & Whitney, Allison, and Hamilton Standard team. The demonstrator system consists of an Allison Model 571 power section, which is currently in service in industrial and marine applications, a new low pressure compressor, a new gear reduction system developed from an Allison/NASA program, a new propfan module, a new nacelle, and a full authority digital electronic control system. Preparation for flight testing includes comprehensive testing of the major components as 'building blocks,' leading to complete propulsion system testing in an ambient test stand. Results of the test program are presented. Flight testing will be conducted in late 1987 on a McDonnell Douglas MD80 aircraft. Author

**A87-45171#**
**UDF/727 FLIGHT TEST PROGRAM**
ROBERT W. HARRIS (General Electric Co., Cincinnati, OH) and R. D. CUTHBERTSON (Boeing Commercial Airplane Co., Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p.
(AIAA PAPER 87-1733)

The Unducted Fan engine design concept, 'UDF', and aircraft/engine configurations are presented as well as the accomplishments of flight testing on a modified Boeing 727 aircraft. Cruise flight speeds up to 0.84 Mach at 36,000 ft were achieved together with system operability and safety, control stability, a good correlation between the model and full-scale data. In addition, UDF acoustic acceptibility and predictability were confirmed.
K.K.

**A87-45180#**
**HIGHLY COMPACT INLET DIFFUSER TECHNOLOGY**
R. H. TINDELL (Grumman Corp., Bethpage, NY) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1747)

The desirable design characteristics of highly compact offset diffuser systems are examined, with a goal of deriving inlet geometry parameters to achieve a separation-free flow. The experimental work employed a diffuser test rig, designed to measure static and total pressures throughout the diffuser and across the exit plane, to evaluate the effects of throat Mach number and active/passive methods for BLC. The paper discusses passive and active BLC methods for providing separation-free diffuser flow and compares CFD methods with the experimental results to validate the applicability of the methods.
I.S.

**A87-45181#**
**F-16 MODULAR COMMON INLET DESIGN CONCEPT**
PAUL E. HAGSETH (General Dynamics Corp., Fort Worth, TX) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p.
(AIAA PAPER 87-1748)

The fixed geometry normal shock inlet of the F-16 fighter yields efficient performance at both subsonic and low supersonic Mach numbers while retaining the use of a simple and lightweight structure. The modular common-inlet duct design which has been developed to accomodate future engine changes without forfeiture of the fixed inlet is presently discussed in light of wind tunnel data on pressure recovery, distortion, and turbulence. Although currently operating with the F100-PW-200 engine, the higher airflows of the larger and more powerful F-110 engine are accomodated by changing the forward inlet modules at the leading 24 inches of the inlet, without disturbing the fuselage fuel tank and nose landing gear structures.
O.C.

**A87-45205#**
**TRANSIENT TEST SYSTEM DESIGN FOR THE T800-APW-800 TURBOSHAFT ENGINE**
J. M. DAVIS (Pratt and Whitney, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p.
(AIAA PAPER 87-1791)

The U.S. Army has released contracts for development of the Light Helicopter Experimental (LHX). Part of the engine development requirements include simulation of engine 'droop' condition following autorotation. This requirement necessitates the design of a high response transient test system. Requirements for the transient test system include performance collective pitch-induced load change from flight idle to 95-percent intermediate rated , .wer (IRP) in one second, decoupling the power absorber at zero torque and recoupling when load is applied, and performance transients from no load to maximum power and maximum power to no load. This paper presents just such a design of a transient test system for the turboshaft engine of the Army's LHX Helicopter.
Author

**A87-45231#**
**DESIGN AND TEST VERIFICATION OF A COMBUSTION SYSTEM FOR AN ADVANCED TURBOFAN ENGINE**
J. W. SANBORN, J. E. LENERTZ, and J. D. JOHNSON (Garrett Turbine Engine Co., Phoenix, AZ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1826)

Modeling has been conducted for both combustor internal and external flow fields in the case of a novel combustion system configuration, evaluating various airflow split schemes and fuel injection locations in order to arrive at the final design. A full-scale annular plexiglass atmospheric test rig was used to measure the local pressure drops across the combustor dome and liners; measured pressure drops were compared to the predicted pressure drops. In addition, a full-scale annular high pressure test rig was employed to record all pertinent combustor performance data. Attention was given to combustion efficiency, pattern factor, ignition characteristics, lean blowout fuel/air ratios, and liner wall temperatures.
O.C.

**A87-45232#**
**THE INFLUENCE OF DILUTION HOLE AERODYNAMICS ON THE TEMPERATURE DISTRIBUTION IN A COMBUSTOR DILUTION ZONE**
S. J. STEVENS and J. F. CARROTTE (Loughborough University of Technology, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. Sponsorship: Ministry of Defence. refs
(Contract MOD-ER/2/1/7/0090-XR)
(AIAA PAPER 87-1827)

An experimental investigation has been carried out to study circumferential irregularities in the temperature distribution downstream of a row of sixteen heated jets injected normally into a confined annular cross-flow at a momentum flux ratio of 4. The heated air was fed to the plunged holes along a representative approach annulus. Temperature distributions measured at a plane 2 hole diameters downstream indicated, despite the uniformity of the approach flow, a lack of symmetry between the dilution jets. This has been shown to be due to an apparent twist of the temperature contours associated with certain jets. Velocity distributions at the same location indicated a corresponding asymmetry in the double vortex structure that is formed in the wake of each jet. Velocity measurements across the face of the dilution jets revealed non-uniformities in both flow direction and distribution.
Author

**A87-45233#**
**HIGH DENSITY FUEL EFFECTS ON GAS TURBINE ENGINES**
V. L. OECHSLE, P. T. ROSS, and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(Contract F33615-86-C-2604)
(AIAA PAPER 87-1829)

Four high density/high volumetric energy fuels are experimentally evaluated on the T56-A-15 combustion system. These fuels represent an increase of up to 11.2 percent volumetric energy content over the baseline JP-4 fuel, and significant increases in the aromatic contents, fuel viscosity, surface tension, and initial and final boiling points. Combustion system degradation is shown in regard to idle combustion efficiency, lean blowout, ignition/restart, smoke emissions, and wall temperature levels.
Author

**A87-45234#**
**HIGH PERFORMANCE TURBOFAN AFTERBURNER SYSTEMS**
A. SOTHERAN (Rolls-Royce, PLC, Bristol, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p.
(AIAA PAPER 87-1830)

An account is given of the design features and performance capabilities of state-of-the-art, low bypass turbofan afterburner

systems. A compact afterburner configuration is achieved by locating the flameholding baffles immediately downstream of the turbine exhaust plane at the confluence of the engine core and fan bypass gas streams. Afterburners are designed to be free of combustion-driven pressure oscillations that can occur either in cross-stream modes, which can destroy engine hardware in fractions of a second, or in longitudinal modes that can cause fan surge. O.C.

**A87-45235*#** General Electric Co., Cincinnati, Ohio.
**SCALE MODEL TEST RESULTS OF A THRUST REVERSER CONCEPT FOR ADVANCED MULTI-FUNCTIONAL EXHAUST SYSTEMS**
A. P. KUCHAR (General Electric Co., Cincinnati, OH) and L. D. LEAVITT (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(AIAA PAPER 87-1833)

An evaluation is made of scale model test results for a 'block-and-turn' thrust reverser design consisting of an internal flow blocker, internal doors, two ports located on the top and bottom of the exhaust duct, cascade-turning vanes located at the port exit to turn the flow, and external doors which guide the exhaust flow. Numerous geometric variations were incorporated in order to obtain parametric aerodynamic design criteria. The baseline reverser configuration exceeded predicted levels of performance. Skewed vane cascade concepts can be as effective in turning the flow as the baseline vane concept. O.C.

**A87-45236*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**STATIC INVESTIGATION OF POST-EXIT VANES FOR MULTIAXIS THRUST VECTORING**
BOBBY L. BERRIER and MARY L. MASON (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p. refs
(AIAA PAPER 87-1834)

Transonic wind tunnel tests are conducted to determine the flow-turning capabilities and nozzle internal performance of axisymmetric and nonaxisymmetric nozzles employing postexit vanes for multiaxis thrust-vectoring. The geometric parameters investigated for the axisymmetric nozzle installation were number of vanes, vane curvature, vane location relative to nozzle exit, and vane deflection angle; for the nonaxisymmetric cases, the parameters were vane planform and curvature, nozzle type, and nozzle exit aspect ratio. Nozzle pressure ratio was varied from 1.5 to 6.0, using high pressure air. O.C.

**A87-45240#**
**DEVELOPMENT OF A LARGE, SPIRAL BEVEL GEAR ROTORCRAFT TRANSMISSION**
RAYMOND J. DRAGO and JOHN C. MACK (Boeing Vertol Co., Philadelphia, PA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p.
(AIAA PAPER 87-1839)

This paper summarizes the results of testing on the U.S. Army XCH-62 Heavy Lift Helicopter (HLH) combiner transmission. This transmission is rated at 10,620 hp. Program elements included design and fabrication of new bevel gears, static and dynamic strain surveys of the transmission gears, optimization of gear bending stresses following the first strain survey, correlation of FEM analysis with measured stresses, evaluation of a new lubricant to raise the scuffing/scoring load limitation, measurement of gear tooth temperatures under operation conditions, and load testing. The findings establish that 100 percent of design loading was attained within the permissible range of measured gear tooth bending stress limits, AEO conditions; 95 percent of design loading was attained within the above limits, OEI conditions. Alternating stresses on the collector gear set the load limits. Further analytical effort is required to accurately predict the stress levels in gears loaded on both sides of the teeth as is the collector gear. Author

**A87-45245#**
**FLIGHT TEST OF THE F100-PW-220 ENGINE IN THE F-16**
MARK T. CHILDRE and KEVIN D. MCCOY (General Dynamics Corp., Fort Worth, TX) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1845)

Results of a 106-flight two-phase test program of the F100-PW-220 engine for the F-16 aircraft are summarized. The program has demonstrated the overall capability and compatibility of the F100-PW-220 engine. The thrust produced by the F100-PW-220 engine is comparable to that of its predecessor, F100-PW200, with the response significantly improved. The new engine has also demonstrated improved augmentor operability and start characteristics. Some minor problems and areas requiring additional testing have been identified. V.L.

**A87-45246#**
**F-15/F100 DIGITAL ELECTRONIC ENGINE CONTROL MAIN FUEL GEAR PUMP FIELD SERVICE EVALUATION**
J. E. TAYLOR and S. C. GERBER (Pratt and Whitney, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1846)

A two-year field service evaluation program is being conducted on F-15 and F-16 aircraft with the purpose of assessing the operability, reliability, and supportability of the full authority digital electronic engine control/gear pump (DP) system for the F100-PW-100 engine. In addition, the program is demonstrating and evaluating the extensive engine monitoring diagnostic system. The operation and the main components of the digital electronic engine control system and engine monitoring system are examined, and results of the field evaluation are presented, with some possible improvements identified. V.L.

**A87-45247*#** National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
**PRELIMINARY FLIGHT RESULTS OF AN ADAPTIVE ENGINE CONTROL SYSTEM OF AN F-15 AIRPLANE**
LAWRENCE P. MYERS and KEVIN R. WALSH (NASA, Flight Research Center, Edwards, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1847)

Results of the flight demonstration of the adaptive engine control system (ADECS), an integrated flight and propulsion control system, are reported. The ADECS system provides additional engine thrust by increasing engine pressure ratio (EPR) at intermediate and afterburning power, with the amount of EPR uptrim modulated in accordance with the maneuver requirements, flight conditions, and engine information. As a result of EPR uptrimming, engine thrust has increased by as much as 10.5 percent, rate of climb has increased by 10 percent, and the time to climb from 10,000 to 40,000 ft has been reduced by 12.5 percent. Increases in acceleration of 9.3 and 13 percent have been obtained at intermediate and maximum power, respectively. No engine anomalies have been detected for EPR increases up to 12 percent. V.L.

**A87-45248#**
**USE OF RPM TRIM TO AUTOMATE THE SUPERSONIC ENGINE/INLET MATCH IN THE SR-71A**
J. R. WILSON and V. A. WRIGHT (Lockheed-California Co., Burbank) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(AIAA PAPER 87-1848)

In the design of an engine for a supercruise vehicle, the capabilities of the anticipated inlet system must be very carefully integrated with the requirements of the engine. Analytical predictions are described that make it possible to achieve significant performance gains in the SR-71A Mach 3+ aircraft by incorporating a fairly simple change into the engine control system which allows the two systems to communicate. In particular, an RPM change is

added to the engine, which makes it possible to effect a match between the engine and inlet airflows. The results of flight testing verified the predicted improvements. I.S.

**A87-45263#**
**SIMULATION OF PERFORMANCE, BEHAVIOUR AND FAULTS OF AIRCRAFT ENGINES**
G. TORELLA (Accademia Aeronautica, Pozzuoli, Italy) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1868)

Italian Air Force Academy efforts to develop numerical codes for simulating aircraft engines are described. Consideration is given to codes for: (1) design point calculations, (2) calculations in off-design conditions, and (3) simulation of faults in the components. These codes are used like 'paper engine test beds' where the engineers and pilots can study the behavior of a particular engine in both steady- and unsteady-state flight conditions. These codes are both reliable and flexible and have emerged as powerful tools in the learning process. K.K.

**A87-45264#**
**SYSTEM PERFORMANCE APPROACH TO AIR BREATHING PROPULSION DESIGN - A NEW UNDERGRADUATE DESIGN COMPETITION**
JACK D. MATTINGLY (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p.
(AIAA PAPER 87-1869)

This paper describes the Air-Breathing Propulsion Design Competition, a new undergraduate design competition sponsored by AIAA through its Air-Breathing Propulsion Technical Committee and Student Activities Committee. This new design program uses the specification of the required aircraft system performance as identified by the customer as the starting point of the engine design process. The design process for this new competition is described in terms of its individual steps, including constraint analysis, mission analysis, cycle analysis, engine cycle selection, engine sizing and performance, component design, and integration and communications. C.D.

**A87-45266#**
**VORTEX-NOZZLE INTERACTIONS IN RAMJET COMBUSTORS**
K. YU, S. LEE, A. TROUVE, H. STEWART, and JOHN W. DAILY (California, University, Berkeley) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 20 p. refs
(Contract N00014-84-K-0372)
(AIAA PAPER 87-1871)

A facility designed to study the role of vortex-nozzle interactions in promoting low frequency instabilities in ramjet combustors is described. The design issues are outlined, as are potential instabilities. Preliminary data are reported for both cold and combusting flow. For the cold flow cases studied it appears that there may be a flapping instability of the jet entering the combustor at the dump plane. For reacting flow, a pulsating, acoustically coupled instability is important for the case studied. Author

**A87-45267#**
**PRESSURE OSCILLATIONS AND ACOUSTIC-ENTROPY INTERACTIONS IN RAMJET COMBUSTION CHAMBERS**
JOSEPH W. HUMPHREY and F. E. C. CULICK (California Institute of Technology, Pasadena) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(Contract N00014-84-K-0434)
(AIAA PAPER 87-1872)

A one-dimensional analytical model is presented for calculating the longitudinal acoustic modes of idealized 'dump-type' ramjet engines. The model contains the matching required to place an oscillating flame sheet in the interior of a combustion chamber with mean flow. The linear coupling of the acoustic and entropy waves at the inlet shock, flame sheet, and exit nozzle along with acoustic admittances at the inlet and exit are combined to determine the stability of the system as well as the acoustic modes. Since the acoustic and entropy waves travel at different velocities, the geometry is a critical factor in determining stability. Typical values of the admittances will produce damped solutions when the entropy is neglected, but, as the ratio of the entropy to acoustic fluctuations is increased, the coupling can either feed acoustic energy into or out of different modes independently. This transfer of energy has a destabilizing or stabilizing effect on the acoustic modes of the system depending upon the phase of the energy transfer. Author

**A87-45275*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A MIXING AUGMENTATION TECHNIQUE FOR HYPERVELOCITY SCRAMJETS**
A. KUMAR, D. M. BUSHNELL, and M. Y. HUSSAINI (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 16 p. refs
(AIAA PAPER 87-1882)

The paper discusses mixing problems in hypervelocity scramjet combustors. Techniques for providing turbulence and/or mixing enhancement are described. One such technique, the oscillating shock interaction, is studied numerically and options for producing oscillatory shock waves for mixing augmentation in scramjet combustors are discussed. Author

**A87-45279*#** Purdue Univ., West Lafayette, Ind.
**A PANEL METHOD FOR COUNTER ROTATING PROPFANS**
M. H. WILLIAMS (Purdue University, West Lafayette, IN) and S. H. CHEN AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(Contract NAG3-499)
(AIAA PAPER 87-1890)

A time domain source-doublet surface paneling method is developed for analyzing the unsteady loads on counter rotating propellers in incompressible irrotational flow. A scheme for treating the blade-wake interaction problem is described. Sample results for single rotation propellers are given, with comparisons to alternate theories and experiment. Finally, some preliminary results for quasi-steady and fully unsteady loads on counter rotating systems are presented. Author

**A87-45289*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**CONTINGENCY POWER FOR SMALL TURBOSHAFT ENGINES USING WATER INJECTION INTO TURBINE COOLING AIR**
THOMAS J. BIESIADNY, BRETT BERGER (NASA, Lewis Research Center, Cleveland, OH), GARY A. KLANN, and DAVID A. CLARK (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. Previously announced in STAR as N87-20280. refs
(AIAA PAPER 87-1906)

Because of one engine inoperative requirements, together with hot-gas reingestion and hot day, high altitude takeoff situations, power augmentation for multiengine rotorcraft has always been of critical interest. However, power augmentation using overtemperature at the turbine inlet will shorten turbine life unless a method of limiting thermal and mechanical stresses is found. A possible solution involves allowing the turbine inlet temperature to rise to augment power while injecting water into the turbine cooling air to limit hot-section metal temperatures. An experimental water injection device was installed in an engine and successfully tested. Although concern for unprotected subcomponents in the engine hot section prevented demonstration of the technique's maximum potential, it was still possible to demonstrate increases in power while maintaining nearly constant turbine rotor blade temperature. Author

**A87-45290#**
**APU FUEL EFFICIENCY AND AFFORDABILITY FOR COMMERCIAL AIRCRAFT**
C. RODGERS and D. C. JOHNSON (Sundstrand Corp., Turbomach Div., San Diego, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p. refs
(AIAA PAPER 87-1907)

The fuel efficiency and life cycle cost of small gas turbine auxiliary power units (APU) for commercial aircraft applications is examined. Fuel efficiency has been improved through the use of higher cycle pressure ratios. However, a higher pressure ratio, and associated increase in compressor discharge temperature, results in an incompatibility with commercial aircraft bleed air temperature and pressure limits. This has led to the introduction of load compressor and dual spool APU's. Both of these approaches have increased design sophistication, increased cost, and reduced durability. A complex trade off arises between the design constraints of fuel efficiency and total cost. The paper identifies the trade off parameters which must be addressed in order to select an optimum APU design solution for future commercial type aircraft applications. Author

**A87-45292#**
**A DERIVATIVE ENGINE BASED ON NEW TECHNOLOGY - LOW RISK; COST EFFECTIVE**
W. P. PAINI (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p.
(AIAA PAPER 87-1910)

The advantages of fulfilling new propulsion system requirements with the derivative engine approach are described using as a specific example the T406 engine, conceived and constructed as a simple engine employing low-risk technology appropriate for the V-22 propulsion system. The V-22 propulsion system requirements are reviewed, and the T406 engine's physical features are described in some detail. The performance of the T406 is summarized, and its risk and cost effectiveness are evaluated, individually studying the compressor, combustor, and gas generator turbine. Improvements that can be made in the basic engine are discussed. C.D.

**A87-45295#**
**INFLUENCE OF VANE/BLADE SPACING AND COLD-GAS INJECTION ON VANE AND BLADE HEAT-FLUX DISTRIBUTIONS FOR THE TELEDYNE 702 HP TURBINE STAGE**
M. G. DUNN (Calspan Advanced Technology Center, Buffalo, NY) and R. E. CHUPP (Teledyne, Inc., Teledyne CAE, Toledo, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. Research supported by the Teledyne CAE Independent Research and Development Funds. refs
(AIAA PAPER 87-1915)

The effects of the vane/blade spacing and the cold gas injection on the vane and blade time-averaged Stanton number distrubutions were determined for the Teledyne CAE 702 HP full-stage rotating turbine for two different vane/blade axial spacings, 0.19 C(s) and 0.50 C(s). The experimental technique used the short-duration shock-tunnel approach for which a shock tube was used as a short-duration source of heated and pressurized air directed into the turbine stage. The cooling gas was injected through discrete circular holes on the vane pressure and suction surfaces, and in one case, through holes in the nozzle guide vane ring near the tip region as well as through the vane holes. It was found that the values of the vane/blade spacing used had little effect on the Stanton number distribution on both the vane and the blade. The cold-gas injection influenced the vane (but not the blade) Stanton-number distribution. I.S.

**A87-45299#**
**AN EXPERIMENTAL INVESTIGATION OF TURBINE CASE TREATMENTS**
L. S. OFFENBERG, J.D. FISCHER, and T. J. VANDER HOEK (Garrett Turbine Engine Co., Phoenix, AZ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-1919)

This paper presents the results of the Garrett Turbine Case Treatment Study Program carried out under the sponsorship of the USAF Aero Propulsion Laboratory. The objective of this program was to develop an understanding of the effect of shroud trenching on axial turbine performance and the trenching parameters that most affect turbine efficiency. A test program that included 12 shroud configurations was completed. At nominal tip clearance, a smooth, untrenched shroud was found to be the most efficient. As tip clearance increased, shroud trenching became more advantageous. Author

**A87-45301#**
**F-15 SMTD HOT GAS INGESTION WIND TUNNEL TEST RESULTS**
WILLIAM B. BLAKE and JAMES A. LAUGHREY (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p. refs
(AIAA PAPER 87-1922)

Key results from a hot gas ingestion test conducted on a 0.075 scale model of the F-15 SMTD (STOL and Maneuver Technology Demonstrator) are presented. Hot exhaust gases of 500 F are used to simulate the reverser flow. Ingestion is determined by temperature increases measured at the engine face. The temperature data are correlated using the reverser jet to free-stream mass flux ratio. Reductions in the reverser vane angle and increases in the sideslip angle reduce the ingestion velocity. Ground pressure data and exterior inlet wall temperature data are compared as indicators of ingestion onset. Author

**A87-45304#**
**MICRO-COMPUTER/PARALLEL PROCESSING FOR REAL TIME TESTING OF GAS TURBINE CONTROL SYSTEMS**
S. P. ROTH and L. A. CELIBERTI (Pratt and Whitney, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1926)

An experimental multiprocessor real time engine simulation system, 'EMPRESS', for the verification of full authority digital electronic controls for gas turbine engines is described. The evolution, design, and use of these microprocessor based simulation benches, and their role in the development and testing of integrated flight and propulsion control systems for future aircraft, are discussed. Parallel processing in EMPRESS provides the fidelity to accurately model engine performance, while offering simplicity and ease of modification. The software verification steps (code read, module test, module integration test, and hardware/software integration test) for the module, software, electronic, and control data acquisition verification benches, are discussed. R.R.

**A87-45305#**
**HIGHLY RELIABLE, MICROPROCESSOR-BASED ENGINE CONTROL**
TIMOTHY J. LEWIS (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p.
(AIAA PAPER 87-1927)

Following a discussion of the evolution of engine controls, the two-phase Integrated Reliable Fault Tolerant Control for Engines (INTERFACE) program, and the fabrication of upgraded versions of the redundant control systems, are considered. Requirements for the INTERFACE controllers are described which are based on engine configurations to be used in the next generation tactical

fighters. The near complete absence of software penalty for redundancy managment implementation is a strength of both the triplex and dual-dual architectures described. The requirement of keeping nonapplication software to a minimum is fulfilled by both controllers. The bench testing is also discusssed. R.R.

**A87-45308#**
**FUTURE ADVANCED CONTROL TECHNOLOGY STUDY (FACTS) - A LOOK AT EMERGING TECHNOLOGIES**
S. J. PRZYBYLKO (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASME, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1930)

Pertinent aspects, identified by the FACTS program, of six emerging technologies which are considered candidates for application to the control and accessory systems of future aircraft turbine engines are discussed. The technologies considered include fiber-optic sensors; VHSIC/GaAs technology; high-temperature electronics; parallel processing using VHSIC technology; electrical power drive and actuation; and the use of composite materials in electronics control housings, actuators, and pumps. Issues considered in the selection of these technologies include weight savings, improvement of material radiation tolerance, reduction of component operating temperatures, and extension of the operating temperature limits of hydraulic systems. R.R.

**A87-45333#**
**INTEGRATION OF PROPULSION/INTEGRATION TEST RESULTS THROUGH THE USE OF REFERENCE PLANE TRANSFERS**
JAMES NEELY (Sverdrup Technology, Inc., Arnold Air Force Station, TN) and TRAVIS BINION (Calspan Corp., Arnold Air Force Station, TN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p.
(AIAA PAPER 87-1964)

Use of the concept of reference plane transfers in designing a test methodology for determination of the various terms in a force accounting system for a hypersonic vehicle is considered. The role played by the technologies of diagnostics and computational fluid dynamics is discussed. It is noted that the effects of specific heat on the aerodynamic forces, and the effects of nonair on combustion, must be quantified. Factors influencing the test objectives include forebody shaping, verification of the aerodynamic reference planes, replication of heat transfer effects on the forebody, and spurious reflected waves. Facility design must be driven by considerations of minimum scale, minimum run time, and measurement accuracy, in addition to the need to reproduce the required test conditions. R.R.

**A87-45347#**
**STANDING OBLIQUE DETONATION WAVE ENGINE PERFORMANCE**
M. J. OSTRANDER, J. C. HYDE, M. F. YOUNG, R. D. KISSINGER (Aerojet TechSystems Co., Sacramento, CA), and D. T. PRATT (Washington, University, Seattle) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(Contract F04611-86-C-0095)
(AIAA PAPER 87-2002)

A ramjet propulsion system concept involving premixing of air and fuel and combustion by means of a stabilized oblique detonation wave, rather than the scramjet's diffusive burning, is presently considered as a basis for hypersonic propulsion. Rapid chemical reactions in the fuel/air mixture downstream of the last shock are used to release energy into the flowing stream and thereby couple with the shock wave to form a standing oblique detonation wave. The propulsion system region exposed to the high temperature, high pressure combustion gases is much smaller than for the diffusive burning scramjet. O.C.

**A87-45348#**
**ADVANCEMENTS IN HYDROGEN EXPANDER AIRBREATHING ENGINES**
M. R. GLICKSTEIN and T. H. POWELL (Pratt and Whitney, Engineering Div., West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-2003)

Three aircraft propulsion system concepts based on variation of the hydrogen expander cycle were examined to determine their relative merits: a single-spool regenerative air-turboramjet (ATR), a preburning ATR, and a twin-spool hydrogen expander. These concepts were compared with respect to their mechanical arrangement, performance, and operational capabilities. The direct use of heated hydrogen was shown to result in a heavy engine, due to requirements for a heat exchanger, a gearbox, and a large number of turbine stages. The preburner ATR produced the lightest weight engine but exhibited a significant loss in specific impulse (Isp) due to the requirement for an onboard oxidizer. On the other hand, the twin-spool gas generator cycle exhibited a moderate engine thrust-to-weight with high Isp, but did so with added mechanical complexity. Thus, the choice of the best engine is mission-dependent: missions with long cruise legs benefit from high Isp, while those with high thrust loadings demand high thrust-to-weight ratio. I.S.

**A87-45353#**
**DIGITAL CONTROL DEVELOPMENT FOR THE T56-A-427**
J. V. DANILUCK (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p.
(Contract NAVAIR TASK AIR-536)
(AIAA PAPER 87-2013)

The T56-A-427 engine control system, with a unique software algorithm for horsepower control, has demonstated horsepower and temperature control superior to previous T56 engines. This control should result in extended engine/gearbox life. The present control system provides bogdown/surge protection, far fewer restrictions on power lever movement, and improved reliability and maintainability. Use of an in-circuit development system permitted on-line control development that significantly reduced time in matching engine program goals. Favorable engine and flight tests results have been obtained. R.R.

**A87-45354#**
**APPLICATION OF COMPUTATIONAL FLUID DYNAMICS TO ANALYSIS OF EXHAUST GAS/DIFFUSER INTERACTIONS IN A TURBINE ENGINE ALTITUDE TEST CELL**
M. A. CROSS (Sverdrup Technology, Inc., Arnold Air Force Station, TN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(AIAA PAPER 87-2014)

An experimental and computational fluid dynamics (CFD) study of exhaust gas/diffuser interaction was performed to identify the cause of excessive heating in a turbine engine altitude test cell. The presence of exhaust gas recirculation indicated by CFD studies was confirmed by experimental infrared scanner results. Increases in temperature levels in the test cell were found to coincide with the overexpansion of the jet and the exhaust gas recirculation. A Navier-Stokes model predicted no recirculation into the test cell when the nozzle was underexpanded, whereas simulation of the overexpanded flow predicted unsteady recirculation into the test cell from within the diffuser. It is noted that modeling of the test cell geometry and boundary conditions is necessary to realistically simulate the recirculation. R.R.

**A87-45369*#** General Electric Co., Evendale, Ohio.
**NASA/GE ADVANCED LOW EMISSIONS COMBUSTOR PROGRAM**
E. E. EKSTEDT (General Electric Co., Evendale, OH) and J. S. FEAR (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-2035)

The Advanced Low Emissions Combustor Program consisted of the design and testing of advanced combustor concepts utilizing lean, premixed, prevaporized fuel and variable geometry. The objective was to evaluate the potential of these combustor systems to provide very low pollutant emissions levels, superior performance and high durability relative to contemporary combustor designs. Four full annular combustor concepts were designed and fabricated for a 30:1 pressure ratio high bypass turbofan engine. The four full annular combustors with active variable geometry were tested at pressures up to approximately 0.7 MPa with Jet A fuel. The two most promising concepts were also tested in a high pressure sector combustor test rig capable of operation at the maximum engine pressures. The high pressure sector combustor tests were conducted with Jet A and a fuel with reduced hydrogen content. Results of the sector combustor tests are presented in this paper. The potential for very low emissions with premixed fuel was demonstrated. However, autoignition or flashback within the premixing systems was encountered at high pressures. Further development effort is required to address this problem area.
Author

**A87-45370#**
**NO(X) REDUCTION AND COMBUSTION PHENOMENA IN THE MULTI-ANNULAR GAS TURBINE SWIRL BURNER**
A. K. GUPTA (Maryland, University, College Park), N. MARCHIONNA (AVCO Lycoming Textron, Stratford, CT), and L. H. ONG AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 14 p. Research supported by AVCO Lycoming Textron. refs
(AIAA PAPER 87-2036)

Experimental studies on a multiannular gas-turbine swirl burner (MASB) were performed to determine the effects of the burner's geometry, swirl distribution, and strength in various annuli, as well as the fuel/air distribution, on the overall NO(x) emission levels. The results obtained on an experimental variable-geometry facility, with natural gas as the fuel at atmospheric conditions, facility, indicate that significant changes in the NO(x) emission levels can be obtained by small changes in the input operational parameters to the burner. Extrapolation of the NO(x) data to practical operating conditions of a gas turbine revealed a potential of MASB for providing very low NO(x) emission levels from gas-turbine combustors. Preliminary results obtained with this combustor also revealed high combustion efficiency and intensity as compared to conventional swirl burners. I.S.

**A87-45376#**
**TRANSMISSION EFFICIENCY IN ADVANCED AEROSPACE POWERPLANT**
J. DOMINY (Rolls-Royce, PLC, Derby, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p. refs
(AIAA PAPER 87-2043)

The consideration of future aerospace powerplant requiring high power reduction gearboxes has necessitated the development of an analytical method of estimating the efficiency of candidate transmissions. Efficiency becomes important not in terms of the cycle itself but to the installed efficiency of the engine. Inefficient gearboxes will require large cooling systems imposing penalties in bulk, weight and drag. The analysis has been calibrated against the existing Tyne transmission and then applied to gearboxes for single and contra rotating propfans and larger Ultra-High-Bypass Ratio engines. In all cases the predicted efficiencies are broadly acceptable. The single most powerful influence is the gearbox configuration which is generally imposed by airframe requirements. It is important that the airframe manufacturer be aware of the implications of his decision during the study phase of the aircraft.
Author

**A87-45378#**
**DESIGNING FOR FRETTING FATIGUE FREE JOINTS IN TURBOPROP ENGINE GEARBOXES**
A. SMAILYS and C. BROWNRIDGE (Pratt and Whitney Canada, Mississauga) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-2046)

Results from the analysis and testing of propeller shafts and flanges were used to develop an empirical relationship for predicting fretting fatigue based on three parameters: (1) the induced surface stress in the parts; (2) the amount of slip between the contacting surfaces; and (3) the maximum localized contact pressure. Experimental data on a dedicated test rig simulating a propeller hub and propshaft flange demonstrated fretting fatigue cracks, and results were correlated with a three-dimensional finite element analysis of the hub/flange. The analysis is applied to the design of press fitted joints between a bullgear and propshaft, also subject to potential fretting fatigue problems. R.R.

**A87-45392*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**AN OUTLOOK ON HYPERSONIC FLIGHT**
GRIFFIN Y. ANDERSON (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-2074)

The NASA Langley Research Center has been active in hypersonic research since the 1950's. A central part of the research conducted since 1970 has focussed on high speed airbreathing propulsion - in particular on supersonic combustion ramjets or scramjets. Renewed interest in very high speed flight in the 1980's has led to some expansion and broadening of this activity with particular attention to extreme speeds approaching orbital velocity. The purpose of this paper is to review the impact of extreme speed on the potential of scramjet propulsion. The implications of system performance objectives on propulsion and vehicle requirements will be explored. Some pertinent results from past studies will be summarized along with examples of engineering design and detailed analysis methods applied to typical scramjet components. Critical areas where fundamental knowledge is lacking will be highlighted, and some proposed studies to deal with these uncertainties will be outlined. Author

**A87-45393#**
**AN IMPROVED COMPUTATIONAL MODEL FOR A SCRAMJET PROPULSION SYSTEM**
THOMAS R. A. BUSSING and GARY L. LIDSTONE (Boeing Military Airplane Co., Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 16 p. refs
(AIAA PAPER 87-2078)

A mixing model representative of three-dimensional H2 fuel injection into a scramjet combustor has been incorporated into the SAIC scramjet propulsion program package. The model conserves mass, momentum and energy and uses the experimentally generated H2 mass fraction correlations due to Cohen, Coulter and Egan for closure. Computations preformed with this package have shown that fuel injection can increase combustor pressures substantially. Author

**A87-45404#**
**OPERATIONAL ENGINE USAGE AND MISSION ANALYSIS**
MARK J. NIENHAUS (General Dynamics Corp., Fort Worth, TX) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-2097)

The use of a flight loads recorder (FLR) system to monitor engine usage and assess the impact of usage on the integrity of

the aircraft is studied. Engine usage and mission analysis are concerned with the correlation of engine events that expend useful engine life with aircraft activity and operational usage mission types. The F-16/F100 FLR engine usage and mission analysis programs, which are a series of four computer procedures that provide engine use/fleet management data, are examined. The functions of the four programs, power level angle (PLA)-1, ADDER, PLA-2, and MIXER are described. The validity of the FLR data is evaluated. Total accumulated life (TAC)/total operating time and TAC/engine flight time ratio are calculated and compared with events history recorder (EHR) data. It is observed that the FLR estimates are lower than the EHR data; however, the FRL data is valid and reliable. The engine structure integrity program for engine usage data analysis is discussed. I.F.

**A87-45406#**
**ENGINE VARIABLE GEOMETRY EFFECTS ON COMMERCIAL SUPERSONIC TRANSPORT DEVELOPMENT**
RONALD B. STEINMETZ and BOB G. HINES (General Electric Co., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 5 p.
(AIAA PAPER 87-2101)

The widely diversified requirements, such as reduced noise at takeoff and approach, efficient supersonic cruise, and significant off-design usage of a commercial SST require a propulsion system capable of efficient performance over a wide range of operation. The benefits to the propulsion/aircraft system accruing from engine variable geometry in meeting the requirements can be quantified in terms of aircraft Take Off Gross Weight (TOGW) and Fuel Burn (FB). These FB and TOGW improvements will be evaluated by comparing a fixed-geometry, mixed-flow turbofan to a variable-geometry/cycle engine at a 1990 IOC. Cycle and configurational changes commensurate with Year 2000 IOC will be implemented for the variable geometry/cycle engine. Further, with this engine definition, a variable capture area inlet will be employed so the engine variable geometry can be used to full advantage in aircraft development. Author

**A87-45407#**
**DUAL CYCLE TURBOFAN ENGINE**
F. A. SCHWEIGER (General Electric Co., Cincinnati, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p.
(AIAA PAPER 87-2102)

The subsonic Dual Cycle Turbofan Engine is a triple flow, dual shaft, double nozzle, partially-mixed turbofan where certain variability has been employed to greatly enhance its flexibility and performance. This engine utilizes a variable area core nozzle to select nozzle thrust split, control shaft power split, control fan operating line, increase takeoff thrust, and enhance performance. This engine also employs a variable mixer area to give additional performance improvement and to provide a significant amount of reverse thrust with a simple reverser system. Author

**A87-45408#**
**VARIABLE CYCLE CONCEPTS FOR HIGH MACH APPLICATIONS**
G. BLEVINS (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH), J. HARTSEL (General Electric Co., Evendale, OH), and T. POWELL (Pratt and Whitney, West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p.
(AIAA PAPER 87-2103)

Efforts made by the Air Force to identify advanced propulsion system candidates for high Mach cruise and acceleration applications are described. Propulsion concepts under consideration include the turbojet, turboramjet, air turboramjet, and a variable cycle turbofan ramjet. An in-house study assessed the feasibility of advanced propulsion systems such as a turbo-scramjet or systems utilizing turbine bypass. K.K.

**A87-45409#**
**THREE STREAM TURBOFAN-VARIABLE CYCLE ENGINE WITH INTEGRAL TURBOCOMPRESSOR**
GARY M. PERKINS (Pratt and Whitney, Engineering Div., West Palm Beach, FL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-2104)

A variable cycle turbofan engine featuring an additional bypass stream has been conceptualized. In conjunction with the conventional thrust-producing duct and core streams, the concept features an independent, coannular bypass stream to provide pressurized air for special application aircraft. This 'turbocompressor' stream can be sized to provide much more flow than possible from core engine bleed and without the attendant debit on core performance. Maximum lift power can be developed at hover or low-speed approach with rapid thrust response for control, go-around, or maneuver. In the low-thrust mode, the engine functions mainly as a turbocompressor. The system can quickly transition to high thrust output while simultaneously supplying bleed power for lift. Author

**A87-45410#**
**CYCLE SELECTION CONSIDERATIONS FOR HIGH MACH APPLICATIONS**
RICHARD A. JOHNSON (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-2105)

The paper utilizes propulsion system efficiency and Breguet range as key relationships. Parametric performance is presented from Mach 1 to 6, showing the need for nozzle supercharging at low speed and sufficiency of ram pressure at high speed. Propulsion system efficiency fundamentally rises with velocity, justifying the choice of high flight speed. Turbomachinery-based cycles, unconstrained by temperature limits, match ramjet performance at high speed. However, high inlet temperature will limit compressor and turbine operation to about Mach 4, necessitating conversion to ramjet mode above that speed. Mach 4 missions studied show the best performance with dry turbojet propulsion. Author

**A87-45444*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EFFECTS OF SCALE ON SUPERSONIC COMBUSTOR PERFORMANCE**
GLENN S. DISKIN and G. BURTON NORTHAM (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 15 p. refs
(AIAA PAPER 87-2164)

A series of tests has been carried out to investigate the effects of various scale parameters on the direct connect scramjet combustor performance. The calculated combustion efficiency appears to be independent of scale for the same geometry, but tests with more precise scaling of the entire combustor are required to verify this. Combustion, however, can be strongly dependent on geometry for the same scale. It is suggested that the beneficial aspects of certain geometric or scale variations can be combined to improve the overall performance. V.L.

**A87-45453#**
**PERFORMANCE ESTIMATION OF AN AIRCRAFT INTERNAL COMBUSTION ENGINE**
JOSEPH J. FRANZ (U.S. Navy, Naval Air Development Center, Warminster, PA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 5 p. refs
(AIAA PAPER 87-2173)

The NAVAIRDEVCEN has developed an analytical model of an aircraft internal combustion engine for performance estimation of an integrated propulsion system. The engine model is designed to be integrated to a turbocharger and heat rejection system for performance design studies. The model accepts manifold air

conditions, fuel/air ratio, engine delta pressure, crankshaft speed, and coolant temperature as inputs to provide output in the form of brake horsepower, fuel flow, exhaust gas temperature, and thermal flow rates. The analytical model has demonstrated good correlation with test data throughout a range of engine performance. Author

**A87-45454#**
**WASTE HEAT RECOVERY SYSTEM FOR HIGH ALTITUDE APPLICATION OF LIQUID COOLED, PISTON ENGINES**
N. J. NAGURNY (U.S. Navy, Naval Air Development Center, Warminster, PA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p. refs
(AIAA PAPER 87-2174)

A High Altitude Long Endurance Remotely Piloted Vehicle (HALE RPV) concept is currently being studied by the Naval Air Development Center. Plans are for initial demonstrator vehicles to be powered by two turbocharged, liquid cooled, piston engines. A major objective is to minimize fuel consumption so that the vehicle can stay aloft at greater than 60,000 feet for several days at a time. Waste heat from the engine coolant and turbochargers may drive a reverse Rankine cycle, producing electrical power for the vehicle's radar and avionics. A nonazeotropic refrigerant mixture was selected as the working fluid for this study because it produces a higher cycle efficiency than single refrigerants. The Rankine cycle, with its advantages and disadvantages, is compared with a baseline, direct heat rejection system. When using the cycle during a candidate mission, the vehicle endurance may be increased by up to seven percent. While the waste heat recovery system in this paper is particularly geared for the Navy high altitude RPV, the general principle would be applicable to other vehicles with critical endurance requirements and large heat sources. Author

**A87-45458#**
**DEVELOPMENT OF DIGITAL ENGINE CONTROL SYSTEM FOR THE HARRIER II**
M. J. CAHILL, F. N. UNDERWOOD (McDonnell Aircraft Co., St. Louis, MO), M. S. POPE (Rolls Royce, PLC, Bristol, England), and J. A. CARVER (U.S. Navy, Naval Air Systems Command, Washington, DC) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p.
(AIAA PAPER 87-2184)

The development of a Digital Engine Control System (DECS) for the Harrier II is reviewed. The program included the development of DECS hardware and software, integration of the system into the Harrier II, and flight test evaluation of the system. Major goals were to significantly reduce fuel control maintenance, improve control capability, and maximize aircraft/engine compatibility. Author

**A87-45875#**
**AIRCRAFT ENGINE DESIGN**
JACK D. MATTINGLY, WILLIAM H. HEISER, and DANIEL H. DALEY (U.S. Air Force Academy, Colorado Springs, CO) Research supported by the General Electric Co. and USAF. New York, American Institute of Aeronautics and Astronautics, Inc., 1987, 609 p. refs

The present work, which is based on a design course offered at the U.S. Air Force Academy and serves as a companion text to Oates' (1984) 'Aerothermodynamics of Gas Turbine and Rocket Propulsion', is broadly organized into considerations of engine cycle design and engine component design. Engine cycle design encompasses aircraft/engine system constraint analysis, mission analysis, on- and off-design condition cycle analyses, and the sizing of the engine for a given installed performance. Engine component design gives attention to global and interface qualities, rotating turbomachine considerations, combustion systems, inlets, and exhaust nozzles. O.C.

**A87-46176**
**INTERNATIONAL SYMPOSIUM ON AIR BREATHING ENGINES, 8TH, CINCINNATI, OH, JUNE 14-19, 1987, PROCEEDINGS**
FREDERICK S. BILLIG, ED. (Johns Hopkins University, Laurel, MD) Symposium organized by General Electric Co. and U.S. National Committee; Sponsored by General Electric Co. and International Society for Air Breathing Engines. New York, American Institute of Aeronautics and Astronautics, 1987, 785 p. For individual items see A87-46177 to A87-46262.

The present conference on air-breathing aircraft engine technology considers topics in inlet design, radial-flow turbomachinery, fuel injection and combustion systems, axial flow compressor design and performance, ramjet configurations, turbine flow phenomena, engine control and service life, fluid flow-related problems, engine diagnostic methods, propfan design, combustor performance and pollutant chemistry, combustion dynamics, and engine system analysis. Attention is given to thrust-vectoring systems, supersonic missile air intakes, three-dimensional centrifugal compressors, airblast atomizers, secondary flows in axial flow compressors, axial compressor blade tip clearance flows, hydrogen scramjets with sidewall injection, the performance of a variable-geometry turbine, advanced tip clearance control systems, rotary jet mixing, fan blade aeroelastic behavior, flow dynamics in combustion processes, and the technology of low cost turbomachinery. O.C.

**A87-46179#**
**FUTURE TRENDS - A EUROPEAN VIEW**
S. C. MILLER (Rolls Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 29-40.

A comprehensive aerothermodynamic and economic evaluation of prospective development trends in both military and civilian aircraft airbreathing propulsion systems is presented in view of West European requirements and technology base resources. While future trends in civil propulsion will be primarily determined by direct operating cost reduction criteria, those for military aircraft powerplants will be directed toward significant improvements in thrust/weight ratio and compatibility with multirole mission capabilities. Supersonic cruise without recourse to afterburners is an attractive design goal for both military aircraft and civilian SSTs. V/STOL and hypersonic propulsion possibilities are also assessed. O.C.

**A87-46180#**
**THRUST VECTORING - WHY AND HOW?**
W.-B. HERBST (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, West Germany) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 41-46.

A comprehensive presentation and development status evaluation is undertaken for thrust-vectoring nozzle research programs associated with the F-15 and F-14 fighters in the USA and the ND-102 and X-31A experimental aircraft in Germany. It is noted that the various applications of jet deflection differ significantly; the essential criterion is the direction of jet deflection in either the pitch and/or yaw plane, or all-round. While square-section nozzle configurations are restricted to deflection in only one plane, circular ones are suited to the all-round deflection requirements of fighter aircraft 'supermaneuverability'. O.C.

**A87-46181#**
**IMPROVED AGILITY FOR MODERN FIGHTER AIRCRAFT. II - THRUST VECTORING ENGINE NOZZLES**
H. A. GEIDEL (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, West Germany) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 47-54. refs

A comparison is made of thrust-vectoring axisymmetric and two-dimensional nozzles for different applications. The

axisymmetric vectoring nozzle will permit vectoring with moderate weight penalty; by contrast, the two-dimensional nozzle involves extraordinary weight penalty and considerable construction complexity. These difficulties are nevertheless offset by takeoff- and landing-improving thrust vectoring capabilities. Further nozzle development efforts favor weight reduction by means of nonmetallic, highly refractory composite materials. O.C.

**A87-46190#**
**PERFORMANCE PREDICTION IN A CENTRIFUGAL COMPRESSOR IMPELLER**
M. E. GILL (Cranfield Institute of Technology, Bedford, England) and A. GOULAS (Salonika, University, Greece) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 133-138. refs

The prediction of performance of a centrifugal impeller at design stage is increasingly important to produce more efficient machines and to reduce development costs. The use of a quasi-three-dimensional stream surface method, to provide both velocity and entropy distributions and overall pressure ratio and efficiency, for a centrifugal impeller is described. A correction for the effect of tip clearance losses is included. The predictions, with correction agree well with measured pressure ratio and efficiency, and the velocity profiles show the same features as those measured by laser anemometry. Author

**A87-46212#**
**EXPENDABLE TURBOJET COMPRESSOR DESIGN, TEST AND DEVELOPMENT**
T. W. VON BACKSTROM (Stellenbosch, University, Republic of South Africa) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 331-338. refs

Two prototype compressors for a small, expendable, low cost turbojet were designed, built and tested. The designs were of the axial transonic type, with double-circular-arc rotor blades machined from solid 17-4 PH stainless steel, electron-beam welded integral rotor, externally inserted stator blades clamped by cables, and an unsplit aluminum compressor casing. The first prototype exhibited adequate surge margin for starting and running up to idle, and for slam acceleration from idle to full speed. Peak and full speed efficiencies were 80 and 71 percent. The second prototype had reduced first stage rotor blade camber, and tip clearance of all rotor blades reduced to 0.35 mm instead of 0.5 mm. Peak and full speed efficiencies increased to 0.84 and 0.75. In up to 75 percent design speed tests on a twice-full scale model, compressor peak efficiencies of up to 0.87 were measured. Tests are continuing. Author

**A87-46217*#** Queensland Univ., St. Lucia (Australia).
**HYDROGEN SCRAMJET WITH SIDEWALL INJECTION - SHOCK TUNNEL SIMULATIONS**
R. G. MORGAN, A. PAULL, N. MORRIS, and R. J. STALKER (Queensland, University, St. Lucia, Australia) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987. Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 381-389. NASA-supported research. refs

A free-piston shock tunnel has been used to obtain test data on a scramjet combustion chamber with sidewall injection. The results obtained indicate that combustion was strongly influenced by a region of fuel whose temperature was held below its ignition temperature by wall-cooling effects; this increased the fraction of unburned fuel and resulted in a significant loss of specific impulse. Aerodynamic heating would keep the walls above hydrogen ignition temperature in an actual scramjet powerplant, however. Maximum specific impulse was obtained with a combination of parallel and transverse injection in a long combustion chamber, followed by a dual stage expansion. O.C.

**A87-46218*#** Virginia Polytechnic Inst. and State Univ., Blacksburg.
**DESIGN AND EVALUATION OF A NEW INJECTOR CONFIGURATION FOR SUPERSONIC COMBUSTION**
TIMOTHY C. WAGNER, WALTER F. O'BRIEN (Virginia Polytechnic Institute and State University, Blacksburg), G. BURTON NORTHAM, and JAMES M. EGGERS (NASA, Langley Research Center, Hampton, VA) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 390-397. refs

Ignition and flameholding behavior data are presented from experiments with a novel scramjet injector configuration consisting of five small upstream pilot fuel injectors, a rearward-facing step, and three primary fuel injectors downstream of the step; all injection is perpendicular to the Mach 2 airflow, and the ignition source is located in the recirculation region downstream of the step. The design attempts to minimize the amount of igniter energy required for ignition, but without introduction of the large losses associated with bluff bodies. Argon plasma, argon-hydrogen plasma, pyrophoric silane/hydrogen, and surface-discharge ignition sources are tested. The injector is found to be able to hold flames at 1400 R total temperatures without the use of large bluff bodies; the argon-hydrogen plasma was the most effective igniter. O.C.

**A87-46226#**
**INTEGRATION OF ENGINE/AIRCRAFT CONTROL - 'HOW FAR IS IT SENSIBLE TO GO'**
V. A. FISHER (Rolls Royce, PLC, Bristol, England) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 453-458. Research supported by the Ministry of Defence (Procurement Executive).

A development history is presented for the propulsion control systems of such high performance aircraft as Concorde, at the outset, the 1970s Tornado, and most recently the European Fighter Aircraft full authority digital engine controls. Engine control systems modulate fuel flow for optimum performance; integration aspects of the operation of single and twin engine aircraft are discussed with a view to practical boundaries encountered in hardware that must be marketable over a 10-20 year period. Integration methods based on communications rather than physical joining are recommended. O.C.

**A87-46227#**
**APPLICATION OF A FUZZY CONTROLLER IN FUEL SYSTEM OF TURBOJET ENGINE**
CHI-HUA WU, YUN-HUA XU, and BEN-WEI LI (Northwestern Polytechnical University, Xian, People's Republic of China) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 459-464.

A fuzzy control algorithm designed by the phase-plane method is presently used in the microprocessor-based control system of a turbojet engine. Attention is given to the principles of fuzzy control, a comparison of the phase plane and membership degree fuzzy control system design methods, the microprocessor program's flow chart, and the projected response of a given system for different values of the adjustment parameter. O.C.

**A87-46228*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**INFLUENCE OF THIRD-DEGREE GEOMETRIC NON-LINEARITIES ON THE VIBRATION AND STABILITY OF PRE-TWISTED, PRECONED, ROTATING BLADES**
K. B. SUBRAHMANYAM and K. R. V. KAZA (NASA, Lewis Research Center, Cleveland, OH) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 465-479. Previously announced in STAR as N86-31920. refs

The governing coupled flapwise bending, edgewise bending, and torsional equations are derived including third-degree goemetric

nonlinear elastic terms by making use of the geometric nonlinear theory of elasticity in which the elongations and shears are negligible compared to unity. These equations are specialized for blades of doubly symmetric cross section with linear variation of Pretwist over the blade length. The nonlinear steady state equations and the linearized perturbation equations are solved by using the Galerkin method, and by utilizing the nonrotating normal modes for the shape functions. Parametric results obtained for various cases of rotating blades from the present theoretical formulation are compared to those produced from the finite element code MSC/NASTRAN, and also to those produced from an in-house experimental test rig. It is shown that the spurious instabilities, observed for thin, rotating blades when second degree geometric nonlinearities are used, can be eliminated by including the third-degree elastic nonlinear terms. Furthermore, inclusion of third degree terms improves the correlation between the theory and experiment. M.G.

**A87-46239#**
**INVESTIGATION ON THE STALL MARGIN OF A TURBOFAN ENGINE**

R. QUERZOLI and A. SBUTTONI (Aeritalia S.p.A., Gruppo Velivoli da Combattimento, Turin, Italy) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 561-567.

The stall margin of twin-spool, mixed flow turbofan engines, and the effect exerted upon it by such factors as installation effects and off-schedule engine controls, are presently assessed by ground tests. High pressure stall lines were identified with the 'in-bleed' method. Aircraft accessory loads are noted to influence the steady-state working line, but do not significantly affect the surge margin during transients. High pressure air bleeds are very effective in lowering both the steady state and the transient working line. The engine is virtually insensitive to inlet air distortion over the investigated speed range. O.C.

**A87-46240#**
**J85 SURGE TRANSIENT SIMULATION**

Y. SUGIYAMA (Japan Defense Agency, Technical Research and Development Institute, Tokyo), W. TABAKOFF, and A. HAMED (Cincinnati, University, OH) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 568-578. refs

Surge transient flow phenomena and unsteady compressor operating-point excursion during surge in J85 turbojet engine, are analyzed using a one-dimensional model which is capable of simulating surge disturbance propagations throughout an entire turbojet engine. Unknown stalled compressor stage characteristics are represented by parameters and predicted through the parametric study in such a way that the overall computed results must agree with surge data, such as hammer over-pressures at the compressor face and reduced burner-pressures. The prediction resulted in the stalled characteristics with faster responses and larger pressure-ratio deterioration compared to low speed compressors. Surge hammer over-pressures are found to have a triangle shape in time-space (engine axis) domain. Different stall methods result in different compressor operating-point excursion, in which mass flows through compressor reduce to almost zero in roughly 10 to 20 milliseconds, and thus affect surge transient flow phenomena such as levels of peak hammer over-pressures at the intake duct and high temperatures in the compressor.

Author

**A87-46246#**
**EROSION PROBLEM OF AXIAL COMPRESSOR BLADES OF A TURBOSHAFT ENGINE**

R. V. NARAYANA MURTHY, V. UNNIKRISHNAN, B. G. AMARNATH (Defence Ministry, Resident Technical Office /Engines/, Bangalore, India), and K. SRINIVASA IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 619-626. refs

An account is given of the axial compressor blade erosion problem encountered during the operation of a single-engine helicopter in a severe, sandy environment, with attention to cases of excessive sand erosion at the blade root which led to a reduction in natural frequency and an increase in fatigue damage due to vibratory resonance. The sand ingestion test requirements in airworthiness specifications emphasize the evaluation of performance loss and stability deterioration; more stringent precertification test requirements for the demonstration of sand erosion resistance are recommended. O.C.

**A87-46247#**
**PROPFAN PROPULSION SYSTEM DEVELOPMENT**

A. S. NOVICK, R. E. RIFFEL (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and C. N. REYNOLDS (Pratt and Whitney, East Hartford, CT) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 629-634.

The Propfan propulsor provides the propulsive efficiency of contemporary propellers while achieving the 0.8 Mach cruise capability of modern turbofan engines. Characteristics of Propfan propulsion systems present unique choices for designers. This paper identifies advantages of the Propfan engine, assesses configurations and their integration with commercial and military aircraft, and describes two Propfan flight test programs. Author

**A87-46248#**
**MECHANICAL EVALUATION OF THE AEROELASTIC BEHAVIOUR OF A FAN BLADE**

J. L. LECORDIX (SNECMA, Villaroche, France), B. VINCENT, and R. HENRY (Lyon, Institut National des Sciences Appliquees, Villeurbanne, France) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 635-645. refs

This paper deals with the prediction of the aeroelastic stability of bladed axisymmetric systems. All the aerodynamic/mechanical couplings are taken into account over the full blade span. The structure consists of twisted blades, modeled by special beam elements, including predominant effects such as bending - bending and bending - torsion coupling. The unsteady supersonic airflow is determined at several airfoils sections along the span and the unsteady nodal forces are calculated. Modal reduction and solution of the aeroelastic system are established. The developed method and the associated computed program is applied to the analysis of aeroelastic stability of a rotating advanced wide chord unshrouded fan blade. The influence of the main aeroelastic parameters are examined in order to find an efficient method capable of delivering accurate solutions at a reasonable price.

Author

**A87-46249*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**AEROELASTIC CONTROL OF STABILITY AND FORCED RESPONSE OF SUPERSONIC ROTORS BY AERODYNAMIC DETUNING**
DANIEL HOYNIAK (NASA, Lewis Research Center, Cleveland, OH) and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 646-658. refs

Aerodynamic detuning, defined as designed passage-to-passage differences in the unsteady aerodynamic flow field of a rotor blade row, is a new approach to passive flutter and forced response control. In this paper, a mathematical model for aerodynamic detuning is developed and utilized to demonstrate the aeroelastic stability enhancement due to aerodynamic detuning of supersonic blade rows. In particular, a model is developed to analyze both the torsion mode and the coupled bending-torsion mode unstalled supersonic flutter and torsion mode aerodynamically forced response characteristics of an aerodynamically detuned rotor operating in a supersonic inlet flow field with a subsonic leading edge locus. As smalll solidity variations do not have a dominant effect on the steady-state performance of a rotor, the aerodynamic detuning mechanism considered is nonuniform circumferential spacing of adjacent blades. Author

**A87-46253#**
**EXHAUST CARBON - THE EFFECTS OF FUEL COMPOSITION**
D. KRETSCHMER and J. ODGERS (Universite Laval, Quebec, Canada) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 687-693. Research supported by the Federal Panel on Energy and DND. refs

Details are given of a series of experiments to determine the carbon (smoke) content of the exhaust of a small aircraft-type combustor tested with a range of commercially pure hydrocarbon compounds. The results are then correlated using a modified version of an equation developed some time ago within these laboratories. If a reference datum is supplied the correlation may be used to predict what happens as conditions and/or fuels are changed within any given combustor but for general prediction purposes the correlation is not very satisfactory since the quantity of exhaust carbon is also a function of combustor air distribution and geometry. Author

**A87-46255#**
**NUMERICAL SIMULATION OF DIFFUSOR/COMBUSTOR DOME INTERACTION**
D. JEANDEL, G. BRUN (Lyon, Ecole Centrale, Ecully, France), S. MEUNIER, and M. DESAULTY (SNECMA, Villaroche, France) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 702-709. refs

Precise knowledge of the aerodynamic field over the cowls on a combustor dome is essential to reach satisfactory performance. A stairstep technique gives a poor description of the geometry. To circumvent this drawback a finite-element method is described in this paper. In addition of its ability to cope with fairly complex configurations, a special treatment of the boundary conditions makes a two-dimensional calculation of the flow around a combustor and prediction of the flow-split in the various orifices possible. Examples of calculated results for typical modern annular combustors are given. Comparisons with experimental data show good predictions of wall static pressures and aerodynamic flow split. Author

**A87-46258*#** Queensland Univ., Brisbane (Australia).
**PRESSURE SCALING EFFECTS IN A SCRAMJET COMBUSTION CHAMBER**
R. G. MORGAN and R. J. STALKER (Queensland, University, Brisbane, Australia) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 730-736. NASA-supported research. refs

The test results obtained for a model scramjet over a range of pressure levels corresponding to different flight altitudes involve enthalpies that vary from the ignition limit, at the low temperature end, to temperatures where the dissociation of combustion products severely limits heat release. The minimum temperature is noted to be highly pressure-sensitive; above the ignition limit, the amount of heat release increased markedly with pressure and with combustion chamber length. A FEM computer code has been used to model the mixing and combustion processes. O.C.

**A87-46261#**
**ADVANCES IN TECHNOLOGY FOR LOW COST TURBOMACHINERY - A POTENTIAL TO ENHANCE THE ECONOMY OF FUTURE PROPULSION SYSTEM FOR GENERAL AND HELICOPTER AVIATION**
UWE DAMMEL (KHD Luftfahrttechnik GmbH, Oberursel, West Germany) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 753-757.

The design criteria presently investigated for application to the small to medium-sized gas turbine engines used by general aviation aircraft and helicopters (as either primary powerplants or auxiliary power units) are oriented toward cost reduction at optimal performance levels. A number of advancements are achieved by this design process on the basis of improved aerodynamic, thermodynamic, and mechanical factors. Attention is given to component-count minimization, short-length centrifugal compressor diffusers, simplified combustion chambers, air bearings, and homopolar alternators. O.C.

**A87-46262#**
**A STUDY ON THE OPTIMIZATION OF JET ENGINES FOR COMBAT AIRCRAFTS**
C. SANCHEZ TARIFA and E. MERA DIAZ (Escuela Tecnica Superior de Ingenieros Aeronauticos, Madrid, Spain) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 758-762.

The optimization of jet engines for combat aircraft is discussed. This optimization is referred to the selection of the values of the engine fan pressure ratio or by-pass ratio, maximum turbine inlet temperature, overall pressure ratio, and maximum reheat temperature: which optimize the specific fuel consumption and the ratio of the thrust to the nozzle throat area (assuming this last parameter to be an indicative of the thrust/weight ratio). The selection is carried out taking into account the aircraft missions for which the engine design is optimized. Author

**A87-46372**
**V.2500 - BACK ON COURSE?**
JULIAN MOXON Flight International (ISSN 0015-3710), vol. 131, June 13, 1987, p. 101-105.

The V.2500 turbofan engine, a 25,000-lb thrust class powerplant intended for the A320 airliner, is being developed by a seven-company, five-nation consortium in order to compete with the CFM56-5 engine after its service entry date of April, 1989. Consortium spokesmen maintain that the V.2500's fuel consumption will be 7-8 percent lower than that of the CFM56-5. Attention is given to difficulties with the high pressure compressor that compelled the reduction of its pressure rise from 22:1 to 18:1. A cut-away drawing is included. O.C.

**N87-25323*#** Garrett Turbine Engine Co., Phoenix, Ariz.
**COMPOUND CYCLE ENGINE FOR HELICOPTER APPLICATION**
JERE G. CASTOR 25 Apr. 1986 12 p
(Contract NAS3-24346; DA PROJ. 1L1-61102-AH-45)
(NASA-CR-175110; NAS 1.26:175110; AD-A180007; USAAVSCOM-TR-86-C-15) Avail: NTIS HC A02/MF A01 CSCL 21E

The Compound Cycle Engine (CCE) is a highly turbocharged, power compounded, ultra-high power density, light-weight diesel engine. The turbomachinery is similar to a moderate pressure ratio, free power turbine engine and the diesel core is high speed and a low compression ratio. This engine is considered a potential candidate for future military light helicopter applications. This executive summary presents cycle thermodynamic (SFC) and engine weight analyses performed to establish general engine operating parameters and configuration. An extensive performance and weight analysis based on a typical two hour helicopter (+30 minute reserve) mission determined final conceptual engine design. With this mission, CCE performance was compared to that of a T-800 class gas turbine engine. The CCE had a 31% lower-fuel consumption and resulted in a 16% reduction in engine plus fuel and fuel tank weight. Design SFC of the CCE is 0.33 lb-HP-HR and installed wet weight is 0.43 lbs/HP. The major technology development areas required for the CCE are identified and briefly discussed. GRA

**N87-25326#** Ecole Polytechnique Federale de Lausanne (Switzerland). Lab. de Thermique Appliquee.
**AEROELASTICITY IN TURBOMACHINES COMPARISON OF THEORETICAL AND EXPERIMENTAL CASCADE RESULTS. APPENDIX A5: ALL EXPERIMENTAL AND THEORETICAL RESULTS FOR THE 9 STANDARD CONFIGURATIONS Final Report, 2 May 1984 - 1 Nov. 1985**
A. BOELCS and T. H. FRANSSON 1986 422 p
(Contract AF-AFOSR-0105-84)
(AD-A180534; AFOSR-87-0605TR-APP-A-5) Avail: NTIS HC A18/MF A01 CSCL 20D

Reliable, efficient methods are needed for calculating unsteady blade forces in turbomachines. The validity of such theoretical or empirical prediction models can be established only if their flutter and forced vibration predictions are applied to a number of well documented experimental test cases. In this report, the geometrical and time average flow conditions of nine two dimensional and quasi-three dimensional experimental (mainly) standard configurations for aeroelasticity in turbomachine cascades are given. Some aeroelastic test cases are defined for each configuration, comprising different incidence angles, Mach numbers, interblade phase angle, reduced frequencies, etc. The comparative investigation has shown that present theoretical models can predict accurately the aeroelastic behavior of certain cascade configurations in two dimensional flow. Other configurations cannot be predicted as well. It is concluded that, although present methods can predict stability limits in some cases, the physical reasons for flutter in cascades are not yet fully understood. GRA

**N87-26009*#** Pratt and Whitney Aircraft, East Hartford, Conn. Engineering Div.
**APPLICATION OF CFD CODES TO THE DESIGN AND DEVELOPMENT OF PROPULSION SYSTEMS**
W. K. LORD, G. F. PICKETT, G. J. STURGESS, and H. D. WEINGOLD *In* NASA. Ames Research Center, Supercomputing in Aerospace p 139-148 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 21E

The internal flows of aerospace propulsion engines have certain common features that are amenable to analysis through Computational Fluid Dynamics (CFD) computer codes. Although the application of CFD to engineering problems in engines was delayed by the complexities associated with internal flows, many codes with different capabilities are now being used as routine design tools. This is illustrated by examples taken from the aircraft gas turbine engine of flows calculated with potential flow, Euler flow, parabolized Navier-Stokes, and Navier-Stokes codes. Likely future directions of CFD applied to engine flows are described, and current barriers to continued progress are highlighted. The potential importance of the Numerical Aerodynamic Simulator (NAS) to resolution of these difficulties is suggested. Author

**N87-26044*#** Texas A&M Univ., College Station. Engineering Experiment Station.
**MEASUREMENT OF THE EFFECT OF MANUFACTURING DEVIATIONS ON NATURAL LAMINAR FLOW FOR A SINGLE ENGINE GENERAL AVIATION AIRPLANE Final Report**
Feb. 1987 118 p
(Contract NAG1-309)
(NASA-CR-180671; NAS 1.26:180671; AERO-TR-87-2) Avail: NTIS HC A06/MF A01 CSCL 21G

Renewed interest in natural laminar flow (NLF) had rekindled designer concern that manufacuring deviations may destroy the effectiveness of NLF for an operational aircraft. Experiments are summarized that attemtped to measure total drag changes associated with three different wing surface conditions on an aircraft typical of current general aviation high performance singles. The speed power technique was first used in an attempt to quantify the changes in total drag. Predicted and measured boundary layer transition locations for three different wing surface conditions were also compared, using two different forms of flow visualization. The three flight test phases included: assessment of an unpainted airframe, flight tests of the same aircraft after painstakingly filling and sanding the wings to design contours, and similar measurement after this aricraft was painted. In each flight phase, transition locations were monitored using with sublimating chemicals or pigmented oil. Two-dimensional drag coefficients were estimated using the Eppler-Somers code and measured with a wake rake in a method very similar to Jones' pitot travers method. The net change in two-dimensional drag coefficient was approximately 20 counts between the unpainted aircraft and the hand-smoothed aircraft for typical cruise flight conditions. Author

**N87-26835** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.
**INTEGRATION OF THE PROPFAN CONCEPT IN AIRCRAFT DESIGN [PROPFAN-INTEGRATION IM FLUGZEUGENTWURF]**
HANS GEORG SCHULZ *In its* Research and Development. Technical-Scientific Publications 1986 p 99-106 1986 In GERMAN Presented at the 4th BMFT-Statusseminar, Munich, West Germany, 28-30 Apr. 1986
(MBB-UT-0001/86) Avail: Issuing Activity

The efforts and costs involved in the integration of the propfan (free-rotating fans) concept in aircraft design are discussed. The prospects of fuel saving due to the propfan integration are presented. The limitations of designs including propfan concepts, and the effects of propulsion systems parameters on the aircraft configuration are discussed. Two basic concepts, one with contrarotating propfan propulsion systems at the airfoil, the second with propulsion systems at the fuselage, were compared. An economic analysis of propfan concepts as compared to turbofan concepts is presented. ESA

# 08

# AIRCRAFT STABILITY AND CONTROL

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

**A87-43405#**
**SIMULATOR EVALUATIONS OF INCEPTORS FOR ACT HELICOPTERS**
C. P. MASSEY (Westland Helicopters, Ltd., Yeovil, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p. refs

Two 3-axis inceptors have been used in ground simulation trials at RAE Bedford during which approximately seventy hours of trials were flown by four primary evaluation pilots. Both inceptors were used as 2-axis as well as 3-axis controllers and systematic evaluations of inceptor forces and control signal shaping were performed. Objective measurements of performance and workload were taken and the pilots were asked to rate various aspects of their task performance as well as rating the system in use. Statistical analysis of these results has shown the benefits of control signal shaping and that the 2-axis configuration has performance advantages but no subjective preference compared with the 3-axis configuration. Guidance towards preferred feel forces has also been gained. The trials procedure has proved successful in producing results in which a high degree of confidence can be placed. Author

**A87-43428*#** Princeton Univ., N. J.
**STABILITY AND CONTROL MODELLING**
H. C. CURTISS, JR. (Princeton University, NJ) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p. refs
(Contract NAG2-244)

This paper discusses the influence of rotor dynamics and dynamic inflow on the stability and control characteristics of single rotor helicopters in near hovering flight. Body attitude and rate feedback gain limitations which arise due to rotor dynamics and dynamic inflow are discussed. It is shown that attitude feedback gain is limited primarily by body-flap coupling and rate gain is limited by the lag degrees of freedom. Dynamic inflow is shown to produce significant changes in the modes of motion. Author

**A87-43429#**
**STUDY OF THE DYNAMIC RESPONSE OF HELICOPTERS TO A LARGE AIRPLANE WAKE**
SHIGERU SAITO (National Aerospace Laboratory, Tokyo, Japan), AKIRA AZUMA, KEIJI KAWACHI, and YOSHINORI OKUNO (Tokyo, University, Japan) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 23 p. refs

A numerical simulation of helicopter flight dynamics is performed in order to get the dynamic characteristics of helicopters which encounter a pair of trailing vortices from a large aircraft such as a jumbo jet. Two types of helicopter rotor (articulated and hingeless) are analyzed to make clear the effects of geometrical configuration of helicopter, rotorblade stiffness, and flight condition on the helicopter dynamic responses. The rotor aerodynamic forces, which are fully coupled to the body motion with six degrees of freedom, are calculated by using the local-momentum theory (Azuma and Kawachi, 1979). The time histories of the dynamic behavior of the helicopter and the blade motion are presented for various parameters, such as the distance between helicopter and large aircraft, the type of helicopter rotor, and the flight path angle with respect to the tip vortices of the large aircraft. The dynamic response of the helicopter is generally moderate in comparison with that of the aircraft. The most severe response is in the vertical direction, with almost 2 g load level, and the flight path follows the shape of the vertical gust. The change of the attitude of the helicopter depends on the flight conditions when the helicopter just hits the vortex core. Author

**A87-43430#**
**HELICOPTER RESPONSE TO AN AIRPLANES'S VORTEX WAKE**
GUNJIT SINGH BIR, INDERJIT CHOPRA (Maryland, University, College Park), and KI-CHUNG KIM DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 23 p. refs
(Contract DOT-RS57-85-C-00105)

An analytical formulation is developed for studying the rotor-fuselage system response to an airplane's trailing vortex field. The blades are modeled as elastic beams undergoing flap bending, lag bending and torsional deflections. The fuselage is modelled as a rigid body with five degrees of freedom: longitudinal, lateral, vertical, roll and pitch. Quasisteady strip theory is used to obtain aerodynamic forces, and a dynamic inflow model is used to include the wake-induced unsteady effect. Dynamic stall and reverse flow effects are also included. The coupled rotor-fuselage equations are linearized about the vehicle trim state and the blade steady-state deflected position, and then solved by a numerical time-integration technique. Dynamic response results are determined in terms of blade deflections, blade stresses, rotor disk tilts, and hub loads and moments. Results are calculated for four cases of vortex encounters: hovering helicopter with vortex axis aligned with hub center: hovering helicopter with descending vortex at 16 ft/sec; helicopter flies along vortex axis; and helicopter flies across a two vortex system. For the vortex model, a fresh wake of a B-747 airplane is used and the response is calculated for typical helicopters including hingeless, articulated and teetering rotors. Author

**A87-43432#**
**AN ANALYTIC METHOD OF QUANTIFYING HELICOPTER AGILITY**
D. G. THOMSON (Glasgow, University, Scotland) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 21 p. refs

This paper outlines a method of measuring the inherent agility (i.e., the agility of the aircraft alone) of a helicopter configuration. The method is based on inverse solutions of the equations of motion and standard performance-measurement techniques. Inverse solutions can be found for a helicopter performing a family of maneuvers within specified limits. An agility performance index is given for each maneuver, forming an agility surface covering this set of limits. An agility rating is then calculated as the volume under the surface. This agility rating corresponds to a single configuration over a single class of maneuver. Other configurations can then be tested over the same maneuvers for comparison. The method is illustrated by comparing the agility of three helicopter configurations (transport, battlefield, and agile) over a series of standard maneuvers. Author

**A87-43433#**
**OBSERVATIONS OF PILOT CONTROL STRATEGY IN LOW LEVEL HELICOPTER FLYING TASKS**
G. D. PADFIELD, M. T. CHARLTON, S. S. HOUSTON (Royal Aircraft Establishment, Bedford, England), H.-J. PAUSDER, and D. HUMMES (DFVLR, Institut fuer Flugmechanik, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 27 p. refs

A series of task-oriented flight test techniques has been developed for flying qualities research with highly augmented helicopters. These techniques encompass task definition, flight testing, debriefing, and task analysis. The 'circle' maneuver has been introduced as a task for the exploration of pilot control strategy and hence of flying qualities associated with precise flight path control at high bank angles. Tests have been conducted with instrumented Puma and BO-105 aircraft involving low level tracking of ground-marked courses. The results presented are derived from

the correlation of pilot opinion with the results of analyses of both performance and pilot control activity. O.C.

**A87-43435#**
**AN ADVANCED MATHEMATICAL MODEL FOR HELICOPTER FLIGHT SIMULATION USING NONLINEAR UNSTEADY AERODYNAMICS**
ULRICH LEISS and SIEGFRIED WAGNER (Muenchen, Universitaet der Bundeswehr, Munich, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p. refs
(Contract BMFT-LFF-83408)

A new mathematical model was formulated for application to a wide variety of helicopter configurations. Quaternions and Euler transformations describe the extended degrees of freedom. Aerodynamic coefficients were expressed in analytical form. Thus, blade elements were eliminated by analytical integration in the radial direction. A new approach to inflow and three-dimensional effects was included. Viscous and nonviscous unsteady effects were formulated separately for pitch, plunge, yaw, and fore-and-aft motion. Separated and reverse flow can be evaluated at high advance ratios and heavily loaded rotors. The application of the new model leads to improved numerical stability and accuracy. Computation time decreases significantly. New effects can be analyzed for isolated rotors or complete helicopters. Author

**A87-43436#**
**THE INFLUENCE OF THE INDUCED VELOCITY DISTRIBUTION AND THE FLAPPING-LAGGING COUPLING ON THE DERIVATIVES OF THE ROTOR AND THE STABILITY OF THE HELICOPTER**
XIN-YU XU and REN-LIANG CHANG (Nanjing Aeronautical Institute, People's Republic of China) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 25 p. refs

The first-harmonic variation of the induced velocity distribution derived by Wang's (1981) generalized vortex theory is invoked in the present discussion of the coupling of the first flapping-lagging-bending mode of helicopter rotor blade elasticity. Sample calculations are presented for a generic helicopter, with attention to the induced velocity distribution and the coupling flapping-lagging of the rotor derivatives and helicopter stability. All basic expressions of the mechanics of a hingeless rotor are given. O.C.

**A87-43440#**
**REALIZATION AND FLIGHT TESTING OF A MODEL FOLLOWING CONTROL SYSTEM FOR HELICOPTERS**
G. BOUWER and M. ZOELLNER (DFVLR, Institut fuer Flugmechanik, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 14 p. refs

The realization of a designed model following-control system on a BO 105 fly-by-wire helicopter is described. A multi-computer system performs the numerous tasks of the in-flight simulation facility. Different displays and flight-test parameters can be easily selected by the simulation pilot. High system capability is achieved by supporting simulation software for different applications. The possibility of real-time ground simulation with the helicopter and the flight test crew allows effective flight-test preparation. Extensive test-data analysis software enables the user of the in-flight simulator to analyze the tests quickly. Flight-test results demonstrate the high effectiveness of the helicopter in-flight simulation. Author

**A87-43441#**
**THE MODEL INVERSE AS AN ELEMENT OF A MANOEUVRE DEMAND SYSTEM FOR HELICOPTERS**
H. LEYENDECKER (DFVLR, Brunswick, West Germany) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p.

A method for the design of flight-control systems for plants with highly coupled dynamics is presented. It exploits the so-called integral inverse as an essential element of the control concept. The method is illustrated with an application to a BO 105 helicopter equipped with a digital FBW system. Results of flight tests are presented. Author

**A87-43446*#** Massachusetts Inst. of Tech., Cambridge.
**HELICOPTER INDIVIDUAL-BLADE-CONTROL RESEARCH AT MIT 1977-1985**
NORMAN D. HAM (MIT, Cambridge, MA) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 10 p. NASA-sponsored research. Previously announced in STAR as N86-28954. refs

A new advanced system for active control of helicopters and its application to the solution of rotor aerodynamic and aeroelastic problems is described. Each blade is individually controlled in the rotating frame over a wide range of frequencies. Application of the system to gust alleviation, attitude stabilization, vibration alleviation, blade lag damping augmentation, stall flutter suppression, blade flapping stabilization, stall alleviation, and performance enhancement is outlined. The effectiveness of the system in achieving most of these applications is demonstrated by experimental results from wind tunnel tests of a model helicopter rotor with individual blade control. The feasibility of achieving many or all of the applications of individual blade control using the conventional helicopter swash plate is demonstrated, and the necessary control laws are presented. Author

**A87-43447#**
**DEVELOPMENT OF AN EXPERIMENTAL SYSTEM FOR ACTIVE CONTROL OF VIBRATIONS ON HELICOPTERS**
MARC ACHACHE and MICHEL POLYCHRONIADIS (Aerospatiale, Division Helicopteres, Marignane, France) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 11 p. refs

A research program sponsored by French government agencies has been conducted to develop an experimental system for active control of vibrations through higher-harmonic controls applied to the main rotor blades. All system-development phases are presented within the framework of an airborne-system design and development methodology. The various stages prior to flight experiments are dealt with, from the theoretical modeling of the helicopter vibratory behavior under higher-harmonic control up to the integration of the system on a rotor test rig. The flight-test campaign conducted at Marignane in 1985 on an SA 349 validated the concept for reducing vibrations through a closed-loop self-adaptive system within the whole SA 349 helicopter flight envelope. In addition to the very important reductions of vibrations obtained from three different algorithms (80 percent as an average in the cabin at 250 km/h), this test campaign showed the efficiency of a test methodology focused on the representativity of an off-line simulation. Author

**A87-43448*#** Princeton Univ., N. J.
**KINEMATIC OBSERVERS FOR ACTIVE CONTROL OF HELICOPTER ROTOR VIBRATION**
ROBERT M. MCKILLIP, JR. (Princeton University, NJ) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 17 p. Research supported by the Engineering Foundation and NASA. refs

A simple scheme for estimating the state variables of a helicopter rotor is presented. The method incorporates the use of blade-mounted accelerometers and/or position transducers to reconstruct modal displacements and velocities. The design of the observer structure and feedback gains is simplified by the fact that the method requires only knowledge of basic kinematic relationships between the various modal quantities. The observer structure described is particularly well-suited to control problems where the use of a traditional Kalman Filter approach would be too complex or costly. The technique can be viewed as decreasing the requirements on observer complexity while increasing the need for an enhanced sensor complement. Author

**A87-43457#**
**EXPERIENCE WITH FREQUENCY-DOMAIN METHODS IN HELICOPTER SYSTEM IDENTIFICATION**
C. G. BLACK, D. J. MURRAY-SMITH (Glasgow, University, Scotland), and G. D. PADFIELD (Royal Aircraft Establishment, Bedford, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 27 p. refs
(Contract MOD-2048/028/XR/STR)

Most applications of system identification techniques to helicopters have involved time-domain methods using reduced-order mathematical models representing six-degree-of-freedom rigid-body motion. Frequency-domain techniques provide an interesting alternative approacch in which data which lies outside the frequency range of interest may be disregarded. This not only provides a basis for establishing reduced order models which are valid over a defined range of frequencies but also results in a significant data reduction in comparison with time-domain methods. This paper presents a systematic approach to frequency-domain identification using both equation-error and output-error techniques. Results are presented from flight data from the Puma helicopter to illustrate the application of the frequency-domain approach to the estimation of parameters of the pitching moment and normal force equations. These results are assessed both on a statistical basis and through comparisons with theoretical values. Author

**A87-43458#**
**HELICOPTER MODEL IN FLIGHT IDENTIFICATION BY A REAL TIME SELF ADAPTIVE DIGITAL PROCESS**
A. DANESI and F. FELICIANI (Roma I, Universita, Rome, Italy) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 7 p.

A feasibility evaluation of an airborne electronic device that automatically identifies helicopter transfer functions is presented. The helicopter frequency response to the impulse response flight test data is computed by a dedicated microprocessor. The software implements an adaptive algorithm that matches a preselected helicopter frequency model with the computed frequency response. This yields the best linearized model approximation to the actual system transfer function. For the selected set of state and control variables, the corresponding numerator and denominator polynomial transfer functions are computed in real time. The basic theory of the adaptive strategy and identificator unit implementation are described in the paper. The simulation results prove the feasibility of the inflight identification digital process as a useful tool in solving helicopter stability and control problems. Author

**A87-44254*** Rice Univ., Houston, Tex.
**MAXIMUM SURVIVAL CAPABILITY OF AN AIRCRAFT IN A SEVERE WINDSHEAR**
A. MIELE, T. WANG (Rice University, Houston, TX), W. W. MELVIN (Delta Air Lines, Inc., Atlanta, GA), and R. L. BOWLES (NASA, Langley Research Center, Hampton, VA) Journal of Optimization Theory and Applications (ISSN 0022-3239), vol. 53, May 1987, p. 181-217. Research supported by Boeing Commercial Airplane Co. refs
(Contract NAG1-516)

The performance of constant-alpha, maximum-alpha, constant-velocity, constant-absolute-inclination, constant-climb-rate, and constant-pitch (CP) vertical-plane guidance schemes for aircraft taking off under horizontal-windshear conditions with a downdraft is compared by means of numerical simulations; the results are presented in tables and graphs, and it is found that CP guidance gives the best aircraft survivability. Optimal, gamma-guidance, and simplified-gamma trajectories are then evaluated to improve the performance of CP, and the correct selection of the feedback gain coefficient and the time delay for response to windshear onset is shown to be of great importance for maximizing survivability. T.K.

**A87-44328#**
**EXTREME ATMOSPHERIC TURBULENCE [PRESENTATION DES TURBULENCES ATMOSPHERIQUES EXTREMES]**
GABRIEL COUPRY (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Meeting, 63rd, Athens, Greece, Sept. 28-Oct. 3, 1986) ONERA, TP, no. 1987-8, 1987, 9 p. In French. refs
(ONERA, TP NO. 1987-8)

A model of extreme atmospheric turbulence is proposed based on five years of commercial flight data for events with load factors in excess of 0.5. The Pratt formula is found to lead to incoherent atmospheric descriptions, while the Hall formula, with appropriate choice of scale, is found to lead to a coherent turbulence description which is relatively independent of the type of aircraft considered. For strong turbulences, the average number of overshoots by a nautical mile are found to decrease exponentially with gust amplitude. The incidences of gusts exceeding a threshold value are found to obey a Poisson distribution whose mean decreases exponentially with amplitude, indicating that the probability of the occurrence of big gusts can be represented by Gumbel's extreme value theory. R.R.

**A87-45096#**
**AN APPROACH TO THE SYNTHESIS OF AN ADAPTIVE FLIGHT CONTROL SYSTEM WITH INCOMPLETE INFORMATION**
KIMIO KANAI and SIGERU UCHIKADO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 399, 1987, p. 214-220. In Japanese, with abstract in English. refs

The change of flight condition leads to variation in an aircraft's parameters. It can also vary the order of the numerator in the pulse-transfer function of such an aircraft. This means, in the discrete-time case, a change in the time delay. It is difficult under these circumstances to maintain the performance of an aircraft with conventional control methods. Here, as an alternative scheme, an adaptive flight control system is proposed which can be used for aircraft with unknown time delay and parameters. By introducing a polynomial identity based on the upper bound on time delay, the control system can be synthesized simply, in spite of the unknown time delay, as in standard model-reference adaptive-control systems. Simulation studies are carried out for small high-performance aircraft to substantiate the analytical work. Author

**A87-45097#**
**DESIGN OF CCV FLIGHT CONTROL SYSTEM OF STOL FLYING BOAT**
KIMIO KANAI, SIGERU UCHIKADO, and YOSHIKAZU MORITA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 399, 1987, p. 221-228. In Japanese, with abstract in English. refs

A control-configured-vehicle (CCV) approach to the flight control of an STOL amphibian aircraft during approach and sea landing (as in rescue operations) is developed analytically and demonstrated by means of numerical simulations. The problems imposed by low-speed approach and the inadequacy of simple automatic throttle control are discussed; the basic principles and implementation of the CCV system are outlined; and the simulation results are presented graphically. T.K.

**A87-45306#**
**VALIDATION OF AN INTEGRATED FLIGHT AND PROPULSION CONTROL DESIGN FOR FIGHTER AIRCRAFT**
PETER D. SHAW, KARL R. HAIGES (Northrop Corp., Aircraft Div., Hawthorne, CA), and CHARLES A. SKIRA (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 14 p. USAF-sponsored research. refs
(AIAA PAPER 87-1928)

An integrated control design methodology has been developed for flight and propulsion control of a fighter aircraft. The approach is one that emphasizes the practical design issues of integrated control. It involves partitioning of the problem into smaller, more conventional design tasks, affording much greater physical insight.

It provides a framework within which specialists in each discipline can apply their experience in the design process. Its structure also readily accommodates nonlinear effects that must be factored into any practical design. A thorough evaluation of the resulting control law has been conducted via digital and piloted simulation. This paper focuses on the results of that evaluation, with particular emphasis placed upon the highly coupled aspects of the flight and propulsion control systems. Performance payoffs are demonstrated in the landing phase of flight and at the limits of the air combat regime. Author

**A87-45307#**
**PERFORMANCE SEEKING CONTROL FOR CRUISE OPTIMIZATION IN FIGHTER AIRCRAFT**
ERIC J. TICH, PETER D. SHAW (Northrop Corp., Aircraft Div., Hawthorne, CA), DONALD F. BERG, SHRIDER ADIBHATLA, JERRY A. SWAN (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) et al. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 15 p. USAF-sponsored research. refs
(AIAA PAPER 87-1929)

An indirect adaptive control algorithm has been developed to minimize fuel flow consumption for an integrated aircraft/engine system in both subsonic and supersonic cruise operation. The algorithm utilizes onboard models of the aircraft and engine, with tracking logic to identify and account for any differences between the engine model and the true engine cycle. A constrained numerical optimization technique is used with the onboard models to identify trim control sets that provide a fuel flow reduction. Revised trim solutions are transmitted to the plant as incremental changes to the scheduled control positions, with the aircraft and engine control systems responding to the adjustments through normal control operation. The adaptive control algorithm is modelled within a high fidelity, six-degree-of-freedom aircraft/engine simulation incorporating advanced fighter aircraft features. This paper presents study results showing both potential and actual performance benefits from the adaptive algorithm, as well as its sensitivity to off-nominal variations. Author

**A87-46315**
**DVI IN THE MILITARY COCKPIT - A THIRD HAND FOR THE COMBAT PILOT**
BRIAN WANSTALL Interavia (ISSN 0020-5168), vol. 42, June 1987, p. 655, 656, 659, 660.

Voice warning systems are already in service, and advancements in both hardware and software development promise usable automatic speech recognition (ASR) systems for next-generation combat aircraft and battlefield helicopters. Direct voice input (DVI) ASR systems have been specified for next-generation NATO fighters and combat helicopters, with the aim of reducing overall workload and stress levels. Noise, g-levels and pressurized breathing, however, militate against the easy incorporation of DVI; verification or feedback of the voice commands in some yet to be defined form is noted to be vital for successful combat use. O.C.

**A87-46767#**
**BOUNDED RANDOM OSCILLATIONS - MODEL AND NUMERICAL RESOLUTION FOR AN AIRFOIL**
F. POIRION (ONERA, Chatillon-sous-Bagneux, France) (IUTAM, Symposium on Nonlinear Stochastic Dynamical Engineering Systems, Innsbruck, Austria, June 21-26, 1987) ONERA, TP, no. 1987-73, 1987. 10 p.
(ONERA, TP NO. 1987-73)

A method of simulating bounded random oscillations arising in a simple two-dimensional case of a flexible aircraft flying in a turbulent wind is demonstrated and compared to results from two more elaborate numerical methods. These two methods are used to calculate the stationary probability distribution and second order statistics of the random oscillations by solving the generalized Fokker-Planck equation using a finite difference scheme and the Galerkin method, respectively. They provide results which are very similar to those from the simple simulation. C.D.

**A87-46792#**
**ACTIVE CONTROL OF AEROFOIL FLUTTER**
X. Y. HUANG AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1126-1132. Research supported by Cambridge University and Academia Sinica. refs

This paper describes a novel method of eliminating aerofoil flutter by an active control technique. The control is attained by adding to the natural case a control-induced force of appropriate amplitude and phase to negate the natural destabilizing tendency of the aerodynamic load. This control force may be induced on wings by actuating tabs or ailerons, however, the present paper concentrates on a scheme that may be more effective at high frequencies and which might, therefore, complement more conventional methods. Acoustic equipment is used to carry out the techniques of active sound control that are known as anti-sound. Although loudspeaker-induced pressures are small it is shown that they can actually induce significant and useful control forces on an aerofoil. This technique offers new flexibility in system design because the loudspeakers can be positioned at a convenient place, not necessarily on the aerofoil surface. This paper describes the theory needed to assess the details of this idea and also contains the results of the experiments in which a fluttering aerofoil was stabilized by switching on a loudspeaker. Author

**N87-25279*#** Sperry Flight Systems, Glendale, Ariz. Avionics Div.
**AUTOMATIC SYSTEMS AND THE LOW-LEVEL WIND HAZARD**
DWIGHT R. SCHAEFFER *In* NASA. Langley Research Center, Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 165-172 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 01C

Automatic flight control systems provide means for significantly enhancing survivability in severe wind hazards. The technology required to produce the necessary control algorithms is available and has been made technically feasible by the advent of digital flight control systems and accurate, low-noise sensors, especially strap-down inertial sensors. The application of this technology and these means has not generally been enabled except for automatic landing systems, and even then the potential has not been fully exploited. To fully exploit the potential of automatic systems for enhancing safety in wind hazards requires providing incentives, creating demand, inspiring competition, education, and eliminating prejudicial disincentitives to overcome the economic penalties associated with the extensive and riskly development and certification of these systems. If these changes will come about at all, it will likely be through changes in the regulations provided by the certifying agencies. Author

**N87-25330*#** Manudyne Systems, Inc., Los Altos, Calif.
**STUDY OF HELICOPTERROLL CONTROL EFFECTIVENESS CRITERIA Final Report, Jul. 1983 - Jul. 1985**
ROBERT K. HEFFLEY, SIMON M. BOURNE, HOWARD C. CURTISS, JR., WILLIAM S. HINDSON, and RONALD A. HESS Apr. 1986 267 p
(Contract NAS2-11665; DA PROJ. 1L1-62209-AH-76)
(NASA-CR-177404; NAS 1.26:177404; AD-A172111; MANUDYNE-83-1; USAAVSCOM-TR-85-A-5) Avail: NTIS HC A12/MF A01 CSCL 01C

A study of helicopter roll control effectiveness based on closed-loop task performance measurement and modeling is presented. Roll control critieria are based on task margin, the excess of vehicle task performance capability over the pilot's task performance demand. Appropriate helicopter roll axis dynamic models are defined for use with analytic models for task performance. Both near-earth and up-and-away large-amplitude maneuvering phases are considered. The results of in-flight and moving-base simulation measurements are presented to support the roll control effectiveness criteria offered. This Volume contains the theoretical analysis, simulation results and criteria development. Author (GRA)

**N87-25331*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**ADVANCED DETECTION, ISOLATION AND ACCOMMODATION OF SENSOR FAILURES: REAL-TIME EVALUATION**
WALTER C. MERRILL, JOHN C. DELAAT, and WILLIAM M. BRUTON Jul. 1987 30 p
(NASA-TP-2740; E-3479; NAS 1.60:2740) Avail: NTIS HC A03/MF A01 CSCL 01C

The objective of the Advanced Detection, Isolation, and Accommodation (ADIA) Program is to improve the overall demonstrated reliability of digital electronic control systems for turbine engines by using analytical redundancy to detect sensor failures. The results of a real time hybrid computer evaluation of the ADIA algorithm are presented. Minimum detectable levels of sensor failures for an F100 engine control system are determined. Also included are details about the microprocessor implementation of the algorithm as well as a description of the algorithm itself. Author

**N87-26047*#** Rice Univ., Houston, Tex. Dept. of Mechanical Engineering and Materials Science.
**OPTIMAL FLIGHT TRAJECTORIES IN THE PRESENCE OF WINDSHEAR, 1984-86 Final Report**
A. MIELE 1986 36 p
(Contract NAG1-516)
(NASA-CR-180316; NAS 1.26:180316; AERO-ASTRONAUTICS-203) Avail: NTIS HC A03/MF A01 CSCL 01C

Optimal flight trajectories were determined in the presence of windshear and guidance schemes were developed for near optimum flight in a windshear. This is a wind characterized by sharp change in intensity and direction over a relatively small region of space. This problem is important in the takeoff and landing of both civilian airplanes and military airplanes and is key to aircraft saftey. The topics covered in reference to takeoff problems are: equations of motion, problem formulation, algorithms, optimal flight trajectories, advanced guidance schemes, simplified guidance schemes, and piloting strategies. Author

**N87-26048** ESDU International Ltd., London (England).
**AN INTRODUCTION TO TIME-DEPENDENT AERODYNAMICS OF AIRCRAFT RESPONSE, GUSTS AND ACTIVE CONTROLS**
Sep. 1984 65 p
(ESDU-84020; ISBN-0-85679-484-8; ISSN-0141-397X) Avail: ESDU

ESDU 84020 explains the derivation and application of the indicial (step-response) functions (also called Wagner and Kuessner functions) used to study aircraft response. The functions are introduced through the Fourier integration of the frequency-dependent generalized airforce coefficients associated with oscillatory motion. Indicial functions for use in predicting response in lift and pitching moment due to heave or pitch rate, or deflection of a 20 percent chord control, are tabulated for thin airfoils in subsonic and supersonic flows. Results obtained for a range of typical airframe two- and three-dimensional geometries, including wing/tailplane combinations, again through the speed range to supersonic, are illustrated graphically. They include the effects of active controls. The results are discussed and various aspects of the mathematical modeling of unsteady flows are highlighted. ESDU

**N87-26049** Maryland Univ., College Park.
**GUST RESPONSE OF HELICOPTERS Ph.D. Thesis**
GUNJIT SINGH BIR 1985 254 p
Avail: Univ. Microfilms Order No. DA8702145

An analysis was developed for investigating the response of a rotor-fuselage system in a three-dimensional gust field wherein the gust velocity components can have arbitrary variation in space and time. Each rotor blade undergoes flap bending, lag bending, and torsional deflections. The blades are divided into beam elements and each element consists of fifteen nodal degrees of freedom. Quasisteady strip theory is used to obtain the aerodynamic loads. Unsteady aerodynamic effects are introduced through dynamic inflow modeling. A dynamic stall model is used to incorporate the unsteady stall effects. Corrections are introduced for the reverse flow effects. The fuselage is allowed five degrees of freedom: vertical, longitudinal, lateral, pitch, and roll motions. Finite element method based on the Hamilton principle is applied to discretize the equations of motion. Results were obtained for the articulated and hingeless rotors in hover as well as forward flight. Dissert. Abstr.

**N87-26050** Stanford Univ., Calif.
**CONTROL OF AIRCRAFT UNDER SEVERE WIND SHEAR CONDITIONS Ph.D. Thesis**
PETER YAOHWA CHU 1987 187 p
Avail: Univ. Microfilms Order No. DA8707646

This research uses feedforward techniques to control a short takeoff and landing transport during landing approach, assuming knowledge of wind states. At the same time, feedback is used to augment stability and handle modeling and estimation errors. Current and future wind states can be detected by ground based Doppler radars that scan the glide scope. Estimates of the current wind states can also be derived from onboard sensors. Three different methods for designing a time-invariant feedforward controller are discussed: asymptotic disturbance rejection, linear quadratic disturbance rejection, and differential game. A wind shear penetration index is proposed. It gives an indication of the ability of the aircraft to penetrate wind shear, and may establish a wind threshold above which the aircraft should not attempt landing or takeoff. Dissert. Abstr.

**N87-26051** Georgia Inst. of Tech., Atlanta.
**AN INVESTIGATION OF HELICOPTER HIGHER HARMONIC CONTROL USING A DYNAMIC SYSTEM COUPLER SIMULATION Ph.D. Thesis**
KIP PETER NYGREN 1986 188 p
Avail: Univ. Microfilms Order No. DA8707859

A free flight computer simulation of helicopter Higher Harmonic Control (HHC) is developed by incorporation of an HHC solution procedure in the Dynamic System Coupler (DYSCO) Program. The simulation can model almost any HHC control and identification scheme tested to date. The simulation is correlated with previous experiments and simulations, and the assumptions of the mathematical model are analyzed. Investigations are conducted which compare fixed gain and adaptive control, local, and global formulations. The OH-6A helicopter with elastic rotor and fuselage is modeled using unsteady aerodynamics. Five baseline regulators are tested at flight velocities of 80, 100 and 120 knots, and the simulation is verified by comparison with previous efforts. Variations in measurement noise, initial transfer matrix, and number of rotor blades is considered. The model is also maneuvered from trimmed flight at 80 knots to trimmed flight at 120 knots using large and small step changes. The results indicate fixed gain, closed loop control can adequately reduce vibration, though not as effectively as adaptive control, except when initialized with an inappropriate transfer matrix. Dissert. Abstr.

**N87-26836** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.
**CONCEPTUAL STUDIES OF CONTROL SYSTEMS FOR WINGS WITH VARIABLE CAMBER [KONZEPTUNTERSUCHUNG ZU STEUERUNGSSYSTEMEN EINES TRAGFLUEGELS VARIABLE WOELBUNG]**
JUERGEN RENKEN and UDO CARL *In its* Research and Development. Technical-Scientific Publications 1986 p 107-114 1986 In GERMAN Presented at the 4th BMFT-Statusseminar, Munich, West Germany, 28-30 Apr. 1986
(MBB-UT-221/86) Avail: Issuing Activity

Geometric-kinematic principles of camber variation, and the corresponding drive and control concepts were investigated, with the restriction of camber variations of trailing edge of the wings. The emphasis was on the control surfaces (spoiler, Fowler flaps, aileron). The premise was that neither the original primary (roll control) and secondary (high-lift) functions be reduced, nor that

complexity, weight and reliability endanger the global utility. The flight-physical background of the camber concept, and the geometric-kinematic-realization of camber variation (via profile depth or wing span) are presented. A flap drive and control concept is explained. The effect of the elastic flap deformations on the camber variation is discussed. The implementation of the function camber variation into existing systems and functions is presented. ESA

# 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.

**A87-43425*#** Army Aviation Systems Command, Moffett Field, Calif.
**A COMPARISON OF THE ACOUSTIC AND AERODYNAMIC MEASUREMENTS OF A MODEL ROTOR TESTED IN TWO ANECHOIC WIND TUNNELS**
D. A. BOXWELL (U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA), F. H. SCHMITZ (NASA, Ames Research Center, Moffett Field, CA), W. R. SPLETTSTOESSER, K. J. SCHULTZ (DFVLR, Brunswick, West Germany), S. LEWY (ONERA, Chatillon-sous-Bagneux, France) et al. DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 54 p. Previously announced in STAR as N87-15178. refs

Two aeroacoustic facilities - the CEPRA 19 in France and the DNW in the Netherlands - are compared. The two facilities have unique acoustic characteristics that make them appropriate for acoustic testing of model-scale helicopter rotors. An identical pressure-instrumented model-scale rotor was tested in each facility and acoustic test results are compared with full-scale-rotor test results. Blade surface pressures measured in both tunnels were used to correlated nominal rotor operating conditions in each tunnel, and also used to assess the steadiness of the rotor in each tunnel's flow. In-the-flow rotor acoustic signatures at moderate forward speeds (35-50 m/sec) are presented for each facility and discussed in relation to the differences in tunnel geometries and aeroacoustic characteristics. Both reports are presented in appendices to this paper. Author

**A87-43460#**
**DESCRIPTION OF, AND PRELIMINARY RESULTS FROM, A NEW BLADE-VORTEX INTERACTION TEST FACILITY**
A. KOKKALIS and R. A. MCD. GALBRAITH (Glasgow, University, Scotland) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 18 p. Research supported by the Ministry of Defence (Procurement Executive). refs

The paper describes the salient design features of a facility for the investigation of parallel blade-vortex interaction as may be experienced by helicopter rotor blades. Preliminary results from the test facility are presented and discussed. Author

**A87-43461#**
**A UNIQUE APPROACH TO AEROELASTIC TESTING OF SCALED ROTORS**
G. ALVIN PIERCE and STEVEN S. KLEIN (Georgia Institute of Technology, Atlanta) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 13 p.
(Contract DAAG29-82-K-0094; DAAG29-85-G-0072)

In 1982 the U.S. Army Research Office commissioned the Georgia Institute of Technology to design and construct a unique testing facility for the purpose of acquiring a comprehensive data base of aeroelastic response characteristics for scaled model helicopter rotors. This data base could then be used in correlation studies to establish the validity or deficiencies of available analytical methods for the prediction of structural dynamic and/or unsteady aerodynamic phenomena. This paper presents detailed description of the facility, the testing philosophy behind its design and use, and current and future test programs conducted in the facility. Author

**A87-43462#**
**VALIDATION OF A METHOD FOR AIR RESONANCE TESTING OF HELICOPTERS AT MODEL SCALE USING ACTIVE CONTROL OF PYLON DYNAMIC CHARACTERISTICS**
RICHARD L. BIELAWA (Rensselaer Polytechnic Institute, Troy, NY) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 32 p. Research supported by the United Technologies Corp. and U.S. Army. refs

A problem inherent in the testing for helicopter air resonance at mode scale is the design and fabrication of the pylon support structure to effect both a proper (Froude) scaling and adequate variability of the pylon parameters by using passive properties. One method of overcoming this difficulty is to provide for active control of the pylon properties using suitably controlled hydraulic feedback servo actuators acting in response to the measured motion of the pylon. The objective of the study is to investigate the validity of such an approach using analytical means. The results compare the air resonance eigensolutions obtained for various approximations inherent in such a method of model testing. Analytical formulations are presented describing the modifications required of a basic air-resonance theory to account for the dynamics of the selected feedback control network. Author

**A87-44714**
**SOME FUNDAMENTALS OF SIMULATOR COCKPIT MOTION GENERATION**
M. BAARSPUL, R. J. A. W. HOSMAN, and J. C. VAN DER VAART (Delft, Technische Hogeschool, Netherlands) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 81-100. refs

Some aircraft simulator motion generation problems are discussed. The basic software and hardware elements for motion generation are described. Examples of motion hardware quality assessment are presented. A definition for motion cue, and a division of cues based on their functions and temporal properties are proposed. The interaction between visual and vestibular motion perception, and the relation between motion perception and aircraft control are investigated experimentally. Analysis of the stimulus-response data reveal that cockpit motion, if properly simulated without delays, decreases human operator time delays and improves control performance. The designing and tuning of drive motion laws are examined, and some examples of false transient cues due to motion filtering are provided. I.F.

**A87-44715**
**A PROGRAM TO INVESTIGATE REQUIREMENTS FOR EFFECTIVE FLIGHT SIMULATOR DISPLAYS**
E. A. MARTIN, G. R. MCMILLAN, R. WARREN, and G. E. RICCIO (USAF, Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 101-126. refs

The effectiveness of flight simulator data is examined in terms of inertial motion display fidelity, visual display dynamic fidelity, and temporal fidelity. The experiments conducted to investigate pilot performance and training transfer under conditions of: (1) dynamic seat roll-axis cuing; (2) visual perceptive transformation and flow field cuing; and (3) time delays in a visual display. Analysis of the dynamic seat cuing data with respect to physical and information fidelity, and the effect of experience on training transfer reveal that the dynamic seat is useful for onset cuing. It is observed that it is necessary to have rich and reduced cue displays in

simulation training; time-delay effects are greater under more demanding situations; and training transfer is inhibited by long time delays. I.F.

**A87-44720**
**THE INTEGRATION OF A SIX AXIS MOTION SYSTEM AND A WIDE ANGLE VISUAL SYSTEM INSIDE A DOME**
A. G. BARNES (British Aerospace, PLC, Military Aircraft Div., Weybridge, England) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 204-211.

A proposal for integrating motion and visual systems is presented. The requirements for the simulator, which is to be integrated inside a single dome, are described. The visual system is composed of three new TV projectors, which cover a field-of-view of 150 x 40 deg, mounted on the gantry, and a sky-ground projector. Methods for matching the horizon position and sky brightness of the computer-generated-image projectors and the sky-ground projector are examined. The size requirement for the motion system is considered in terms of translational and rotational performance. A diagram of the configuration for the motion/visual system, which is to be located on a platform in a 60-cm pit, is provided. The advantages and disadvantages of the selected configuration are discussed. I.F.

**A87-44954*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**DESIGNING TRANSONIC WIND-TUNNEL TEST SECTIONS FOR FLOW DIAGNOSTICS AND LASER VELOCIMETER APPLICATIONS**
G. S. JONES (NASA, Langley Research Center; Complere, Inc., Hampton, VA), L. R. GARTRELL, W. G. SEWALL, and P. C. STAINBACK (NASA, Langley Research Center, Hampton, VA) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 19th, Honolulu, HI, June 8-10, 1987. 12 p. refs
(AIAA PAPER 87-1434)

The design, fabrication, and validation of the Basic Aerodynamic Facility (BARF), developed for the direct comparison of three-dimensional laser velocimetry (LV) and hot-wire techniques at transonic speeds, are discussed. To accommodate the installation of the three-dimensional orthogonal LV system in the BARF, the transonic slots were redesigned to house windows, and the test section mounting was redesigned to facilitate LV transversing. Two-dimensional and three-dimensional code validation tests of the LV test section showed uniform mean flow through the test section to sonic speeds, and fluctuating pressure measurements at subsonic speeds which are consistent with facilities with good flow quality. R.R.

**A87-45125#**
**THE AIR FORCE FLIGHT TEST CENTER - NOW AND THE FUTURE**
CHARLES E. ADOLPH (USAF, Flight Test Center, Edwards AFB, CA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 535-537.

The Air Force Flight Test Center (AFFTC) conducts and supports manned and unmanned aircraft flight tests, development testing of parachutes, operates the Edwards Flight Test Range, the USAF Test Pilot School, and the Utah Test and Training Range. This paper summarizes the evolutionary forces in the technical and management areas which gave impetus to today's methods of operation. Current capabilities and procedures are then described, followed by a discussion of improvements planned to meet the demands of the late 1980's. The largest single challenge facing the military flight test community in the next decade is the efficient evaluation of software-intensive avionics systems. Author

**A87-45203*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**FULL-SCALE THRUST REVERSER TESTING IN AN ALTITUDE FACILITY**
CHARLES M. MEHALIC and ROY A. LOTTIG (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 14 p. Previously announced in STAR as N87-18575. refs
(AIAA PAPER 87-1788)

A two-dimensional convergent-divergent exhaust nozzle designed and fabricated by Pratt and Whitney Aircraft was installed on a PW1128 turbofan engine and tested during thrust reverser operation in an altitude facility at NASA Lewis Research Center. A unique collection system was used to capture the thrust reverser exhaust gas and transport it to the primary exhaust collector. Tests were conducted at three flight conditions with varying amounts of thrust reverse at each condition. Some reverser exhaust gas spillage by the collection system was encountered but engine performance was unaffected at all flight conditions tested. Based on the results of this test program, the feasibility of altitude testing of advanced multifunction exhaust nozzle systems has been demonstrated. Author

**A87-45204#**
**STATE-OF-THE-ART TEST FACILITIES FOR DEVELOPMENT OF THE ARMY'S T800-LHT-800 LHX HELICOPTER ENGINE**
WILLIAM R. STIEFEL (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) and ALBERT SELDER (Garrett Turbine Engine Co., Phoenix, AZ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1790)

The T800-LHT-800 helicopter engine is being developed for the U.S. Army. The members of the development teams are in competition with another contractor for full-scale development and ultimate production of the engine. One of the many aspects of teaming is the requirement to test the engine at two separate test sites. This paper describes the coordination activities between the test organizations of two team members and the efforts to achieve commonality or equivalence of test facilities, equipment, and procedures. It also describes the state-of-the-art engine test facilities, both general purpose and specialized, that the team members have provided for development of the engine. Author

**A87-45276#**
**GROUND TESTING FACILITIES REQUIREMENTS FOR HYPERSONIC PROPULSION DEVELOPMENT**
V. K. SMITH (Sverdrup Technology, Inc., Arnold Air Force Station, TN), L. C. KEEL, and A. H. BOUDREAU (USAF, Arnold Engineering Development Center, Arnold Air Force Station, TN) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 5 p. refs
(AIAA PAPER 87-1884)

To meet the requirements of transatmospheric missions (TAVs), revolutionary advances are needed in airbreathing propulsion systems; high-strength high-temperature lightweight fully reusable materials; super-computer-based aerodynamic, structural, and propulsion design codes; high-efficiency energy management of the hydrogen fuel; and advanced computers and adaptive-intelligence control systems. In this paper, requirements of ground testing facilities, in terms of Mach number, altitude, and size, for hypersonic and TAV missions are analyzed and translated into the facility-oriented parameters of pressure, temperature, weight flow, and run time. The current and near-term propulsion test capabilities are evaluated, and the facility deficiencies, the propulsion ground test facility design issues, and enabling technologies are identified. I.S.

**A87-45277*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MODIFICATION TO THE LANGLEY 8-FOOT HIGH TEMPERATURE TUNNEL FOR HYPERSONIC PROPULSION TESTING**
DAVID E. REUBUSH, RICHARD L. PUSTER (NASA, Langley Research Center, Hampton, VA), and H. NEALE KELLY (PRC Kentron, Inc., Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-1887)

This paper describes the modifications currently underway to the Langley 8-Foot High Temperature Tunnel to produce a new, unique national resource for testing of hypersonic air-breathing propulsion systems. The current tunnel, which has been used for aerothermal loads and structures research since its inception, is being modified with the addition of a LOX system to bring the oxygen content of the test medium up to that of air, the addition of alternate Mach number capability to augment the current M = 7 capability, improvements to the tunnel hardware to reduce maintenance downtime, the addition of a hydrogen system to allow the testing of hydrogen powered engines, and a new data system to increase both the quantity and quality of the data obtained. The paper discusses both the modifications and the development thereof. Author

**A87-45303*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EXPLORATORY EVALUATION OF A MOVING-MODEL TECHNIQUE FOR MEASUREMENT OF DYNAMIC GROUND EFFECTS**
GUY T. KEMMERLY, JOHN W. PAULSON, JR. (NASA, Langley Research Center, Hampton, VA), and MICHAEL COMPTON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-1924)

An attempt is presently made to measure the dynamic or time-dependent ground effects that may be encountered by aircraft during approach and landing by means of a ground-based testing technique that employs a model moving horizontally over an upwardly inclined ground plane to simulate the rate of descent. Results have been thus obtained for a 60-deg delta wing and for an F-18 full configuration, with and without thrust reversal, at forward speeds of up to 100 ft/sec. An analysis of the results gathered indicates that ground effects were reduced when the rate of descent was included in the test conditions. O.C.

**A87-45381*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A SUBSONIC TO MACH 5.5 SUBSCALE ENGINE TEST FACILITY**
EARL H. ANDREWS, JR. (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-2052)

The NASA-Langley Mach 4 facility, in which air-hydrogen combustion is used to heat the test gas, was modified to make the facility suitable for tests of ramjet-type models at subsonic and transonic, as well as supersonic, Mach numbers. The construction details and the instrumentation of this facility, designated the Combustion-Heated Scramjet Test Facility, are described, and modifications to enhance the test capability range from the subsonic/transonic and Mach 3.5 to 5.5 are discussed. Design diagrams and test result graphs are included. I.S.

**A87-45445*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**TEST FLOW CALIBRATION STUDY OF THE LANGLEY ARC-HEATED SCRAMJET TEST FACILITY**
SCOTT R. THOMAS, RANDALL T. VOLAND, and ROBERT W. GUY (NASA, Langley Research Center, Hampton, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(AIAA PAPER 87-2165)

The test flow at the exits of two square cross-section contoured nozzles with nominal exit Mach numbers of 4.7 and 6 has been studied as calibration data for the NASA-Langley Arc-Heated Scramjet Test Facility over simulated flight conditions from Mach 5.5 (at altitudes from 98,600-128,000 ft) to Mach 7 (at altitudes from 108,000-149,000 ft). Nozzle exit contour maps of measured thermodynamic properties, calculated Mach number, and calculated mass flow are used to determine the mass flow approaching the inlets of various scramjet engines. Good agreement is found between experimentally measured facility total mass flow and facility total mass flow determined by integration of the nozzle exit mass flow contours. R.R.

**A87-46183*#** Queensland Univ., Brisbane (Australia).
**SCRAMJET TESTING IN IMPULSE FACILITIES**
R. J. STALKER and R. G. MORGAN (Queensland, University, Brisbane, Australia) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 66-74. refs
(Contract NAGW-674)

The use of impulse facilities for gas dynamic experimentation on scramjets at high stagnation enthalpies is discussed. It is seen that, although such facilities will produce adequate stagnation enthalpies, it is necessary to compromise somewhat on the requirements for simulating test section densities, in order to allow realistic operating pressure levels. The shock tunnel and the expansion tube are briefly described, before focusing on operation of the reflected shock tunnel. It is shown that test times and flow starting times are such as to allow testing with models of reasonable size, provided that large regions of flow recirculation do not exist. Some examples of experimental scramjet studies, conducted in a reflected shock tunnel, are presented, demonstrating that the reflected shock tunnel is suitable for basic studies of scramjet flow processes. Provided that the effective enhancement of fuel calorific value by free stream 'freezing' of oxygen in the shock tunnel nozzle expansion does not prove to be an insuperable obstacle, the reflected shock tunnel may be expected to provide realistic simulation of scramjet flows up to speeds approaching earth orbital velocity. Author

**A87-46222#**
**THE ROLE OF SHORT DURATION FACILITIES IN GAS TURBINE RESEARCH**
D. L. SCHULTZ, R. W. AINSWORTH (Oxford University, England), and C. T. J. SCRIVENER (Rolls-Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 417-424. Research supported by the Ministry of Defence (Procurement Executive) and Rolls-Royce, PLC. refs

It is shown that, for certain classes of studies on gas turbines, there is an advantage to be gained from the use of short duration testing. Not only are total power demands substantially reduced whilst retaining the ability to carry out the required aerodynamic studies but short duration techniques are in many ways superior to steady state methods for the measurement of heat transfer rate to turbine blading. Comparisons between aerodynamic tests in a short duration cascade show excellent agreement with those carried out in a high power continuous cascade. The advantages of short duration facilities for heat transfer rate studies are illustrated by reference to comparative studies in a short duration facility and in a conventional high pressure high temperature sector cascade. The effect of the scale of turbulence and of the turbulence

level on the heat transfer rate is identified and it is shown that the high turbulence level frequently associated with combustion chamber flows may be due to large scale eddy structures which do not affect the blade surface momentum transfer and hence the heat transfer rate from the freestream to the blade. Author

**A87-46241#**
**MICROPROCESSOR BASED SURGE MONITORING SYSTEM**
K. VENKATARAJU, A. G. SATHEERATNAM, and R. RAMANATHAN (Gas Turbine Research Establishment, Bangalore, India) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 579-581.

During the development phase of a gas turbine engine, it is highly desirable to have an indication of the operating condition of the engine all the time to ensure its safety. Compressor is one of the most critical components of an air breathing gas turbine engine. It has, as is well known, unstable regions of operation. Instability in this component can lead to catastrophe. It is, therefore, necessary to monitor, wherever possible, the operating regions of the compressor during the development phase. A microprocessor based system has been developed for online monitoring of the operating region of a compressor during an engine test. Relevant parameters like inlet and outlet pressures and inlet temperatures are fed as inputs to this processing system. A color graphic terminal displays the operating line on the compressor map. It enables one to know the surge margin at all the operating regions of the compressor. It is a very helpful tool during development testing of the engine. Author

**A87-46243#**
**DIAGNOSTIC METHODS FOR AIR-BREATHING ENGINES**
D. LAREDO, Y. LEVY, and Y. M. TIMNAT (Technion - Israel Institute of Technology, Haifa) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 591-597. refs

The process of combustion in a sudden-expansion chamber is presently studied experimentally using a modified LDA technique to measure the local velocity distribution of the gas and fuel droplets of various diameters. Cold and hot flow results for kerosene fuel injected at 1-3 MPa are in good agreement with numerical predictions obtained from a modified TEACH computer code, which takes into account chemical reactions and two-phase flow. The reattachment length of the recirculation zone varies over 5-7 times the step height, and is a function of the inlet Reynolds number based on step height, chemical reaction, and the presence of the liquid phase. O.C.

**A87-46353#**
**CLASSIFICATION OF THE LOAD-CARRYING CAPACITY OF RUNWAY SURFACES BY THE ACN-PCN METHOD. I [KLASYFIKACJA NOSNOSCI NAWIERZCHNI LOTNISKOWYCH METODA ACN-PCN. I]**
KRZYSZTOF CZARNECKI (Instytut Techniczny Wojsk Lotniczych, Warsaw, Poland) Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 42, Jan. 1987, p. 19-21. In Polish.

The paper examines problems in the classification of the load-carrying capacity of runway surfaces using the ACN-PCN method. A definition of and general infromation about the ACN-PCN method are presented. Attention is given to examples of the determination of load classification numbers for aircraft and runway surfaces with reference to various classification procedures. B.J.

**A87-46354#**
**CLASSIFICATION OF THE LOAD-CARRYING CAPACITY OF RUNWAY SURFACES BY THE ACN-PCN METHOD. II [KLASYFIKACJA NOSNOSCI NAWIERZCHNI LOTNISKOWYCH METODA ACN-PCN. II]**
KRZYSZTOF CZARNECKI Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 42, Feb. 1987, p. 19-21, 25. In Polish. refs

A method for determining the ACN numbers of aircraft is presented. This is followed by a method for the determination of the PCN numbers of runway surfaces. B.J.

**A87-46438**
**NEW STANDARDS ESTABLISHED FOR REALISM IN VISUAL SIMULATION**
KEITH W. FRAY (Singer Co., Link Flight Simulation Div., Binghamton, NY) ICAO Bulletin, vol. 42, May 1987, p. 9-12.

The designs of the 200 deg field-of-view Aircraft Wide Angle Reflective Display System (AWARDS) and Image IV computer-generated imagery (CGI) visual system for commercial flight simulation are described. The AWARDS provides a continuous, panoramic, cross-cockpit view for pilots, copilots, and other occupants of the simulated aircraft flight deck. The AWARDS uses a dome-segment display system, a forward-facing relay-optics CRT projector system, and an image surface of precision ground glass for the mirror assembly. The average brightness level of the system is 10.3 cd/sq m, with a high light brightness of 27.4 cd/sq m, a display resolution of greater than 3 arcmin, and a surface contrast ratio of 30:1. The basis of the Image IV system is parallel, multiple microprocessors. The typical features of the Image IV system, and the benefits it provides to pilot training are discussed. The Image IV architecture provides a large number of surfaces, and improves antialiasing, translucency, and full planar texture. I.F.

**A87-46955#**
**TWO-DIMENSIONAL SUBSONIC AND TRANSONIC WIND TUNNEL WALL INTERFERENCE CORRECTIONS FOR VARIED WALLS**
QIWEI ZHANG (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamic Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 132-140. In Chinese, with abstract in English. refs

Two-dimensional subsonic and transonic wall interference corrections are evaluated from experimental pressure distributions near the tunnel walls and aerodynamic forces on a model. The corrections can be used for both ventilated and solid walls. The knowledge of wall cross-flow properties is not required. Different equations are used for different Mach number ranges. Two methods are provided to suit different needs. One method is a fast computing method which can be used while the flow near tunnel walls is subcritical. Another is a finite difference method which can be used in both subsonic and transonic tests and can judge whether the test data are correctable. Two practical examples are given. The effect of using different equations on the computing results is shown. Author

**A87-46958#**
**THE PITCHING DAMPING DERIVATIVES MEASURED BY FORCE-OSCILLATION METHOD AT TRANSONIC AND SUPERSONIC WIND TUNNEL**
CHENGZENG WANG (China Aerodynamic Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 162-170. In Chinese, with abstract in English. refs

A test mechanism for measuring pitching damping derivatives and data reduction equations for obtaining pitching dynamic derivatives are outlined. The experimentally measured pitching damping derivatives obtained in an FL-23 wind tunnel for AGARD Calibration Model C indicate that the variation trend of damping derivatives with Mach numbers is reasonable and the damping derivatives of Model C at M = 2.5 is in good agreement with the data obtained in AEDC 4-ft wind tunnel. The results obtained in repeated tests show that this test mechanism can be used to

measure the pitching damping derivatives for vehicle models in transonic and supersonic wind tunnels. Author

**A87-46960#**
**DEVELOPMENT OF EXPERIMENTAL INVESTIGATION ON TRANSONIC WIND TUNNEL WALL INTERFERENCE**
YIYI HUANG (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 5, June 1987, p. 181-187. In Chinese, with abstract in English. refs

This paper introduces the development of experimental investigation on the transonic wind tunnel wall interference and provides some quantitative results. Some comments on the recently developed wall interference correcting methods using measured wall pressure are given. The problems which should be noticed and have not yet been solved are pointed out. A feasible program for reducing tunnel wall interference is discussed, and appropriate technique for tunnel wall interference investigation is proposed. The conclusions are believed to be useful for improving the design of transonic wind tunnels and model tests. Author

**N87-25275*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**APPLICATION OF DATA TO PILOTED SIMULATORS**
RICHARD S. BRAY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 97-115 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 14B

The application of a further developed analytical model and JAWS data to a piloted simulator is addressed. The Ames simulator provides a facility for the development of piloting procedures, and for the selection of training scenarios. The system is operational with the new wind shear models and comprehensive data output. The use of these models with the simulator is dicussed in detail. Author

**N87-25278*#** Boeing Commercial Airplane Co., Seattle, Wash
**MICROBURST MODEL REQUIREMENTS FOR FLIGHT SIMULATION: AN AIRFRAME MANUFACTURER'S PERSPECTIVE**
RICHARD L. SCHOENMAN *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 153-164 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 14B

A brief outline is given of topics for presentation and discussion at the workshop. As manufacturers and certifiers of transport airplanes and associated on-board systems, an interest in the prevention of wind shear related accidents and incidents is inherent. The near term objectives are to provide the customers technical support in the areas of training as well as to research existing and potentially improved on-board systems. In the future, many improved systems should be implemented. This will require certification as well as further educational activity in the use of these new systems. A set of wind models is needed for design work which characterize a wide variety of real microbursts as measured during the JAWS project. The wind models should be limited in both size and complexity to just those features which degrade aircraft performance. Author

**N87-25280*#** CAE Industries, Ltd., Montreal (Quebec).
**SIMULATOR MANUFACTURERS' REQUIREMENTS**
DAVID R. REILLY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 173-180 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 14B

Simulator manufacturers must continue to provide the customers the latest wind shear models available for pilot training. The release of the JAWS data package enabled the provision of a much more realistic wind shear package to the customer rather than just the standard six SRI wind shear profiles currently in use. In this brief presentation, the steps taken in implementing the JAWS data into the FAA 727 simulator are highlighted. Author

**N87-25283*#** Flight Safety International, Inc., Tulsa, Okla.
**SIMULATOR SYSTEMS INTEGRATION**
KEITH W. SHIPMAN *In* NASA. Langley Research Center, Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 205-207 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 14B

The implementation of available wind shear data into general aviation flight training simulators is discussed. Currently, there are 11 simulators with wind shear models installed involving some 9 different aircraft models. Retrofits to other systems that were put out earlier are currently underway, and all the new simulators will have wind shear available for the instructors to use for demonstrations and training. There are three types of computer systems involved, and two different types of instructor stations. Most of the systems with wind shear are the CRT-type displays. The integration of wind shear models in flight simulators is discussed in detail. Author

**N87-25333#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensbereich Apparate.
**THE ROLE OF SIMULATION IN HELICOPTER DEVELOPMENT [DIE ROLLE DER SIMULATION IN DER HUBSCHRAUBERENTWICKLUNG]**
HUBER and KRAUSPE 1986 31 p In GERMAN Presented at the 16th Internat. Hubschrauberforum Bueckeburg, Hanover, West Germany, 11-12 Jun. 1986; and at the AGARD FMP Lecture Series No. 139 on Helicopter Aeromechanics
(MBB-UD-435/86; ETN-87-99925) Avail: Issuing Activity

Real time ground-based and flight simulation for helicopter development are reviewed. Simulators are listed. ESA

**N87-25334*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**AIRFOIL FLUTTER MODEL SUSPENSION SYSTEM Patent**
WILMER H. REED, inventor (to NASA) (DEI-Tech, Inc., Newport News, Va.) 28 Jul. 1987 9 p Filed 30 Jul. 1986 Supersedes N86-31594 (24 - 23, p 3560)
(NASA-CASE-LAR-13522-1-SB; US-PATENT-4,682,494; US-PATENT-APPL-SN-890575; US-PATENT-CLASS-73-147; US-PATENT-CLASS-73-856) Avail: Issuing Activity CSCL 14B

A wind tunnel suspension system for testing flutter models under various loads and at various angles of attack is described. The invention comprises a mounting bracket assembly affixing the suspension system to the wind tunnel, a drag-link assembly and a compound spring arrangement comprises a plunge spring working in opposition to a compressive spring so as to provide a high stiffness to trim out steady state loads and simultaneously a low stiffness to dynamic loads. By this arrangement an airfoil may be tested for oscillatory response in both plunge and pitch modes while being held under high lifting loads in a wind tunnel.
Official Gazette of the U.S. Patent and Trademark Office

**N87-26053#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Hauptabteilung Windkanaele.
**THE 0.6 M X 0.6 M TRISONIC SECTION (TMK) OF DFVLR IN COLOGNE-PORZ, WEST GERMANY Status Report, 1986**
HELMUT ESCH Mar. 1986 82 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1052) Original contains color illustrations
(DFVLR-MITT-86-21; ISSN-0176-7739; ETN-87-99681) Avail: NTIS HC A05/MF A01; DFVLR, Cologne, West Germany DM 46.50

Information for users of a blowdown wind tunnel is provided. It has a Mach number range from 0.5 to 4.5, with Reynolds numbers, based on a reference length of 1 m, between 10 million and 90 million. Typical running times are 60 sec. The Mach number range is extended by the neighboring hypersonic wind tunnel H2K, in which the same models can be tested at Mach numbers up to 11. ESA

**N87-26054#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Hauptabteilung Windkanaele.
**THE VERTICAL TEST SECTION (VMK) OF DFVLR IN COLOGNE-PORZ, WEST GERMANY Status Report, 1986**
KLAUS TRIESCH and ERNST-OTTO KROHN May 1986 99 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1053)
(DFVLR-MITT-86-22; ISSN-0176-7739; ETN-87-99682) Avail: NTIS HC A05/MF A01; DFVLR, Cologne, West Germany DM 38

Information for users of a vertical test section blowdown wind tunnel with test section diameters from 150 to 340 mm is presented. The axisymmetric free jet has a Mach number range from 0.5 to 0.95 at subsonic speeds, and from 1.57 to 3.23 at supersonic speeds, with Reynolds numbers, based on a reference length of 1 m, between 3 million and 300 million. Typical testing times are between 30 and 60 sec. ESA

**N87-26055#** Royal Aircraft Establishment, Farnborough (England).
**FATIGUE-LIFE MONITORING OF THE 5 METRE WIND TUNNEL**
D. E. LEAN Aug. 1986 20 p
(RAE-TM-AERO-2084; BR100661; ETN-87-90093) Avail: NTIS HC A02/MF A01

The method used in the processing of fatigue-life data relating to the pressure shell of a 5 m wind tunnel is summarized. The processing of a typical set of data illustrates the method. ESA

**N87-26056** ESDU International Ltd., London (England).
**FIRST APPROXIMATION TO LANDING FIELD LENGTH OF CIVIL TRANSPORT AEROPLANES (50 FT., 15.24 M SCREEN)**
Dec. 1984 11 p
(ESDU-84040; ISBN-0-85679-504-6; ISSN-0141-4054) Avail: ESDU

ESDU 84040 gives graphs from which quick first approximations can be obtained to the landing field lengths for all types of conventional-landing civil transport aircraft. The estimation method assumes the use of typical civil-transport-certification style landing maneuvers from the screen on to a hard, level, dry runway. The data are applicable over a wide range of ambient conditions and the effect of non-still-air conditions can be taken into account. The method is intended for use in initial or project design work but may also be of use in checking results of more detailed estimation methods. It is based on an analysis of landing data obtained from aircraft flight manuals and the use of true groundspeed at the screen and mean brakes-on deceleration as correlating parameters. A practical worked example illustrates the use of the data, and a table is included summarizing landing field length factors from current civil certification requirements. ESDU

# 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.

**A87-45443#**
**STUDIES OF SCRAMJET FLOWFIELDS**
J. A. SCHETZ (Virginia Polytechnic Institute and State University, Blacksburg) and F. S. BILLIG (Johns Hopkins University, Laurel, MD) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 16 p. Navy-supported research. refs
(AIAA PAPER 87-2161)

The effective and efficient analytical/numerical treatment of the complex flows encountered in the combustors and nozzles of scramjet vehicles by a modular approach is considered in detail. The general modular approach and the specific methods that have been successfully applied to various separate flow modules are illustrated for representative configurations and conditions for both small, low hypersonic flight Mach number and large, high flight Mach number vehicles. Formulations of the equations of motion, numerical methods, grid arrangement, turbulence modeling, and chemistry are discussed. Author

# 11

# CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

**A87-43398*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**THERMAL AND FLAMMABILITY CHARACTERIZATION OF GRAPHITE COMPOSITES**
D. A. KOURTIDES (NASA, Ames Research Center, Moffett Field, CA) Journal of Fire Sciences (ISSN 0734-9041), vol. 4, Nov.-Dec. 1986, p. 397-426. refs

Thermal, mechanical, and flammability properties of graphite composites fabricated with XU71775/H795, a bismaleimide/vinyl-polystyrylpyridine formulation; H795, a bismaleimide; Cycom 6162, a phenolic; and PSP 6022M, a polystyrylpyridine and two types of graphite reinforcement were evaluated and compared with a composite made with an epoxy resin as a matrix. The measured properties included limiting-oxygen index, smoke evolution, thermal degradation products, total-heat release, heat-release rates, mass loss, flame spread, ignition resistance, thermogravimetric analysis, and selected mechanical properties. It was found that the combination of XU71775/H795 with the graphite tape was the optimum design giving the lowest heat release rate. I.S.

**A87-43454#**
**THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF VARIOUS ALUMINIUM-LITHIUM ALLOY PRODUCT FORMS FOR HELICOPTER STRUCTURES**
A. F. SMITH (Westland Helicopters, Ltd., Yeovil, England) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 16 p. Research supported by the Ministry of Defence (Procurement Executive). refs

This paper describes tests carried out and results obtained from various aluminum-lithium alloy product forms, including

metallographic examination, mechanical property determination and conclusions drawn from heat treatment and component manufacturing trials. Particular emphasis is placed upon aspects of behavior and properties of aluminum-lithium which differ significantly from those of conventional aluminum alloys, together with features unique to the new material. Finally, brief mention is made of disadvantages, limitations, and difficulties which may arise in the introduction of aluminum-lithium alloys for the manufacture of helicopter structures. Author

**A87-44729**
**MATERIALS IN AEROSPACE; PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE, LONDON, ENGLAND, APR. 2-4, 1986. VOLUMES 1 & 2**
Conference sponsored by the Royal Aeronautical Society. London, Royal Aeronautical Society, 1986. Vol. 1, 243 p.; vol. 2, 213 p. For individual items see A87-44730 to A87-44750.

The present conference on state-of-the-art applications of advanced materials in the aerospace industries considers topics in helicopter components, guided missiles, propulsion systems, spacecraft, and airframe primary structures. Attention is given to Ti alloy castings, thermoplastic matrix composites, microwave/IR transparencies, self-reinforcing polymers, carbon/carbon composites, engine hot component ceramics, and mechanical alloying of Al-Mg-Li alloys. Also discussed are superalloy component durability enhancement methods, metal-matrix composites, the superplastic forming/diffusion bonding of Ti alloys, and Al-Li alloys for aerospace applications. O.C.

**A87-44739**
**HIGH TEMPERATURE TITANIUM ALLOYS**
P. A. BLENKINSOP (IMI Titanium, Ltd., Birmingham, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 1 . London, Royal Aeronautical Society, 1986, p. 189-208. refs

A development history and current status evaluation is presented for high temperature Ti alloys intended primarily for aircraft gas turbine engine applications. Since 1970, attention has primarily been given to the fatigue strength of the alloys as well as their tensile and creep strength. Control of alloy composition and thermomechanical processing has recently led to the development of IMI 834; the alloy can be alpha + beta heat-treated using 5-percent volume fractions of alpha phase to pin beta boundaries, thereby restricting the grain growth of the 95-percent beta matrix. Great creep and fatigue resistance characteristics are offered by this alloy. Prospective alloy and coating developments are projected. O.C.

**A87-44743**
**ADHESIVES IN AEROSPACE**
A. J. KINLOCH (Imperial College of Science and Technology, London, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 279-289.

A development history and current development status evaluation are presented for the use of structural adhesives in aircraft manufacturing, with emphasis on these adhesives' essential role in honeycomb core sandwich airframe structure panels, flooring, and control surfaces. Attention is given to the effect of environmental corrosive attack on structural adhesive joints with a view to consequent mechanical performance, as well as to the locus of joint failure, and the chemistry, temperature and humidity factors affecting joint durability. Joints to metallic surfaces are noted to be the most susceptible to environmental degradation; metallic substrate surface pretreatments are therefore prescribed. O.C.

**A87-44744**
**DEVELOPMENTS IN TITANIUM ALLOYS**
D. K. PEACOCK (Titanium Metal and Alloys, Ltd., Essex, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 290-302. refs

A comprehensive comparison is undertaken of the mechanical properties of the novel aerospace Ti alloys Ti-10V-2Fe-3Al and Ti-15V-3Cr with such competitive materials as Ti-6Al-4V in aircraft applications. Ti-10-2-3 is an ideal candidate for isothermal forgings produced to near net shape. Ti-15-3 complements Ti-10-2-3 in providing meltable, fabricable alloys capable of heat treatments tailored for various uses. Both alloys are judged to yield a quantum improvement in structural efficiency. O.C.

**A87-44745**
**MATERIALS FOR STRUCTURES OF THE FUTURE**
G. B. EVANS (British Aerospace, PLC, Hatfield, England) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 303-347. refs

The present evaluation of aircraft structural material development requirements and possibilities gives attention to the complex and consequential ways in which material property advantages, material costs, and aircraft operation fuel costs, interact under pressures exerted by manufacturing costs, politics and the development time horizon for new aircraft designs. The factors of environmental corrosion and protective measures, galvanic corrosion protection, sealants for fuel tanks, adhesively bonded aircraft structures, residual manufacturing stresses, and novel hydraulic systems are also discussed. O.C.

**A87-44747**
**SUPERPLASTIC FORMING/DIFFUSION BONDING OF TITANIUM**
J. R. WILLIAMSON (USAF, Wright-Patterson AFB, OH) IN: Materials in aerospace; Proceedings of the First International Conference, London, England, Apr. 2-4, 1986. Volume 2 . London, Royal Aeronautical Society, 1986, p. 373-393.

An evaluation is made of the technology development maturity and cost effectiveness of superplastically formed/diffusion bonded (SPF/DB) titanium alloy methods, as found in the cases of titanium components for the B-1B, F-15, F-18, and AV-8B aircraft. SPF/DB of F-18 environmental central system ducts is noted to result in a 40-percent fabrication labor cost reduction, an 11-fold reduction in the number of tools, and 90-percent reductions in tooling labor and materials costs. Tool fabrication time was reduced from 7-10 months to 6-10 weeks. A total of 77 B-1B structural components are produced by SPF/DB processing of Ti alloy. O.C.

**A87-44861**
**A DECADE OF COMPOSITE RUDDER SERVICE REVIEWED**
L. J. HART-SMITH and ARTHUR V. HAWLEY (Douglas Aircraft Co., Long Beach, CA) Aerospace Engineering (ISSN 0736-2536), vol. 7, June 1987, p. 57-59.

Carbon-epoxy upper aft rudders installed on 15 DC-10 jet transport aircraft have completed almost 350,000 hours of service with no significant failures. Installation of the composite rudders resulted in a 33-percent weight savings, and the structures withstood over four times the design limit load. Design of these rudders is unique in the use of a thin-skinned buckled multirib structure rather than the usual honeycomb sandwich structure, and in the out-of-autoclave cocuring of the structure as a one-piece assembly. In the postbuckled design, the spar and rib caps act to restrict the maximum strains which can develop within the skins. R.R.

**A87-45198#**
**APPLICATION OF LOW-REYNOLDS-NUMBER K-EPSILON MODEL TO SOLID FUEL TURBULENT BOUNDARY LAYER COMBUSTION**
DAVID YU-YUNG SHAN and JAMES S. T'IEN (Case Western Reserve University, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p. refs
(Contract AF-AFOSR-85-0340)
(AIAA PAPER 87-1778)

In this study, turbulent combustion in a boundary layer adjacent to a pyrolyzing solid fuel surface is analyzed. For the velocity field and turbulence viscosity, the low-Reynolds-number two-equation model by Jones and Launder is adopted. Consistent with this fluid mechanical treatment, the combustion model, which is modified from the mixing layer formulation using infinite fast chemical kinetics and beta probability density function for the mixture fraction, also consists of the same set of governing equations and coefficients in the entire computational domain, including the vicinity of the solid surface. The flame and flow field are solved numerically by a downstream marching scheme. At the Reynolds number where the computation has been carried out, the flame structure predicted by this model shows that the time averaged mass fractions of fuel and oxidizer overlap substantially. A rounded temperature profile is observed with the maximum mean temperature well below the adiabatic value. In addition a comparison of the boundary layer structure with incompressible cases is made. Author

**A87-45202#**
**DIAGNOSTICS IN SUPERSONIC COMBUSTION**
Y. M. TIMNAT (Technion - Israel Institute of Technology, Haifa) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-1787)

Diagnostic techniques which have shown promise in their application to supersonic combustion are discussed. Consideration is given to temperature measurements by thermocouple and nonintrusive optical methods, velocity determination with lasers, concentration measurements using probes, and regression rates in solid propellants employing microwaves and ultrasonics. Different types of measurements of the same parameter are compared and it is concluded that the suitability of a particular technique depends on the experimental conditions. K.K.

**A87-45274#**
**PROGRESS TOWARD SHOCK ENHANCEMENT OF SUPERSONIC COMBUSTION PROCESSES**
FRANK E. MARBLE, GAVIN J. HENDRICKES, and EDWARD E. ZUKOSKI (California Institute of Technology, Pasadena) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(AIAA PAPER 87-1880)

A mechanism for enhancing the rate of mixing between air and hydrogen fuel over rates that are expected in shear layers and jets is investigated. Particular attention is given to the rapid mixing induced by the interaction of a weak oblique shock with a cylindrical jet of hydrogen embedded in air. It is concluded that shock-induced mixing enhancement permits a significant reduction in the time (length) required for the mixing process and that the technique merits incorporation into engine development programs. K.K.

**A87-45372*#** Drexel Univ., Philadelphia, Pa.
**DEGRADATION MECHANISMS OF SULFUR AND NITROGEN CONTAINING COMPOUNDS DURING THERMAL STABILITY TESTING OF MODEL FUELS**
K. T. REDDY, N. P. CERNANSKY (Drexel University, Philadelphia, PA), and R. S. COHEN (Temple University, Philadelphia, PA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. Research supported by the Drexel University. refs
(Contract NAG3-183)
(AIAA PAPER 87-2039)

The degradation behavior of n-dodecane (singly or in combination with S- and N-containing dopants) was studied using a modified Jet Fuel Thermal Oxidation Tester facility between 200 and 400 C. The products were analyzed by gas chromatography and mass spectrometry. The soluble products consisted mainly of n-alkanes and 1-alkenes, aldehydes, tetrahydrofuran derivatives, dodecanol and dodecanone isomers, C21-C24 alkane isomers, and dodecylhydroperoxide (ROOH) decomposition products. The major products were always the same, with and without dopants, but their distributions varied considerably. The 3,4-dimercaptotoluene and dibutylsulfide dopants added individually to n-dodecane interferred with the hydrocarbon oxidation at the alkylperoxy radical and the alkylhydroperoxide link, respectively, while the 2,5-dimethylpyrrole dopant inhibited ROOH formation. Pyridine, pyrrole, and dibenzothiophene added individually showed few significant effects. I.S.

**A87-45898*#** Garrett Turbine Engine Co., Phoenix, Ariz.
**DURABILITY CHARACTERIZATION OF CERAMIC MATERIALS FOR GAS TURBINES**
W. D. CARRUTHERS and L. J. LINDBERG (Garrett Turbine Engine Co., Phoenix, AZ) International Committee for Advanced Materials Technology, Ceramic Workshop, 2nd, Nagoya, Japan, Mar. 9, 10, 1987, Paper. 15 p. NASA-supported research.

The strength retention of ceramic materials during extended high-temperature cyclic exposure is critical to their widespread application in gas turbine engines. During a continuing NASA funded program initated in 1979, reaction bonded silicon nitride (RBSN), sintered silicon carbide (SSC), reaction sintered silicon carbide (RSSC), and sintered silicon nitride (SSN) materials were evaluated following simulated gas turbine engine exposures. Exposures were performed by cycling specimens five times per hour between a high velocity burner discharge and a rapid air quench. The retained flexural strengths were determined following up to 3500 hours of exposure at temperatures up to 1370 C. Post-exposure strengths have been correlated with fractography and surface examination using SEM. Results illustrate excellent strength retention of SSC materials after 3500 hours of exposure to 1370 C. At 1200 C, RBSN and RSSC also demonstrate significant strength retention. Although SSN materials typically suffer significant strength losses during exposures at 1200 C, a new composition, which has improved high-temperature strength, also shows improved durability. In the majority of the materials, strength loss is typically associated with flaw formation in the protective SiO2 layer. Author

**A87-46221#**
**APPLICATION OF CERAMICS TO RAMJET ENGINE NOZZLES**
SHIMON SHANI, JOSEPH BARTA, and ARIE PERETZ (Rafael Armament Development Authority, Haifa, Israel) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 408-414. refs

Several ceramic materials were evaluated experimentally for application to ramjet nozzle throats under simulated ramjet configuration and operation conditions. The test nozzles were mounted to a ramjet combustor, which burns JP-4/air/oxygen mixture. The concepts mostly tested were sintered yttria-stabilized zirconia structures and zirconia coatings on porous graphites. Appropriate fabrication processes have been developed and test survivability criteria were determined. Nozzle throat inserts made of sintered stabilized zirconia and zirconia-coated graphites (with

intermediate molybdenum layer) sustained successfully (no disintegration and no measurable erosion) total temperature and pressure of 2450 K and 0.6MPa, respectively, for 100 sec. The results of the study point out that these materials and concepts may be used successfully at nozzle throats, subjected to severe internal environment conditions, such as those encountered in high-performance ramjet engines. Author

**A87-46772#**
**CRACK GROWTH PREDICTION IN 3D STRUCTURES UNDER AERONAUTICAL-TYPE SPECTRUM LOADINGS**
R. LABOURDETTE, G. BAUDIN, and M. ROBERT (ONERA, Chatillon-sous-Bagneux, France) (International Conference on Fatigue and Fatigue Thresholds, University of Virginia, Charlottesville, VA, June 28-July 2, 1987) ONERA, TP, no. 1987-79, 1987, 11 p. refs
(ONERA, TP NO. 1987-79)

A model predicting the behavior of crack fronts in three-dimensional structures subjected to aeronautical spectrum loadings is presented. The model is based on the work of Baudin and Robert (1984) for two-dimensional structures, coupled to a description by Labourdette and Baudin (1981) of crack growth in three-dimensional structures subjected to constant-amplitude loadings. A comparison of predictions for 7075-T7351 alloy bending specimens undergoing FALSTAFF and mini-TWIST sequences with experimental results yielded reasonably good agreement. I.S.

**A87-46874#**
**AIRCRAFT SKIN THAT BRUISES**
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 25, July 1987, p. 33, 34.

The use of a microencapsulated dye system on aircraft to indicate areas of damage and the severity is examined. The capsules, which are made from gelatine or polyurea materials, and the indicators, which are enclosed inside the capsules and remain liquid over the aircraft-skin operating temperature range, bruise under impact. The inspection of impact damage using X-ray or UV detection is described. The dye system has been tested on graphite-epoxy panel samples, and it is shown that it is effective for passively assessing impact damage to aircraft parts. I.F.

**N87-25435*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**PRELIMINARY STRUCTURAL DESIGN OF COMPOSITE MAIN ROTOR BLADES FOR MINIMUM WEIGHT**
MARK W. NIXON Jul. 1987 28 p Prepared in cooperation with Army Aviation Research and Development Command, Hampton, Va.
(Contract DA PROJ. 1L1-62209-AH-76)
(NASA-TP-2730; L-16310; NAS 1.60:2730; AVSCOM-TM-87-B-6)
Avail: NTIS HC A03/MF A01 CSCL 11D

A methodology is developed to perform minimum weight structural design for composite or metallic main rotor blades subject to aerodynamic performance, material strength, autorotation, and frequency constraints. The constraints and load cases are developed such that the final preliminary rotor design will satisfy U.S. Army military specifications, as well as take advantage of the versatility of composite materials. A minimum weight design is first developed subject to satisfying the aerodynamic performance, strength, and autorotation constraints for all static load cases. The minimum weight design is then dynamically tuned to avoid resonant frequencies occurring at the design rotor speed. With this methodology, three rotor blade designs were developed based on the geometry of the UH-60A Black Hawk titanium-spar rotor blade. The first design is of a single titanium-spar cross section, which is compared with the UH-60A Black Hawk rotor blade. The second and third designs use single and multiple graphite/epoxy-spar cross sections. These are compared with the titanium-spar design to demonstrate weight savings from use of this design methodology in conjunction with advanced composite materials. Author

**N87-25436#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
**EFFECTS OF IMPACT LOADING ON CARBON FIBER REINFORCED STRUCTURES [AUSWIRKUNGEN VON SCHLAGBEANSPRUCHUNGEN AUF CFX-STRUKTUREN]**
J. BAUER and J. WARNECKE 1986 5 p In GERMAN Presented at DGLR-Jahrestagung, Munich, West Germany, 9-10 Oct. 1986
(MBB-Z-83/86; ETN-87-99975) Avail: Issuing Activity

The effects of impact loading on carbon fiber reinforced plastics aircraft structures were investigated. Structures which are damage-tolerant and light can only be realized if possible impact loading is already taken into account during the construction and the static design. This requires an estimate of the impact energy and suitable comparative values for the dimensioning criterium (acceptable fiber extension). Another possibility of a damage-tolerant construction is the optimization of the laminate via the stacking sequence. ESA

**N87-25439*#** Lockheed-California Co., Burbank.
**FLIGHT SERVICE EVALUATION OF ADVANCED COMPOSITE AILERONS ON THE L-1011 TRANSPORT AIRCRAFT Annual Flight Service Report No. 5**
R. H. STONE Jun. 1987 14 p
(Contract NAS1-15069)
(NASA-CR-178321; NAS 1.26:178321) Avail: NTIS HC A02/MF A01 CSCL 11D

This report covers flight service evaluation of composite inboard ailerons on the L-1011 under contract NAS1-15069 for a period of five years. This is the fifth and final annual report of the maintenance evaluation program, and covers the period from July 1986 when the fourth yearly inspections were completed, through May 1987. Four shipsets of graphite/epoxy composite inboard ailerons were installed on L-1011 aircraft for this maintenance evaluation program. These include two Delta and two TWA aircraft. A fifth shipset of composite ailerons was installed in 1980 on Lockheed's flight test L-1011. The previous four annual inspections had been visual exterior inspections only. For this final inspection, the lower covers were removed for access and both interior and exterior surfaces, spars and ribs, and fastener holes were inspected. No damage or defects were observed on any of the composite ailerons, and no maintenance actions had occurred except for repainting of areas with paint loss. Flight hours on the airline components at the time of inspection ranged from 14,597 to 17,180 hours, after approximately 5 years of service. Author

**N87-25988#** Idaho Univ., Moscow. Dept. of Mechanical Engineering.
**DYNAMIC MECHANICAL PROPERTIES OF ADVANCED COMPOSITE MATERIALS AND STRUCTURES: A REVIEW**
R. F. GIBSON *In* Vibration Inst., The Shock and Vibration Digest, Volume 19, No. 7 p 13-22 Jul. 1987
Avail: NTIS HC A05/MF A01

Progress is reviewed in the analytical and experimental characterization of dynamic properties of advanced composite materials and structures during the period 1983 to 1986. The implications of this research and the directions of continued research are discussed. Author

**N87-26151#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Unternehmensbereich Transport- und Verkehrsflugzeuge.
**DEVELOPMENT AND TESTING OF CRITICAL COMPONENTS FOR THE TECHNOLOGICAL PREPARATION ON AN AIRBUS FUSELAGE MADE OF CARBON FIBER REINFORCED PLASTICS, PHASE 1 Final Report, Oct. 1985**
DIETER SCHULZ, WOLF-DIETRICH DOLZINSKI, UDO HERRMANN, SAMIR MALEK, KLAUS-HEINER SCHNEIDER, SIEGFRIED STENZEL, HANS-JUERGEN RIECKHOF, PETER FORNELL, and MICHAEL KOLAX Bonn, West Germany BMFT Dec. 1986 141 p In GERMAN; ENGLISH summary Sponsored by BMFT
(BMFT-FB-W-86-017; ISSN-0170-1339; ETN-87-99906) Avail: NTIS HC A07/MF A01; Fachinformationszentrum, Karlsruhe, West Germany DM 29.50

Technological premises for the introduction of carbon fiber reinforced plastics (CFRP) in wide-body fuselage structures of passenger aircraft were constituted. Design principles in accordance with criteria of operating costs such as weight, manufacturing costs, and in-service expenses, were evaluated. The specifications for a CFRP fuselage were prepared. A program aiming at lower development risks for the critical components was defined, scheduled, and implemented. Critical components were manufactured. Materials for composite structures were selected and tested as to impact, hot/wet performance, and burning behavior. ESA

# 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.

**A87-42851*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**CASE HISTORIES INVOLVING FATIGUE AND FRACTURE MECHANICS; PROCEEDINGS OF THE SYMPOSIUM, CHARLESTON, SC, MAR. 21, 22, 1985**
C. MICHAEL HUDSON, ED. (NASA, Langley Research Center, Hampton, VA) and THOMAS P. RICH, ED. (Bucknell University, Lewisburg, PA) Symposium sponsored by ASTM. Philadelphia, PA, American Society for Testing and Materials , 1986, 435 p. For individual items see A87-42852 to A87-42857.

Papers are presented on cracking at nozzle corners in the nuclear pressure vessel industry, applied fracture mechanics for assessing defect significance in a crude oil pipeline, failure analysis of a large wind-tunnel compressor blade, analysis of a compressor-wheel failure, and preventing fracture by inspection and analysis. Consideration is also given to the fatigue crack growth predictions of welded aircraft structures containing flaws in the residual stress field, the fatigue and fracture mechanics analysis of a compression loaded aircraft structure, fracture of an aircraft horizontal stabilizer, fatigue life analysis of fuel tank skins under combined loads, and aircraft structural maintenance recommendations based on fracture mechanics analysis. Additional papers discuss an analysis of two metal-forming die failures, an analysis of a failed saw arbor, and the role of fracture mechanics in assessing the effect on fatigue life of design changes in welded fabrications. I.S.

**A87-42852*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**FAILURE ANALYSIS OF A LARGE WIND TUNNEL COMPRESSOR BLADE**
ROY W. HAMPTON and HOWARD G. NELSON (NASA, Ames Research Center, Moffett Field, CA) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 153-180. refs

A failure analysis was performed to establish the cause of a 2014-T6 aluminum compressor rotor blade failure in a large NASA-Ames wind tunnel. Metallurgical failure analysis by light photography, fractographic SEM examinations, and fatigue experiments showed that a 0.13-mm-deep scratch in the shank of the blade had acted as an initiation site for a fatigue crack, which subsequently grew by Stage II fatigue before occurrence of the final fracture by unstable crack growth. Studies of modal deformation plots and blade FEM analysis indicated that Mode-3 was the most likely mode responsible for the resonance condition which produced the vibration loading that effected crack growth. Tunnel measurements data showed that the crack growth was controlled by both the tunnel resonance and the dampening from the crack itself. I.S.

**A87-42853**
**FATIGUE CRACK GROWTH PREDICTIONS OF WELDED AIRCRAFT STRUCTURES CONTAINING FLAWS IN THE RESIDUAL STRESS FIELD**
JAMES B. CHANG (Northrop University, Inglewood, CA) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 226-242. refs

This paper presents a procedure for fatigue crack analysis which makes it possible to predict the remaining crack life in a welded aircraft structure subjected to a fully reversed flight spectrum loading. The results of the analysis, which employed the EFFRGO 111 computer code, showed good correlation when compared with test data. The results indicate that residual stresses play a very important role for a flaw or a crack growing in the welded structure and that the residual stress effect should be accounted for in the analysis of crack growth behavior. I.S.

**A87-42854**
**FATIGUE AND FRACTURE MECHANICS ANALYSIS OF COMPRESSION LOADED AIRCRAFT STRUCTURE**
DANIEL L. RICH, R. E. PINCKERT (McDonnell Aircraft Co., St. Louis, MO), and T. F. CHRISTIAN, JR. (USAF, Warner Robins Air Logistics Center, Robins AFB, GA) IN: Case histories involving fatigue and fracture mechanics; Proceedings of the Symposium, Charleston, SC, Mar. 21, 22, 1985 . Philadelphia, PA, American Society for Testing and Materials, 1986, p. 243-258. refs

Fatigue and fracture mechanical analysis was performed to determine exact nature of cracking discovered during inspection of an F-15 fighter aircraft in the wing upper spar cap at the inboard end of the spar (which is a compression member during normal flight). A detailed finite element model was developed to determine the local stresses at the fastener holes in the seal groove, as well as the overall stresses in the flange. An experimental program was conducted in which element specimens were subjected to spectrum loading to obtain crack initiation and crack growth characteristics. The analyses gave accurate predictions of in-service crack initiation and crack growth, provided the residual stresses were included. I.S.

**A87-42905**
**ELECTROCHEMICAL MACHINING PROCESSES IN AIRCRAFT ENGINE BUILDING [TEKHNOLOGIIA ELEKTROKHIMICHESKOI OBRABOTKI DETALEI V AVIADVIGATELESTROENII]**
VASILII ALEKSANDROVI SHMANEV, VLADIMIR GEORGIEVICH FILIMOSHIN, AL'BERT KHAMZOVICH KARIMOV, B. I. PETROV, and N. D. PRONICHEV Moscow, Izdatel'stvo Mashinostroenie, 1986, 168 p. In Russian. refs

Electrochemical machining processes used in the fabrication of the compressor and turbine blades of gas turbine engines and the use of electrochemical methods for machining the surfaces of aircraft engine components made of high-temperature high-strength alloys and steels are examined. Methods for calculating the process variables and electrode parameters are presented. Attention is also given to ways of increasing the efficiency of electrochemical machining. V.L.

**A87-42914**
**HONEYCOMB STRUCTURES: PARAMETER SELECTION AND DESIGN [SOTOVYE KONSTRUKTSII: VYBOR PARAMETROV I PROEKTIROVANIE]**
ASKOL'D IVANOVICH ENDOGUR, MARK VLADIMIROVICH VAINBERG, and KONSTANTIN MOISEEVIC IERUSALIMSKII Moscow, Izdatel'stvo Mashinostroenie, 1986, 200 p. In Russian. refs

The book is concerned with the efficient design of aircraft components using sandwich panels with a honeycomb core. In particular, attention is given to the mechanical characteristics of various honeycomb cores, including honeycomb structures of aluminum and titanium alloys and Nomex polyamide paper; the load-bearing capacity of honeycomb panels and shells; fracture characteristics of honeycomb structures; and optimal parameters of honeycomb plates and shells under various kinds of loading. The discussion also covers the design and performance characteristics of bonded, welded, and soldered sandwich panels, typical joint configurations, and optimal design of some specific aircraft components using honeycomb panels. V.L.

**A87-42916**
**THREE-DIMENSIONAL PROBLEMS IN COMPUTATIONAL FLUID DYNAMICS [PROSTRANSTVENNYE ZADACHI VYCHISLITEL-'NOI AEROGIDRODINAMIKI]**
IURII DMITRIEVICH SHEVELEV Moscow, Izdatel'stvo Nauka, 1986, 368 p. In Russian. refs

Current approaches to the numerical solution of some three-dimensional problems in fluid dynamics are examined with emphasis on finite difference methods. In particular, attention is given to the mathematical principles of the design of complex geometries and construction of arbitrary systems of curvilinear coordinates; three-dimensional flows in an incompressible fluid near blunt bodies; and three-dimensional supersonic flow of an ideal gas past blunt bodies. The discussion also covers three-dimensional laminar boundary layers in a compressible gas and numerical modeling of three-dimensional turbulent flows. V.L.

**A87-43046#**
**NATURAL CONVECTION FLOW OF A RADIATING RAREFIED GAS BETWEEN CONCENTRIC ROTATING SPHERES**
A. R. BESTMAN (International Centre for Theoretical Physics, Trieste, Italy) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 8 p. refs
(AIAA PAPER 87-1523)

The gasdynamics of a rarefied gas between two concentric rotating spheres is studied when the temperatures of the spheres are large enough for radiative heat transfer to be significant. Assuming the gas is slightly rarefied, the problem is modelled by the differential Navier Stokes equations and slip boundary conditions. When the buoyancy parameter is small, asymptotic approximation is adopted for the solution. On the assumption that the gas is optically thick and invoking the Rosseland differential approximation for radiation, the basic nonlinear approximation is integrated in a close form. The higher approximations which are linear are tackled by finite difference scheme. Quantitative discussions of the results are presented. The problem is important in vacuum technology, astrophysics and new aircraft and rocket technology. Author

**A87-43053*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MOLECULAR FLOW VELOCITY USING DOPPLER SHIFTED RAMAN SPECTROSCOPY**
REGINALD J. EXTON, MERVIN E. HILLARD, JR., WALTER R. LEMPERT, PETER F. COVELL, and DAVID S. MILLER (NASA, Langley Research Center, Hampton, VA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 10 p. refs
(AIAA PAPER 87-1531)

Measurements of molecular flow velocity, static pressure, and translational temperature in the free-stream of a supersonic wind tunnel and behind the shock of a simple model are reviewed. Based on the free-stream demonstration using inverse Raman spectroscopy, an experiment is outlined to investigate the lee-side flow field above a swept delta wing and simulated spectra expected for the leading-edge vortex are included. The extension of the technique to hypersonic wind tunnels is also explored through the use of simulated spectra. Author

**A87-43381*#** Naval Surface Weapons Center, Silver Spring, Md.
**NUMERICAL SIMULATION AND COMPARISON WITH EXPERIMENT FOR SELF-EXCITED OSCILLATIONS IN A DIFFUSER FLOW**
T. HSIEH (U.S. Navy, Naval Surface Weapons Center, Silver Springs, MD), T. J. BOGAR (McDonnell Douglas Research Laboratories, St. Louis, MO), and T. J. COAKLEY (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 936-943. Research supported by the U.S. Navy and McDonnell Douglas Independent Research and Development Program. Previously cited in issue 18, p. 2662, Accession no. A85-39799. refs

**A87-43453#**
**RESEARCH ON THE STRESS ANALYSIS METHOD OF RUBBER STRUCTURE - CALCULATION OF THE FREQUENCY ADAPTER STRESSES**
YUQI LIU, ZHANGJIN, YONGKANG TU (Chinese Helicopter Research and Development Institute, People's Republic of China), and HEXIANG LU (Dalian Institute of Technology, People's Republic of China) DGLR, European Rotorcraft Forum, 12th, Garmisch-Partenkirchen, West Germany, Sept. 22-25, 1986, Paper. 10 p. refs

In this paper, the incremental method and Newton-Raphson iteration method are used for calculating the frequency adapter stresses. The F.E. method is used to solve the stresses of the rubber structure that can be simplified as the problem of plane strain. All the formulations are based on the strain energy function, considering nonlinear relation of the stress-strain of rubber materials, the nonlinear relation of displacement-strain, and incompressibility of the rubber materials. Author

**A87-43610**
**MATHEMATICAL MODEL FOR CALCULATING THE ATOMIZATION OF A LIQUID JET BY AN ANNULAR GAS STREAM [RASCHETNO-TEORETICHESKAIA MODEL' DROBLENIIA STRUI ZHIDKOSTI KOL'TSEVYM GAZOVYM POTOKOM]**
IU. O. KAS'IANOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 30-36. In Russian.

The paper proposes a model for calculating the mixing of coaxial gas and liquid jets at interaction angles close to zero. The model makes it possible to determine the form of the spray flow field, the size of the droplets formed, the configuration of the unatomized part of the liquid jet, and other parameters of the two-phase flow. The results are of interest in connection with the development of gas-liquid mixing elements for use in aircraft engines. B.J.

**A87-43611**
**EFFICIENCY OF THE UTILIZATION OF ROTOR BLADE SHROUD LABYRINTH SEALS IN AN AXIAL-COMPRESSOR STAGE WITH LARGE RADIAL CLEARANCES [EFFEKTIVNOST' PRIMENENIIA NADROTORNYKH USTROISTV LABIRINTNOGO TIPA V STUPENI OSEVOGO KOMPRESSORA PRI UVELICHENNYKH RADIAL'NYKH ZAZORAKH]**
V. A. KOVAL', G. V. PAVLENKO, and S. N. SHILO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634)

**A87-43622**
**PARAMETERS OF OPTIMAL PLANETARY GEARS OF AI TYPE [PARAMETRY OPTIMAL'NYKH PLANETARNYKH PEREDACH TIPA AI]**
V. M. RYDCHENKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 53, 1986, p. 90-93. In Russian.

Computer calculations of the kinematic and geometric characteristics of AI planetary gears (used in aircraft) are presented. Optimal solutions for various gear ratios and satellite numbers are sought according to a combination of five particular optimization criteria. B.J.

**A87-44725**
**VISUAL SYSTEMS DEVELOPMENTS**
M. R. HASWELL (Singer Link-Miles, Ltd., Lancing, England) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 264-271.

Recent advances in visual system technology which fulfill the requirements of field of view (FOV) and resolution are examined. The capabilities of modern visual systems are discussed in terms of an image generator that produces the visual scene and a display system that presents the visual scene to the pilot. The improved training effectiveness achieved with area-of-interest techniques, in particular the modular digital image generator, is evaluated. Consideration is given to image generator requirements for training effectiveness and area-of-interest displays, and display system requirements for training effectiveness. A eye-slaved projected raster inset visual system that provides a high-resolution display area within a wide FOV background of low resolution has been developed. The visual system consists of a helmet-mounted occulometer system, a foveal projection system, peripheral projectors, merge electronics, distortion correction electronics, and a high gain dome screen; the functions of these components are described. I.F.

**A87-44726**
**AOI DISPLAYS USING LASER ILLUMINATION**
B. BARBER (Rediffusion Simulation, Ltd., Crawley, England) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 272-294. refs

The development and design of a helmet-mounted laser projector are described. The projector design features are: laser illumination, two channel eye-coupled area-of-interest (AOI) visual display, close proximity, and exit pupil and eye point. The helmet-mounted optics include galvanometer driven mirrors which perform vertical scanning and deflect the projected rasters vertically and horizontally. The display system of the helmet-mounted laser projector is coupled to the visual technology research simulator flight computer and receives video from the two channels of the image generator. Consideration is given to the system's line image generator, fiber optic links, head and eye trackers, computer-image generation, and visual processor. The assembly of the helmet and the calibration of the head and eye trackers are discussed. The performance of the projector is evaluated, and it is observed that the system performs well. An alternative design for an AOI projector requirement is proposed. I.F.

**A87-45104*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A MINIATURE REMOTE DEADWEIGHT CALIBRATOR**
FRANK H. SUPPLEE, JR. and PING TCHENG (NASA, Langley Research Center, Hampton, VA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings Research Triangle Park, NC, Instrument Society of America, 1986, p. 65-85.

A miniature, computer-controlled, deadweight calibrator was developed to remotely calibrate a force transducer mounted in a cryogenic chamber. This simple mechanism allows automatic loading and unloading of deadweights placed onto a skin friction balance during calibrations. Equipment for the calibrator includes a specially designed set of five interlocking 200-milligram weights, a motorized lifting platform, and a controller box taking commands from a microcomputer on an IEEE interface. The computer is also used to record and reduce the calibration data and control other calibration parameters. The full-scale load for this device is 1,000 milligrams; however, the concept can be extended to accommodate other calibration ranges. Author

**A87-45107**
**OPTICALLY INTERFACED SENSOR SYSTEM FOR AEROSPACE APPLICATIONS**
DOUGLAS R. PATRIQUIN, FRED L. LICHTENFELS, and RICHARD P. ANDRESEN (Hercules, Inc., Instrument Systems Div., Vergennes, VT) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 117-124.

With the increasing use of composites in aircraft, emphasis has been placed on reduction of the number of wired connections between various components. This concern is reflected in the development of fiberoptic systems for new aircraft. This paper details a technique for fiberoptic interconnection of interfaces to conventional sensors. The benefit of this technique is that wired interconnections are eliminated while using proven sensor technology. The interfaces employ optical powering with power requirements compatible with solid state sources. Sensor data is then converted to a modulated optical signal for transmission. An experimental system of several multiplexed optically interfaced sensors is described. The results of testing the system and potential aerospace applications are discussed. Author

**A87-45123*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**CRASH RESPONSE DATA SYSTEM FOR THE CONTROLLED IMPACT DEMONSTRATION (CID) OF A FULL SCALE TRANSPORT AIRCRAFT**
RAYMOND S. CALLOWAY and VERNIE H. KNIGHT, JR. (NASA, Langley Research Center, Hampton, VA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 409-427.

NASA Langley's Crash Response Data System (CRDS) which is designed to acquire aircraft structural and anthropomorphic dummy responses during the full-scale transport CID test is described. Included in the discussion are the system design approach, details on key instrumentation subsystems and operations, overall instrumentation crash performance, and data recovery results. Two autonomous high-environment digital flight instrumentation systems, DAS 1 and DAS 2, were employed to obtain research data from various strain gage, accelerometer, and tensiometric sensors installed in the B-720 test aircraft. The CRDS successfully acquired 343 out of 352 measurements of dynamic crash data. K.K.

**A87-45124**
**A RUGGED ELECTRONIC PRESSURE SCANNER DESIGNED FOR TURBINE TEST**
TIMOTHY W. WORST and DOUGLAS B. JUANARENA (Pressure Systems, Inc., Hampton, VA) IN: International Instrumentation Symposium, 32nd, Seattle, WA, May 5-8, 1986, Proceedings . Research Triangle Park, NC, Instrument Society of America, 1986, p. 429-444.

This paper describes a rugged 16 channel electronic pressure scanner capable of withstanding the extreme environmental conditions associated wiith turbine test. It consists of a transducer per port, internal multiplexing, amplification and an integral calibration valve permitting on-line calibrations. Its design also includes a heater or cooling chamber to permit extreme cold or hot applications. In addition to the benefits of past electronic pressure scanner instruments such as on-line calibration and scan rates of up to 20,000 measurements per second, this type of scanner also can offer individual reference ports for true differential measurements and the ability to apply a separate calibration reference pressure during calibration. This rugged electronic pressure scanner also offers the ability to field replace the pressure transduction modules in the event one should be destroyed or be rendered inoperative. This paper describes its design, performance and presents typical applications. Author

**A87-45178#**
**ROTOR WAKE SEGMENT INFLUENCE ON STATOR-SURFACE BOUNDARY LAYER DEVELOPMENT IN AN AXIAL-FLOW COMPRESSOR STAGE**
J. L. HANSEN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) and T. H. OKIISHI (Iowa State University of Science and Technology, Ames) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p. USAF-sponsored research. refs
(AIAA PAPER 87-1741)

The boundary layer development on blades in an axial-flow compressor is an important design consideration. The influence of upstream-blade wake segments on downstream-blade boundary layers is not yet satisfactorily modeled for design purposes. Surface hot-film gages were used to sense the influence of rotor wake segments on stator-surface boundary layers at midspan in a low-speed, axial-flow compressor stage. It was clear that rotor wake segments moved along the stator-blade pressure and suction surfaces much like a turbulent spot would; the region of influence of each wake segment became larger further downstream. Boundary layer transition was not expected on the low-speed stator blade surface till about midchord. Nevertheless, the laminar boundary-layer flow on the forward portion of the stator blade appeared to be turbulent when a rotor wake segment was present. This periodic alternating of the stator boundary-layer flow was observed further aft on the blade also. Author

**A87-45186#**
**A NONINTERFERENCE BLADE VIBRATION MEASUREMENT SYSTEM FOR GAS TURBINE ENGINES**
WILLIAM B. WATKINS (Pratt and Whitney, Engineering Div., West Palm Beach, FL) and RAY M. CHI (United Technologies Research Center, East Hartford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(Contract F33657-79-C-0730)
(AIAA PAPER 87-1758)

A noninterfering blade vibration system has been demonstrated in tests of a gas turbine first stage fan. Conceptual design of the system, including its theory, design of case mounted probes, and data acquisition and signal processing hardware was done in a previous effort. The current effort involved instrumentation of an engine fan stage with strain gages; data acquisition using shaft-mounted reference and case-mounted optical probes; recording of data on a wideband tape recorder; and posttest processing using off-line analysis in a facility computer and a minicomputer-based readout system designed for near- real-time readout. Results are presented in terms of true blade vibration frequencies, time and frequency dependent vibration amplitudes and comparison of the optical noninterference results with strain gage readings. Author

**A87-45189#**
**REAL-TIME NEUTRON IMAGING OF GAS TURBINES**
P. A. E. STEWART (Rolls-Royce, PLC, Advanced Projects Dept., Bristol, England) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 17 p. Research supported by the Ministry of Defence (Procurement Executive), Admiralty Weapons Research Establishment, and Atomic Energy Research Establishment. refs
(AIAA PAPER 87-1762)

The current status of real-time neutron radiography imaging is briefly reviewed, and results of tests carried out on cold neutron sources are reported. In particular, attention is given to demonstrations of neutron radiography on a running gas turbine engine. The future role of real-time neutron imaging in engineering diagnostics is briefly discussed. V.L.

**A87-45201#**
**MORPHOLOGY OF A STANDING OBLIQUE DETONATION WAVE**
DAVID T. PRATT, JOSEPH W. HUMPHREY, and DENNIS E. GLENN (Advanced Projects Research, Inc., Sacramento, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. refs
(AIAA PAPER 87-1785)

The morphology of the standing oblique detonation wave (ODW) is examined with particular reference to propulsion system applications. It is shown that the maximum amount of heat that can be released in an overdriven weak ODW increases with approach static temperature and Mach number and decreases with increasing wedge angle; it is insensitive to pressure and considerably less than the Chapman-Juguet heat addition for normal detonation. It is also shown that there are wide ranges of approach Mach number, temperature, and turning angles within which overdriven weak ODW can be stabilized without variations of total pressure loss. V.L.

**A87-45241#**
**COMPLEX MODAL BALANCING OF FLEXIBLE ROTORS INCLUDING RESIDUAL BOW**
W. L. MEACHAM, P. B. TALBERT (Garrett Turbine Engine Co., Phoenix, AZ), H. D. NELSON (Arizona State University, Tempe), and N. K. COOPERRIDER (Failure Analysis Associates, Phoenix, AZ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-1840)

A balancing procedure utilizing the Complex Modal Method is presented for linear flexible rotor dynamic systems, including the effect of residual shaft bow. The method does not require trial runs; however, a valid mathematical model of the system dynamics is required to obtain the system's modal parameters, which are used to relate the balance corrections to measured responses. Several balancing strategies, based on extension of previous work, are suggested for single-speed balancing. Two applications are presented: (1) a gas turbine system with computer-generated response data, and (2) an operating steam turbine-generatior system. Author

**A87-45243#**
**A BIDIRECTIONAL TAPERED ROLLER THRUST BEARING FOR GAS TURBINE ENGINES**
R. LENGLADE, G. KREIDER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and R. PECH (Timken Co., Canton, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 9 p. refs
(Contract F33615-84-C-2409)
(AIAA PAPER 87-1842)

The paper iscusses a single row, bidirectional tapered roller thrust bearing, which will take the full range of forward thrust without thrust balance and, in addition, will take thrust in the reverse

direction caused by compressor surge. The higher load capacity of a tapered roller bearing offers improved reliability over a ball bearing. To verify this concept, a tapered roller bearing was designed, manufactured, and tested at speeds up to 24,000 rpm, at loads up to 66.7 kN in the major thrust direction, and for reverse thrust up to 8.9 kN at 20,000 rpm. Bearing reliability was tested up to 10 times the calculated L(10) fatigue life. The bearing performed successfully in all phases of testing and the concept of reverse thrust load on a high speed tapered roller bearing was proved. The feasibility of a tapered roller bearing on a gas turbine engine mainshaft was demonstrated at high speed as well as heavy load. Author

**A87-45273#**
**A SIMPLE MODEL FOR FINITE CHEMICAL KINETICS ANALYSIS OF SUPERSONIC TURBULENT SHEAR LAYER COMBUSTION**
PAUL E. DIMOTAKIS (California Institute of Technology, Pasadena) and JEFFERY L. HALL AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 13 p. refs
(Contract AF-AFOSR-83-0213)
(AIAA PAPER 87-1879)

A simple flow/thermodynamic model is proposed to describe finite chemical kinetic rate combustion in a turbulent supersonic shear layer for the purposes of assessing Damkoehler number effects in such flows. Sample calculations and comparisons for the H2/NO/F2 chemical system and the H2/air system are described for a set of initial flow and thermodynamic conditions of the entrained reactants. Author

**A87-45293#**
**DEVELOPMENT OF LOW-COST TEST TECHNIQUES FOR ADVANCING FILM COOLING TECHNOLOGY**
F. O. SOECHTING, K. K. LANDIS (Pratt and Whitney, West Palm Beach, FL), and R. DOBROWOLSKI (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 7 p. refs
(AIAA PAPER 87-1913)

A program for studying advanced film hole geometries that will provide improved film effectiveness levels relative to those reported in the literature is described. A planar wind tunnel was used to conduct flow visualization studies on different film hole shapes, followed by film effectiveness measurements. The most promising geometries were then tested in a two-dimensional cascade to define the film effectiveness distributions, while duplicating a turbine airfoil curvature, Mach number, and acceleration characteristics. The test techniques are assessed and typical results are presented. It was shown that smoke flow visualization is an excellent low-cost technique for observing film coolant-to-mainstream characteristics and that reusable liquid crystal sheets provide an accurate low-cost technique for measuring near-hole film effectiveness contours. Cascade airfoils constructed using specially developed precision fabrication techniques provided high-quality film effectiveness data. I.S.

**A87-45296#**
**AERODYNAMIC AND HEAT TRANSFER ANALYSIS OF THE LOW ASPECT RATIO TURBINE**
O. P. SHARMA (Pratt and Whitney, East Hartford, CT), P. NGUYEN, R. H. NI, C. M. RHIE, J. A. WHITE et al. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 12 p. refs
(Contract F33615-79-C-2050)
(AIAA PAPER 87-1916)

The available two- and three-dimensional codes are used to estimate external heat loads and aerodynamic characteristics of a highly loaded turbine stage in order to demonstrate state-of-the-art methodologies in turbine design. By using data for a low aspect ratio turbine, it is found that a three-dimensional multistage Euler code gives good averall predictions for the turbine stage, yielding good estimates of the stage pressure ratio, mass flow, and exit gas angles. The nozzle vane loading distribution is well predicted by both the three-dimensional multistage Euler and three-dimensional Navier-Stokes codes. The vane airfoil surface Stanton number distributions, however, are underpredicted by both two- and three-dimensional boundary value analysis. V.L.

**A87-45309#**
**XMAN - A TOOL FOR AUTOMATED JET ENGINE DIAGNOSTICS**
T. G. JELLISON, J. A. FRENSTER, N. S. PRATT, and R. L. DEHOFF (Systems Control Technology, Inc., Palo Alto, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 6 p.
(AIAA PAPER 87-1931)

The development and operation of XMAN, a knowledge-based software tool designed for automated jet engine diagnostics, is presented. XMAN is an expert interface to the Comprehensive Engine Management System Increment IV (CEMS IV), which makes it possible to automate the diagnostic procedures. The application of expert diagnostics to the TF-34 engine equipped with the Turbine Engine Monitoring System is described. As an integrated diagnostics tool, the XMAN system allows an insight into actual troubleshooting performed and the evaluation of the results. Interactive user training and a feedback loop to improve the diagnostic process are discussed. I.S.

**A87-45349*#** Avco-Everett Research Lab., Mass.
**EXPERIMENTAL DATA CORRELATIONS FOR THE EFFECTS OF ROTATION ON IMPINGEMENT COOLING OF TURBINE BLADES**
J. C. KREATSOULAS (Avco Everett Research Laboratory, Inc., MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p. Research supported by Teledyne CAE, Avco Everett Research Laboratory, Inc., and NAS. refs
(AIAA PAPER 87-2008)

The effects of rotation on impingement cooling have been experimentally studied under simulated gas turbine operating conditions. A large scale model of a blade is spun in vacuum. External heating is simulated by resistve dissipation in the thin wall of the model, which is impingement cooled. The local internal Nu is measured by an IR radiometric technique with high spatial resolution. At low rotational speeds the data agree well with published measurements taken under stationary conditions. At higher speeds, a decrease in the average Nu by up to 20-30 percent is observed. Severe gradients are generated near the hub region. Empirical correlations, which fit the data well and render it more useful for design purposes, are presented. Measurements and correlations suggest that rotational effects are very important and can cause premature blade failure. Author

**A87-45350#**
**FRICTION FACTORS AND HEAT TRANSFER COEFFICIENTS IN TURBULATED COOLING PASSAGES OF DIFFERENT ASPECT RATIOS. I - EXPERIMENTAL RESULTS**
M. E. TASLIM (Northeastern University, Boston, MA) and S. D. SPRING (General Electric Co., Aircraft Engine Business Group, Lynn, MA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p. refs
(AIAA PAPER 87-2009)

In advanced turbine airfoil cooling designs where multiple-pass cooling circuits are used, a range of cooling passage aspect ratios (height/width) are encountered. The objective of this experimental investigation was to determine the effect that increasing aspect ratios have on friction factors and Nusselt numbers in internal cooling passages with rib-roughened (turbulated) surfaces. Aspect ratios ranging from 0.5 to 3.5 were tested over a Reynolds number range of 30,000 to 190,000. Each aspect ratio was tested at three different turbulator-height/hydraulic-diameter ratios and at a constant turbulator-height/pitch ratio of 0.10. Author

**A87-45379#**
**FINITE ELEMENT ANALYSIS OF LARGE SPUR AND HELICAL GEAR SYSTEMS**
S. SUNDARARAJAN and B. YOUNG (Pratt and Whitney Canada, Longueuil) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 5 p.
(AIAA PAPER 87-2047)

The application of the 3D finite element sub-structure method has helped to improve the accuracy of calculation of gear tooth contact and fillet stresses in large spur and helical gear systems. The development of a dedicated preprocessor has significantly reduced the manual effort involved in the analysis. The methodology is explained using the example analyses of the gear systems in the two stages of a typical speed reduction gearbox used in the Pratt and Whitney Canada PW100 turbo propeller engines. Author

**A87-45398*#** General Electric Co., Cincinnati, Ohio.
**DYNAMIC DATA ACQUISITION, REDUCTION, AND ANALYSIS FOR THE IDENTIFICATION OF HIGH-SPEED COMPRESSOR COMPONENT POST-STABILITY CHARACTERISTICS**
S. D. DVORAK, W. M. HOSNY, W. G. STEENKEN (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH), and J. H. TAYLOR (General Electric Co., Schenectady, NY) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 14 p. refs
(Contract NAS3-2483; NAS3-24211)
(AIAA PAPER 87-2089)

A compressor test was conducted in which transient data were obtained for the purpose of identifying the high-speed post-stability characteristics. The transient, surge-cycle nature of high-speed post-stability operation precludes the possibility of obtaining the characteristics in a steady-state manner, as is possible during low-speed poststability operation, which is characterized by quasi-steady rotating-stall behavior. Specialized compressor instrumentation was developed and was used to obtain the necessary surge-cycle performance data, which were then digitized, filtered, and analyzed. The high-speed post-stability characteristics were obtained through the use of a maximum likelihood-parameter estimation technique. The estimated characteristics were found to be insensitive to the presence of measurement noise and unmodelled system dynamics, but the compressor time-response constants, which were also estimated, were more sensitive to these same disturbances. Author

**A87-45405#**
**THE DESIGN OF LOW-STRESS/HIGH PERFORMANCE CENTRIFUGAL IMPELLERS**
P. S. KUO, M. B. FLATHERS, and P. J. ROONEY (Avco Corp., Avco Lycoming Textron, Stratford, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p.
(AIAA PAPER 87-2099)

The highly swept blades employed by state-of-the-art, high performance centrifugal impellers tend to exhibit high localized stresses that may prove detrimental to the structural service life of the component; this problem is exacerbated by the higher operating speeds and elevated temperatures of modern gas turbine engines. Attention is presently given to an interdisciplinary process for impeller design and analysis which recent experience has shown to accomodate structural integrity requirements. Localized blade stresses have been translated into local shape modifications which improve the overall tradeoff between aerodynamic performance and component durability. O.C.

**A87-45450#**
**NAVIER-STOKES ANALYSIS OF A VERY-HIGH-BYPASS-RATIO TURBOFAN ENGINE IN REVERSE THRUST**
JEFFREY J. BROWN (Boeing Commercial Airplane Co., Seattle, WA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-2170)

An algorithm based upon MacCormack's implicit line Gauss-Seidel Navier-Stokes scheme has been modified to model the flowfield in very-high-bypass-ratio turbofan engines under reverse-thrust conditions. It is assumed that reverse thrust is to be achieved through fan blade pitch changes. The physics at the fan blade is modeled using an actuator disk to simulate the fan pumping characteristics. The algorithm, including boundary conditions, is described, and three different flowfields are presented as illustrations of possible results. Author

**A87-45457#**
**ON THE EVOLUTION OF PARTICLE-LADEN JET FLOWS - A THEORETICAL AND EXPERIMENTAL STUDY**
A. A. MOSTAFA, H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), V. G. MCDONNELL, and G. S. SAMUELSEN (California, University, Irvine) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 14 p. refs
(AIAA PAPER 87-2181)

A combined experimental/analytical investigation is being conducted to study the interaction of a fuel nozzle spray with a swirler stabilized flow field. As a first step, the developing regions of an unconfined axisymmetric turbulent jet with and without glass beads of 105 micron diameter has been addressed for two mass loading ratios, LR = 0.2 and 1.0. Benchmark quality data were obtained by using a two-component phase/Doppler technique. The theoretical calculations based on a stochastic Lagrangian treatment along with a two-equation turbulence model for two-phase flows yield reasonable and encouraging agreement with the measurements. Author

**A87-45689**
**CONFORMAL MICROSTRIP COMMUNICATION ANTENNA**
R. E. MUNSON (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) IN: MILCOM '86 - Military Communications Conference, Monterey, CA, Oct. 5-9, 1986, Conference Record. Volume 2 . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 23.3.1-23.3.4.

The characteristics and performance of four types of conformal microstrip antennas are described. The four antennas are: (1) single element antennas with broad coverage; (2) wraparound omnidirectional, missile and satellite antennas; (3) fixed beam conformal microstrip antennas; and (4) electrically scanned microstrip arrays. The advantages associated with using microstrip antennas in communication systems are discussed. Various applications for these four conformal microwave antennas are considered. I.F.

**A87-45876**
**RADAR TECHNOLOGY 1986; SYMPOSIUM, 6TH, BREMEN, WEST GERMANY, NOV. 4-6, 1986, REPORTS [RADARTECHNIK 1986; SYMPOSIUM, 6TH, BREMEN, WEST GERMANY, NOV. 4-6, 1986, VORTRAEGE]**
Symposium sponsored by the Deutsche Gesellschaft fuer Ortung und Navigation, Senatskansle, Bremen, Messerschmitt-Boelkow-Blohm GmbH, et al. Duesseldorf, Deutsche Gesellschaft fuer Ortung und Navigation, 1986, 558 p. In German. For individual items see A87-45877 to A87-45895.

Advances in radar instrumentation, data processing, and applications are discussed in reviews and reports of recent work in West Germany. Topics examined include GaAs ICs for active phased arrays, the biophysics of low-level effects, a surveillance and collision-avoidance system based on standard DME, radar requirements for future avionics systems, rotating-antenna SARs, and a CW radar for ranging with pseudonoise PSK modulation. Consideration is given to a statistical analysis of the ground

interference background in the mm band, ranging with a pulse Doppler radar, wind determination from data on aircraft movement, and a frequency- and polarization-agile 94-GHz pulse Doppler radar. T.K.

**A87-45886**
**AN AUTOMATED RADAR-SIGNATURE MEASUREMENT SYSTEM [AUTOMATISIERTES RADAR-SIGNATUR-MESSSYSTEM]**
JUERGEN KRUSE (Messerschmitt-Boelkow-Blohm GmbH, Bremen, West Germany) IN: Radar Technology 1986; Symposium, 6th, Bremen, West Germany, Nov. 4-6, 1986, Reports . Duesseldorf, Deutsche Gesellschaft fuer Ortung und Navigation, 1986, p. E5.1-E5.21. In German.

The design and operation of an automated measurement facility permitting determination of radar cross sections and location and characterization of scattering centers on aircraft models up to 4.5 m in length are described and illustrated with diagrams, drawings, graphs, and photographs. The facility comprises a 15 x 5.8 x 3.8-m measurement chamber, a rotating platform with maximum load 270 kg and elevation range from -5 to +35 deg (precision 0.1 deg), a tunable broadband 2-18-GHz transmitter, a phase-sensitive receiver, and control and data-processing computers. The analytical techniques employed to correct for measurement errors and to resolve scattering centers both longitudinally and transversely (two-dimensional representation) are explained and demonstrated. The facility is currently being used to develop and evaluate stealth-type aircraft designs. T.K.

**A87-46198#**
**INFLUENCE OF FUEL TEMPERATURE ON ATOMIZATION PERFORMANCE OF PRESSURE-SWIRL ATOMIZERS**
X. F. WANG and A. H. LEFEBVRE (Purdue University, West Lafayette, IN) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 193-199. refs

The influence of fuel temperature on mean drop size and drop-size distribution is examined for aviation gasoline and diesel oil, using three pressure-swirl simplex nozzles. Spray characteristics are measured over wide ranges of fuel injection pressure and ambient air pressure using a Malvern spray analyzer. Fuel temperatures are varied from -20 C to +50 C. Over this range of temperature, the overall effect of an increase in fuel temperature is to reduce the mean drop size and broaden the distribution of drop sizes in the spray. Generally, it is found that the influence of fuel temperature on mean drop size is far more pronounced for diesel oil than for gasoline. For both fuels the beneficial effect of higher fuel temperatures on atomization quality is sensibly independent of ambient air pressure. Author

**A87-46229#**
**A STUDY ON THE EFFECT OF NON-DIMENSIONAL SYSTEM PARAMETERS ON SQUEEZE FILM DAMPER PERFORMANCE USING EXPERIMENTAL DATA**
V. ARUN KUMAR, B. S. PRABHU (National Aeronautical Laboratory, Bangalore, India), and P. A. PARANJPE (Indian Institute of Technology, Madras, India) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 480-485. refs

An attempt is made to formulate guidelines for the design of airbreathing engines' squeeze film dampers, with emphasis on dimensionless shaft amplitude and transmitted force in the bearing-damper plane. Seven important nondimensional sets of variables, taken to be invariants, have been established with respect to various significant squeeze damper parameters. Attention is given to the effects of different nondimensional system parameters on two important nondimensional response parameters. The nondimensional analysis indicates that good vibration attenuation can be obtained for larger values of a newly postulated nondimensional number defined in terms of external oil supply pressure, oil viscosity, and operating speed. O.C.

**A87-46230#**
**APPLICATION OF ENGINE COMPONENT LIFE METHODOLOGY TO LIFE ASSESSMENT**
N. S. SWANSSON and J. D. CYRUS (U.S. Naval Material Command, Naval Air Development Center, Warminster, PA) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 486-493. refs

To provide an assurance that the life of aircraft engine components will meet requirements, a simple methodology has been developed for independently assessing component life and predicting its sensitivity to engine upgrades, material changes, or modifications in usage. Techniques used for life estimation are outlined, and examples of applications given. The relative magnitude of cyclic and hot section usage is of primary significance in predicting specific component failures and failure modes. Predictions based on comparative usage agree with available failure data. Author

**A87-46231#**
**THE MIXING OF JETS UNDER SIMULATED ENGINE-LIKE TURBULENCE**
T. FREUDENBERG and D. K. HENNECKE (Darmstadt, Technische Hochschule, West Germany) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 497-506. Research supported by trhe Stiftung Volkswagenwerk. refs

The effect of engine-like free-stream turbulence on mixing layers of jets in a duct was studied using hot-wire anemometry. The kinetic energy and the length-scale of turbulence were varied. For this purpose a new type of turbulence generator was designed where the turbulence is generated by a large number of jets issuing perpendicular into the main stream. The influence of different length scales could be isolated while the mean velocity distribution and the kinetic energy distribution at the entry of the mixing chamber were kept constant. The experiments were backed up by calculations using the k-epsilon-model. The results show that not only the turbulence intensity has a strong influence on the mixing process but also its spectral distribution, characterized by a length scale. Thus the turbulence scales should be included in more detailed flow calculations for the design of engines. Author

**A87-46244#**
**DEVELOPMENT OF A LASER INTERFEROMETRIC SYSTEM FOR VELOCITY MEASUREMENTS INSIDE A TRANSONIC AXIAL FLOW COMPRESSOR STAGE**
D. ADLER, J. KRIMERMAN, R. SASSON, and M. KLEINER (Technion - Israel Institute of Technology, Haifa) IN: International Symposium on Air Breathing Engines, 8th

**A87-46245#**
**OPTICAL FLOW DIAGNOSTIC MEASUREMENTS IN TURBOMACHINERY**
D. G. JONES and R. J. PARKER (Rolls-Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 607-618. Research supported by the Ministry of Defence (Procurement Executive). refs

Detailed flow measurements within the passages of rotating model fans have been made using nonintrusive laser techniques of holographic flow visualization and laser transit anemometry. The complementary nature of these two techniques uses the ability of holography to provide a diagnostic identification in three dimensions of some of the main features of the flow and the ability of laser anemometry to provide quantitative measurements of the flow velocity at selected spatial locations. The paper shows how these optical techniques, when suitably designed and ruggedized for a hostile environment, have provided quantitative information of the intra-passage flows for a sequence of tests on wide chord fan blades which has aided the validation of their design intent. Author

**A87-46250#**
**STRESS ANALYSIS AND OPTIMISATION OF TURBINE ROTOR BLADE SHROUDS**
R. PADMANABHAN, K. RAMACHANDRA, M. CHANDRASEKARAN, R. V. MADHUSOODHANAN, and B. J. RAGHUNATH (Gas Turbine Research Establishment, Bangalore, India) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings. New York, American Institute of Aeronautics and Astronautics, 1987, p. 659-665

Shroud design and optimization of turbine rotor-blade is quite an involved and important task which influences the mechanical and aerodynamic peeformance of modern aeroengines. This paper deals with some aspects of shroud-failure mechanisms involved in turbine rotor-blades and discusses the results obtained from photoelastic and finite-element stress analysis. Author

**A87-46361**
**CONTRIBUTION OF LASER ANEMOMETRY TO AIRCRAFT SAFETY [APPORT DE L'ANEMOMETRIE LASER A LA SECURITE AERIENNE]**
JACQUES MANDLE (Crouzet, S.A., Division Aerospatiale, Valence, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 122, 1987, p. 2-9. In French. refs

The contribution of laser anemometry to aircraft safety through its use in the calibration of aircraft wind and pressure measurements and in wind shear detection is considered. Following a discussion of the principles of laser anemometry and four standard pressure error calibration methods, the application of laser anemometry to the calibration of aircraft incidence and sideslip is discussed. Calibration precisions of 0.2 deg at 100 kts and 0.1 deg at 200 kts are possible. Ground-based laser anemometry systems for wind shear detection are considered, and a detection range of several dozen kilometers with an intrinsic precision of the order of 3 kts should be possible. Airborne wind shear detection systems provide 5-10 seconds of alert prior to the onset of the phenomenon. R.R.

**A87-46715#**
**THE F-15E R&M CHALLENGE**
FREDRIC L. ABRAMS (USAF, Logistics Operations Center, Wright-Patterson AFB, OH) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 253-257.

The reliability and maintainability drivers, actions taken, and initiatives pursued to meet the objectives for the F-15 Dual Role Fighter program are discussed. Application of the R&M 2000 to both the F-15E and the Mobile Electronic Test Set (METS) will result in increased warfighting capability, with increased F-15E sortie generation, and increased survivability, with the F-15E containing additional systems to counter threats along with additional suppressant foam and more robust structures. The F-15E has conformal fuel tanks to increase its range, thus requiring less tanker support. Better R&M will lead to lower Life Cycle Costs, and changes brought about by METS will reduce intermediate avionics manpower requirements. R.R.

**A87-46728**
**RELIABILITY, 'BETTER THAN THE BEST'**
JOHN SIECZKOS and WILLIAM G. KINDIG (General Electric Co., Binghamton, NY) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 428-432.

The design, testing, and production of commercial and military engine controls are addressed, and the successful transfer of technology and program structure/discipline from the flight control product line to engine controls is reported. Special considerations in the areas of operating environment, operating hours, cycle times, and technology changes from potted modules with hard wiring to printed circuit boards with interconnecting motherboards are discussed. Hardware complexity, including the MIL-HDK-217 predicted analytical failure rate, is also considered. Initial field tests in both the commercial and military user environment demonstrate the high reliability performance of the engine controls. R.R.

**A87-46797#**
**AEROELASTIC DERIVATIVES AS A SENSITIVITY ANALYSIS OF NONLINEAR EQUATIONS**
PAOLO MANTEGAZZA (Milano, Politecnico, Milan, Italy) and GIAMPIERO BINDOLINO AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1145, 1146. refs

It is noted that it is possible to use an appropriate adjoint system of linear equations to reduce the operations required for the calculation of aeroelastic eigensensitivities to O(n) operations, with a consequent substantial gain in efficiency; this is especially true where a large number of parameters is involved in the design process. The approach is useful if the divergence constraint is expressed by a minimum acceptable divergence speed for advanced altitudes or Mach numbers. O.C.

**N87-25496*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**TRUSS-CORE CORRUGATION FOR COMPRESSION LOADS Patent Application**
RANDALL C. DAVIS, inventor (to NASA) and L. ROBERT JACKSON, inventor (to NASA) 5 Mar. 1987 15 p
(NASA-CASE-LAR-13438-1; NAS 1.71:LAR-13438-1; US-PATENT-APPL-SN-022298) Avail: NTIS HC A02/MF A01 CSCL 13M

A corrugated panel structure for supporting compressive loads is described which includes curved cap strips separated by truss-core web segments. The truss-core web segments are formed from first and second flat panels with a corrugated filler therebetween. The corrugated filler extends in the direction of the compressive load. As a result, all components of the panel structure have a compressive load carrying capability resulting in a high strength-to-weight ratio when the compressive load is limiting. Application to rocket and aircraft structures is suggested. NASA

**N87-25534#** Aeronautical Research Inst. of Sweden, Stockholm. Aerodynamics Dept.
**DEVELOPMENT OF A GEOMETRY HANDLING PROGRAM FOR THE FFA SUBSONIC HIGHER ORDER PANEL METHOD**
LARS G. TYSELL Oct. 1986 43 p Sponsored by the Swedish Board for Technical Development
(Contract FFA-AU-PROJ-1731:1; FFA-AU-PROJ-1801:1; FFA-AU-PROJ-1881:1; FFA-AU-PROJ-2041:1; FFA-AU-PROJ-2240)
(FFA-TN-1985-48; ETN-87-99778) Avail: NTIS HC A03/MF A01

A program that simplifies the geometry input procedure to a subsonic higher order panel program, for a complete aircraft is described. All necessary programs were coupled together to a system. A fast equation solver was developed. A user's manual to the whole program system is given. Pressure distributions for a wing-fuselage configuration test case are presented. The agreement between the measurement and the calculation is very good. ESA

**N87-25536#** McDonnell Aircraft Co., St. Louis, Mo.
**VISCID/INVISCID SEPARATED FLOWS Final Report, Sep. 1983 - Mar. 1986**
T. CEBECI, K. C. CHANG, R. W. CLARK, D. P. MACK, and S. M. SCHIMKE Jul. 1986 94 p
(Contract F33615-83-C-3026)
(AD-A179858; MDC-J3968; AFWAL-TR-86-3048) Avail: NTIS HC A05/MF A01 CSCL 20D

A method has been developed for calculating subsonic three-dimensional flows over fighter aircraft configurations at flow conditions including separation. The method employs a viscid inviscid interaction approach, with a panel method used for the inviscid analysis and a finite difference boundary layer method for the viscous analysis. The viscid and inviscid analyses are coupled using an interactive technique based on inverse boundary layer theory. This approach allows efficient calculation of flows with

large separation regions, including both leading and trailing edge separations. The method was validated on three fighter aircraft geometries and comparisons with test data are presented. GRA

**N87-25538#** Sandia National Labs., Albuquerque, N. Mex.
**INFLUENCE OF A HEATED LEADING EDGE ON BOUNDARY LAYER GROWTH, STABILITY AND TRANSITION**
D. B. LANDRUM and J. M. MACHA 1987 11 p Presented at the 19th Fluid Dynamics, Plasma Dynamics and Laser Conference, Honolulu, Hawaii, 8 Jun. 1987
(Contract DE-AC04-76DP-00789)
(DE87-008516; SAND-86-2718C; CONF-870622-3) Avail: NTIS HC A02/MF A01

This paper presents the results of a combined theoretical and experimental study of the influence of a heated leading edge on the growth, stability, and transition of a two-dimensional boundary layer. The findings are directly applicable to aircraft wings and nacelles that use surface heating for anti-icing protection. The potential effects of the non-adiabatic condition are particularly important for laminar-flow sections where even small perturbations can result in significantly degraded aerodynamic performance. The results of the study give new insight to the fundamental coupling between streamwise pressure gradient and surface heat flux in laminar and transitional boundary layers. DOE

**N87-25550#** Aerodyne Products Corp., Billerica, Mass.
**PORTABLE FUEL LEAK DETECTOR Final Report, 1 Jul. 1986 - 1 Jan. 1987**
BURTON D. FIGLER Jan. 1987 37 p
(Contract F33615-86-C-2652)
(AD-A180095; AFWAL-TR-87-2021) Avail: NTIS HC A03/MF A01 CSCL 01C

Aerodyne Products Corp. successfully met the objective of this program by the development of a device for measurement of fuel leaks in aircraft. This device satisfies the two requirements: (1) monitor enclosed bays for fuel leaks, and (2) measure the fuel leak rate. The first application requires a rugged, reliable and inexpensive device that can be mounted in aircraft bays, continuously monitoring for fuel leaks. The second application uses the same device with a battery attachment for ease in handling by personnel to measure fuel leak rates. In this Phase I SBIR program, tests were performed with a breadboard spectral correlation device to determine detection sensitivity and to develop techniques for fuel leak measurements. The device determines the presence of fuel vapor in air by measuring the absorption of infrared radiation by the vapor. Air to be analyzed is drawn into an absorption cell. The device was calibrated with decane and can observe vapor down to 1 part per million. Fuels have the same infrared absorption band. Measurements were made of the leak rate from an aluminum sheet with a 6 mil pinhole. An air sampling tube was placed above the leak, drawing air through the absorption cell. GRA

**N87-25558*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MINIATURE REMOTE DEAD WEIGHT CALIBRATOR Patent Application**
FRANK H. SUPPLEE, JR., inventor (to NASA) and TCHENG PING, inventor (to NASA) 30 Apr. 1987 13 p
(NASA-CASE-LAR-13564-1; US-PATENT-APPL-SN-044180)
Avail: NTIS HC A02/MF A01 CSCL 14B

The invention is a miniature, remote, computer-controlled dead weight calibrator. This device which is comprised of an interlocking rod and dead weight assembly, a motorized lifting mechanism, a controller, and a microcomputer, allows automatic calibration of force transducers needed for wind tunnel operations while the transducers are located within a cryogenic chamber. The operation of a cryogenic transonic wind tunnel requires calibration of force transducers at cryogenic operating temperatures. The invention allows remote, automatic, and sequential loading and unloading of preselected weights. NASA

**N87-25584*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**AUXILIARY DATA INPUT DEVICE Patent Application**
H. DOUGLAS GARNER, inventor (to NASA), ANTHONY M. BUSQUETS, inventor (to NASA), THOMAS W. HOGGE, inventor (to NASA), and RUSSELL V. PARRISH, inventor (to NASA) 18 Jun. 1987 15 p
(NASA-CASE-LAR-13626-1; US-PATENT-APPL-SN-063557)
Avail: NTIS HC A02/MF A01 CSCL 13I

an object of this invention is to provide in a control lever, a continuous, bi-coordinate, data entry device that can be manipulated by an operator's hand without the necessity of removing the hand from the control lever. The improved data entry device is provided with a handle element having a finger portion. A ball element is rotatably disposed in the finger portion and remains subject to manipulation by a single finger of the human hand grasping the handle element. The combination of drive shafts, roller elements, disk elements, light sources, and photodetection elements provide continuous output signals that describe the magnitide and direction of the ball element in two dimensions. The output signals can then be utilized, for example, to change the heading of an aircraft. NASA

**N87-25604#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
**ANALYTICAL DESCRIPTION OF CRACK RESISTANCE CURVES FOR ALUMINUM SHEETS USED IN AIRCRAFT CONSTRUCTION**
VUI NGUYEN-HOANG 1986 4 p Repr. from Aluminum, v. 62, no. 8, 1986 p 593-595 In GERMAN; ENGLISH summary
(MBB-UT-133/85; ETN-87-99964) Avail: Issuing Activity

The R-curve concept was applied to predict the load-bearing capacity and the critical damage parameters for aluminum sheet aircraft components. The R-curves for the alloys 2024-T3, 7075-T6, and 7475-T761 are given, and the materials constants for the R-curves were determined. It was assumed that the contants C1 to C4 are valid for various sheet widths, sheet thicknesses, and crack lengths. This assumption was justified by the agreement found between predicted and experimental values of these constants. It is therefore justified to recommend the R-curve concept in the presented form for the prediction of residual strength and critical crack length. ESA

**N87-26004*#** General Dynamics Corp., St. Louis, Mo.
**COMPUTATIONAL FLUID DYNAMICS: TRANSITION TO DESIGN APPLICATIONS**
R. G. BRADLEY, I. C. BHATELEY, and G. A. HOWELL *In* NASA. Ames Research Center, Supercomputing in Aerospace p 69-76 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 20D

The development of aerospace vehicles, over the years, was an evolutionary process in which engineering progress in the aerospace community was based, generally, on prior experience and data bases obtained through wind tunnel and flight testing. Advances in the fundamental understanding of flow physics, wind tunnel and flight test capability, and mathematical insights into the governing flow equations were translated into improved air vehicle design. The modern day field of Computational Fluid Dynamics (CFD) is a continuation of the growth in analytical capability and the digital mathematics needed to solve the more rigorous form of the flow equations. Some of the technical and managerial challenges that result from rapidly developing CFD capabilites, some of the steps being taken by the Fort Worth Division of General Dynamics to meet these challenges, and some of the specific areas of application for high performance air vehicles are presented. Author

**N87-26007*#** McDonnell-Douglas Research Labs., St. Louis, Mo. Flight Sciences Dept.
**COMPUTATIONAL FLUID DYNAMICS APPLICATIONS AT MCDONNEL DOUGLAS**
R. J. HAKKINEN *In* NASA. Ames Research Center, Supercomputing in Aerospace p 109-121 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 20D

Representative examples are presented of applications and development of advanced Computational Fluid Dynamics (CFD) codes for aerodynamic design at the McDonnell Douglas Corporation (MDC). Transonic potential and Euler codes, interactively coupled with boundary layer computation, and solutions of slender-layer Navier-Stokes approximation are applied to aircraft wing/body calculations. An optimization procedure using evolution theory is described in the context of transonic wing design. Euler methods are presented for analysis of hypersonic configurations, and helicopter rotors in hover and forward flight. Several of these projects were accepted for access to the Numerical Aerodynamic Simulation (NAS) facility at the NASA-Ames Research Center. Author

**N87-26011*#** United Technologies Research Center, East Hartford, Conn. Aeromechanics Research.
**COMPUTATIONAL FLUID DYNAMICS RESEARCH AT THE UNITED TECHNOLOGIES RESEARCH CENTER REQUIRING SUPERCOMPUTERS**
ANTON J. LANDGREBE *In* NASA. Ames Research Center, Supercomputing in Aerospace p 159-174 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 20D

An overview of research activities at the United Technologies Research Center (UTRC) in the area of Computational Fluid Dynamics (CFD) is presented. The requirement and use of various levels of computers, including supercomputers, for the CFD activities is described. Examples of CFD directed toward applications to helicopters, turbomachinery, heat exchangers, and the National Aerospace Plane are included. Helicopter rotor codes for the prediction of rotor and fuselage flow fields and airloads were developed with emphasis on rotor wake modeling. Airflow and airload predictions and comparisons with experimental data are presented. Examples are presented of recent parabolized Navier-Stokes and full Navier-Stokes solutions for hypersonic shock-wave/boundary layer interaction, and hydrogen/air supersonic combustion. In addition, other examples of CFD efforts in turbomachinery Navier-Stokes methodology and separated flow modeling are presented. A brief discussion of the 3-tier scientific computing environment is also presented, in which the researcher has access to workstations, mid-size computers, and supercomputers. Author

**N87-26022*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS ABOUT THREE-DIMENSIONAL CONFIGURATIONS: A SURVEY**
TERRY L. HOLST *In its* Supercomputing in Aerospace p 281-298 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 20D

The numerical solution of the Navier-Stokes equations about three-dimensional configurations is reviewed. Formulational and computational requirements for the various Navier-Stokes approaches are examined for typical problems including the viscous flow field solution about a complete aerospace vehicle. Recent computed results, with experimental comparisons when available, are presented to highlight the presentation. The future of Navier-Stokes applications in three-dimensions is seen to be rapidly expanding across a broad front including internal and external flows, and flows across the entire speed regime from incompressible to hypersonic applications. Prospects for the future are described and recommendations for areas of concentrated research are indicated. Author

**N87-26259#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Abteilung HF-Physik.
**A CONFORMAL AIRCRAFT PHASED ARRAY ANTENNA FOR AIRPLANE-SATELLITE COMMUNICATION IN THE L BAND**
GEORG SPLITT and HANS FORSTER Sep. 1986 94 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1057)
(DFVLR-FB-86-47; ISSN-0171-1342; ETN-87-99688) Avail: NTIS HC A05/MF A01; DFVLR, Cologne, West Germany DM 34

A medium gain antenna was developed for direct reception of the MARECS satellite. The antenna system is conformal with the outer skin of the airplane. It was designed as a phased-array system consisting of six individual elements placed in a vertical row. The radiation pattern can be moved in elevation, and can thus be pointed towards the satellite. The halfwidth in elevation direction is 17 deg arc, and in azimuthal direction 120 deg arc. The measurements show a gain between 9 and 10.8 dBi, depending on the lobe, and an efficiency of 65%. The suppression of the mirror reflection by the antenna diagram is between -20 and -25 dB. ESA

**N87-26301** ESDU International Ltd., London (England).
**ESTIMATION OF SPILLAGE DRAG FOR A WIDE RANGE OF AXISYMMETRIC INTAKES AT M 1**
Apr. 1984 42 p
(ESDU-84004; ISBN-0-85679-466-X; ISSN-0141-4054) Avail: ESDU

ESDU 84004 gives a correlation of experimental data drawn from a large number of sources that enables spillage drag to be estimated for a wide range of configurations at incidences up to 20 degrees and for mass flow ratios from zero to unity. The method is well suited to aircraft project studies and one particular application is providing spillage drag at low values of intake mass flow (i.e., 0.4) for use with the bare-engine windmilling drag and airflow data of ESDU 81009. That combined use of those two ESDU methods to estimate the drag of an inoperative turbojet or turbofan engine is described in ESDU 84005. Two comprehensive practical worked examples illustrate the use of the correlation. ESDU

**N87-26324** ESDU International Ltd., London (England).
**THE TREATMENT OF CALIBRATIONS OF TOTAL AIR TEMPERATURE PROBES FOR USE IN FLIGHT-TEST ANALYSIS WORK**
Jul. 1984 20 p Supersedes ESDU-Perf-RG1/5
(ESDU-84007; ESDU-PERF-RG1/5; ISBN-0-85679-469-4; ISSN-0141-4054) Avail: ESDU

ESDU 84007 is concerned with the necessary further treatment of data provided by the manufacturer of the total temperature probe to ensure that results obtained using it are correct under flight conditions. The systematic errors to probe temperature recovery treated are those due to radiation, self heating and, in the case of unsteady conditions, lag. Methods are given for deriving true values of total and ambient temperature which include consideration of the effects of both aircraft and probe-generated shock waves. A particular feature is the treatment of the lag response of a probe having two terms in its response equation. A worked example illustrates the evaluation of true total temperature from flight tests data recorded in supersonic flight through an area of changing temperature. ESDU

**N87-26399*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**A HIGH TEMPERATURE FATIGUE AND STRUCTURES TESTING FACILITY**
PAUL A. BARTOLOTTA and MICHAEL A. MCGAW Aug. 1987 24 p
(NASA-TM-100151; E-3712; NAS 1.15:100151) Avail: NTIS HC A02/MF A01 CSCL 20K

As man strives for higher levels of sophistication in air and space transportation, awareness of the need for accurate life and material behavior predictions for advanced propulsion system components is heightened. Such sophistication will require complex

operating conditions and advanced materials to meet goals in performance, thrust-to-weight ratio, and fuel efficiency. To accomplish these goals will require that components be designed using a high percentage of the material's ultimate capabilities. This serves only to complicate matters dealing with life and material behavior predictions. An essential component of material behavior model development is the underlying experimentation which must occur to identify phenomena. To support experimentation, the NASA Lewis Research Center's High Temperature Fatigue and Structures Laboratory has been expanded significantly. Several new materials testing systems have been added, as well as an extensive computer system. The intent of this paper is to present an overview of the laboratory, and to discuss specific aspects of the test systems. A limited discussion of computer capabilities will also be presented. Author

**N87-26837** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.
**DEVELOPMENT OF NOVEL BEARINGLESS ROTOR SYSTEMS [ENTWICKLUNG NEUARTIGER LAGERLOSER ROTORSYSTEME]**
HENNING STREHLOW and HUBERT FROMMLET *In its* Research and Development. Technical-Scientific Publications 1986 p 147-166 1986 In GERMAN Presented at the 4th BMFT-Statusseminar, Munich, West Germany, 28-30 Apr. 1986
(MBB-UD-471/86) Avail: Issuing Activity

An efficient bearingless main rotor system for a light multipurpose helicopter was developed. It concerns a further development of the Boelkow fiber composite jointless rotor system. Two bearingless rotor systems with different systems design and blade-angle control were tested on a rotor teststand and on the BO-105 helicopter. Experimental and theoretical investigation, including components testing were carried out. The test results were successful, and can be used for the definition of the final prototypes, especially with respect to the aerodynamic and structural systems optimization. An optimized blade form and profile are proposed. Profile wind tunnel measurements and power measurements on the rotor teststand show a 6% power increase compared to the BO-105 series blade. ESA

## 13

## GEOSCIENCES

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

**A87-44702**
**WHERE AND WHEN HELICOPTER ICING OCCURS**
DAVID A. FORRESTER (Meteorological Office, Bracknell, England) IN: Helicopter Rotor Icing Symposium, London, England, Jan. 14, 1986, Proceedings . London, Royal Aeronautical Society, 1986, p. 1-23.

The use of temperature and liquid water content (LWC) data to accurately forecast icing conditions is considered. Hazardous conditions are created by subzero temperatures, snow, and freezing rain. Estimating the adiabatic values of LWC for various cloud types, and the properties of clouds are examined. It is observed that there is no significant icing near the cloud base; precipitating clouds have large LWC and often exceed the adiabatic values; and cumulus, stratocumulus, low frontal clouds, and deep mature fog approach the adiabatic limit. The effect of droplet size distribution on icing and the relation between air mass origin and LWC are investigated. Seasonal and annual vertical frequency cloud profiles; the frequency of subzero clouds, clouds at 900 mb, and of encountering freezing rain; 0 C isotherm levels; and the ratio of convective to layer cloud are analyzed using flight reconnaissance data. The frequencies of various types of precipitation, and the correlation between precipitation type and temperature are studied. The need for improvement in observing LWC and for a numerical output model in order to improve icing forecasts is discussed. I.F.

**A87-45892**
**WIND DETERMINATION FROM AIRCRAFT-MOVEMENT DATA [WINDBERECHNUNG AUS DATEN VON FLUGZEUGBEWEGUNGEN]**
H. J. HERMANNS (Eurocontrol, Maastricht, Netherlands) IN: Radar Technology 1986; Symposium, 6th, Bremen, West Germany, Nov. 4-6, 1986, Reports . Duesseldorf, Deutsche Gesellschaft fuer Ortung und Navigation, 1986, p. G3.1-G3.55. In German.

The importance of accurate wind data for ATC is discussed; the inadequacy of wind data based on global forecasts, airport measurements, and pilot reports is indicated; and techniques for estimating the prevailing upper winds by comparing the true airspeeds (TASs) of aircraft on particular routes with their radar-determined ground speeds are proposed and demonstrated. The theoretical basis of the TAS-based method (Ehrmanntraut and Hermanns, 1985) and the steps required for its practical implementation are explained in detail and illustrated with extensive diagrams, maps, flow charts, and graphs. T.K.

**A87-45962**
**ANALYSIS OF A MICROBURST IN THE FACE METEOROLOGICAL MESONETWORK IN SOUTHERN FLORIDA**
FERNANDO CARACENA (NOAA, Boulder, CO) and MICHAEL W. MAIER (Lightning Location and Protection, Inc., Tucson, AZ) Monthly Weather Review (ISSN 0027-0644), vol. 115, May 1987, p. 969-985. refs

As a part of a study to produce a basis for forecasting all microbursts, the multiscale environmental conditions which resulted in a wet microburst that occurred in the Florida Area Cumulus Experiment meteorological mesonetwork at 1747 UTC on July 1, 1975 were investigated. Several features were found: (1) a dry layer above 500 mb overlying a nearly moist adiabatic lower tropospheric layer, (2) a short-wave trough approaching the area from the north-northeast along the western side of a synoptic-scale trough, (3) an increased shear in the lower troposphere, and (4) a strong boundary-layer forcing, first by a lake breeze front off the Lake Okeechobee, then by convective gust fronts. The site of the microburst itself was in the portion of the storm where a new cell was initiated by a strong gust front in the area where rain was still falling from an older, dissipating cell. I.S.

**A87-46481**
**LARGE-SCALE DISTRIBUTION OF PEROXYACETYLNITRATE RESULTS FROM THE STRATOZ III FLIGHTS**
J. RUDOLPH, B. VIERKORN-RUDOLPH, and F. X. MEIXNER (Kernforschungsanlage Juelich, GmbH, Institut fuer Chemie, West Germany) Journal of Geophysical Research (ISSN 0148-0227), vol. 92, June 20, 1987, p. 6653-6661. BMFT-supported research. refs

**A87-46757#**
**STATISTICAL DISTRIBUTION OF EXTREME ATMOSPHERIC TURBULENCES [DISTRIBUTION STATISTIQUE DES TURBULENCES ATMOSPHERIQUES EXTREMES]**
G. COUPRY (ONERA, Chatillon-sous-Bagneux, France) (Canadian Congress of Applied Mechanics, 11th, University of Alberta, Edmonton, Canada, May 31-June 4, 1987) ONERA, TP, no. 1987-56, 1987, 3 p. In French. refs
(ONERA, TP NO. 1987-56)

Data from close to one million hours of flight obtained over a five year period, including 600 events corresponding to high turbulence, have been analyzed to study the variations of loading factors due to turbulence with an amplitude exceeding 0.5 g and the corrresponding flight parameters. The Hall formula is used to relate the acceleration data bank to the turbulence data bank. Results verify that the static distribution of these strong turbulences is well represented by Gumbel's extreme value theory, making possible extrapolation of the data to exceptional events. R.R.

**N87-25268*#** Federal Aviation Administration, Washington, D.C.
**CASE HISTORY OF FAA/SRI WIND SHEAR MODELS**
HERBERT SCHLICKENMAIER *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 3-10 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

In order to understand the development of the FAA/SRI wind fields, it is important to understand the operating philosophy of the FAA's Wind Shear Program Office. The goal of the office was to ensure an integrated solution to the wind shear problem which addressed three area: ground based equipment and coordination; airborne systems and procedures; and weather prediction. This triply addressed goal was central to the development of the wind fields. The primary user of the wind shear modeling during the FAA's program was airborne simulation. The project requirement was to use wind shear models that resulted from accidents so that effective procedures and/or equipment could be found for hazardous wind shear encounters. The wind shear model development is discussed in detail. Author

**N87-25269*#** Federal Aviation Administration, Washington, D.C. Office of Flight Operations.
**HISTORY OF WIND SHEAR TURBULENCE MODELS**
LOU CUSIMANO *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 11-12 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

The Office of Flight Operations, Flight Technical Programs Div., at the FAA Headquarters, interfaces with industry, R&D communities and air carriers during the introduction of new types of equipment into operational services. A brief highlight of the need which FAA operations sees for new wind shear and turbulence data sets from the viewpoint of equipment certification and simulation is presented. Author

**N87-25270*#** National Center for Atmospheric Research, Boulder, Colo. JAWS Project.
**INTRODUCTION TO THE JAWS PROGRAM**
JOHN MCCARTHY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 13-27 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

The JAWS Project is the Joint Airport Weather Studies project conceived in 1980 jointly between the National Center for Atmospheric Research and the Univ. of Chicago. The objectives of the program are threefold: (1) Basic scientific characterization of the microbursts and the statistics of microbursts occurrence; (2) Detection and warning, using the Low Level Wind Shear Alert System (LLWSAS) operation and performance; and (3) Doppler radar and airborne systems. These goals and the operation of the JAWS system in general are discussed in detail. Author

**N87-25271*#** National Center for Atmospheric Research, Boulder, Colo. Joint Airport Weather Studies Project.
**JAWS MULTIPLE DOPPLER DERIVED WINDS**
KIMBERLY L. ELMORE *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 29-42 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

An elementary working knowledge is given of the advantages and limitations of the multiple Doppler radar analyses that have recently become available from the Joint Airport Weather Studies (JAWS) project. What Doppler radar is and what it does is addressed and the way Doppler radars were used in the JAWS project to gather wind shear data is described. The working definition of wind shear used is winds that affect aircraft flight over a span of 15 to 45 seconds and turbulence is defined as air motion that cause abrupt aircraft motions. The JAWS data current available contain no turbulence data. The concept of multiple Doppler analysis and the geometry of how it works are described, followed by an explanation of how data gathered in radar space are interpolated to a common Cartesian coordinate system and the limitations involved. A discussion is also presented of the analysis grid and how it was constructed. What the user actually gets is discussed, followed by a discussion of the expected errors in the three orthogonal wind components. Finally, a discussion is presented of why JAWS data are significant. Author

**N87-25272*#** National Center for Atmospheric Research, Boulder, Colo. JAWS Project.
**STATUS OF THE JAWS PROGRAM**
JOHN MCCARTHY *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 43-47 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

Preliminary data description of the August 5, 1982, microburst case is available. Its use in simulation of microburst is discussed, excluding the turbulence part, since it is not available. Author

**N87-25274*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**WIND SHEAR AND TURBULENCE SIMULATION**
ROLAND L. BOWLES *In its* Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 67-95 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

The aviation community is increasing its reliance on flight simulators. This is true both in pilot training and in research and development. In moving research concepts through the development pipeline, there is a sequence of events which take place: analysis, ground based simulation, inflight simulation, and flight testing. Increasing fidelity as progress toward the flight testing arena is accompanied by increasing cost. The question that seems to be posed in relation to the meteorological aspects of flight simulation is, How much fidelity is enough and can it be quantified. As a part of the Langley Simulation Technology Program, there are three principal areas of focus, one being improved simulation of weather hazards. A close liaison with the JAWS project was established because of the Langley Simulation Technology interests regarding reliable simulation of severe convective weather phenomena and their impact on aviation systems. Simulation offers the only feasible approach for examining the utility of new technology and new procedures for coping with severe convective weather phenomena such as wind shear. These simulation concepts are discussed in detail. Author

**N87-25277*#** FWG Associates, Inc., Tullahoma, Tenn.
**TURBULENCE MODELS**
WALTER FROST *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 125-151 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 04B

The subject of modeling turbulence for use with the JAWS wind shear data sets is addressed. The present FAA AC 120-41 wind shear models are quasisteady wind models. FAA recommends superimposing upon these winds a Dryden spectrum model of turbulence. For the JAWS data, it must be decided whether this approach is adequate or whether turbulence must be analyzed and modeled differently. This question is discussed in detail. Author

**N87-25621*#** Ohio State Univ., Columbus.
**WIND TUNNEL EVALUATION OF A TRUNCATED NACA 64-621 AIRFOIL FOR WIND TURBINE APPLICATIONS Final Report**
S. P. LAW and G. M. GREGOREK Jul. 1987 37 p
(Contract NAG3-330)
(NASA-CR-180803; DOE/NASA/0330-2; NAS 1.26:180803)
Avail: NTIS HC A03/MF A01 CSCL 10A

An experimental program to measure the aerodynamic performance of a NACA 64-621 airfoil with a truncated trailing edge for wind turbine applications has been conducted in the Ohio State University Aeronautical and Astronautical Research Laboratory 6 in. by 21 in. pressurized wind tunnel. The blunted or trailing edge truncated (TET) airfoil has an advantage over similar trailing edge airfoils because it is able to streamline a larger spar structure, while also providing aerodynamic properties that are quite good. Surface pressures were measured and integrated to

determine the lift, pressure drag, and moment coefficients over angles of attack ranging from -14 to +90 deg at Mach 0.2 and Reynolds numbers of 1,000,000 and 600,000. Results are compared to the NACA 0025, 0030, and 0035 thick airfoils with sharp trailing edges. Comparison shows that the 30 percent thick NACA 64-621-TET airfoil has higher maximum lift, higher lift curve slope, lower drag at higher lift coefficients, and higher chordwise force coefficient than similar thick airfoils with sharp trailing edges. Author

**N87-26476#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Abteilung Wolkenphysik.

**EXPERIENCES WITH HOT-WIRE INSTRUMENTS FOR THE MEASUREMENT OF THE LIQUID WATER CONTENT IN CLOUDS**

HANS-EBERHARD HOFFMANN, JOHANN DEMMEL, and HEINZ LOEBEL Aug. 1986 47 p In GERMAN; ENGLISH summary (DFVLR-MITT-86; ISSN-0176-7739; ETN-87-99678) Avail: NTIS HC A03/MF A01; DFVLR, Cologne, West Germany DM 16.50

Experiences with hot-wire instruments obtained in special calibrating flight, in research on icing, and in wind tunnel calibrations, are discussed. The results of airborne measurement of the liquid water content by the hot-wire instruments Johnson-Williams (J-W) and Csiro-King (C-K) are in very good agreement. This is valid for a liquid water content between 0.04 and 0.46 g/cum, and after a perfect calibration in dry air and an elimination of systematic errors. The values for dry air of the J-W instrument are not or very little affected by changes of flight velocity, altitude and temperature; the values of the C-K instrument are strongly affected. Radio signals have a large influence on the C-K signals. Atmospheric turbulence and banking in flight cause output signals similar to those due to the liquid water content. For the C-K instrument, the transfer of wind tunnel calibration data to flight measurements is not possible with sufficient accuracy. ESA

## 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.

**A87-43388#**

**COMPONENT MODE ITERATION FOR FREQUENCY CALCULATIONS**

JEFFREY K. BENNIGHOF (Texas, University, Austin) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 996-1002. refs (AIAA PAPER 86-1023)

This paper presents component mode iteration, a new method for carrying out a form of subspace iteration on the substructure level, for structures composed of substructures. In component mode iteration, substructure displacement is in terms of 'component modes' with the interface displacements as coefficients. Component modes are chosen such that exact compatibility is assured throughout the structure. The reduced structure eigenvalue problem is assembled and solved for lower mode approximations. The resulting estimates of lower mode interface motion are used to refine the component modes by approximating the dynamic response of substructures to interface motion with a vector iteration process. For this step, the substructures are independent and can be processed in parallel. Reassembly and solution of the reduced structure yields improved lower mode estimates. Further iterations of refinement and reassembly are performed until convergence takes place. The initial component modes are generated automatically and at negligible expense and numerical examples show that convergence with these is excellent, yielding very accurate results after only one iteration. Indeed, convergence is shown to be significantly faster than in the standard subspace iteration method. Author

**A87-44241**

**DESIGN OF AN AUTOMATED INFORMATION-PROCESSING SYSTEM [ENTWURF EINES AUTOMATISIERTEN INFORMATIONSVERARBEITUNGSSYSTEMS]**

MANFRED SCHUELER (Interflug Gesellschaft fuer Internationalen Flugverkehr mbH, Berlin, East Germany) Technisch-oekonomische Information der zivilen Luftfahrt (ISSN 0232-5012), vol. 23, no. 2, 1987, p. 59-62. In German.

The design concept of the information-processing system developed for the aircraft-maintenance department of Interflug is outlined, and the software for reliability analysis (RA) is described in detail, summarizing selected chapters of the author's dissertation (1985). The overall system is designed to optimize the way in which the maintenance capacity of the department is applied to meet the demand for flight-ready aircraft. A functional model of department operations is broken down into objects and attributes which are used to divide the system into task complexes and construct the appropriate data bases. The programs and subprograms of the menu-based RA software framework, written in BASIC, are listed and briefly characterized. Routine use of a PC implementation of the RA program began in January 1987. T.K.

**A87-44712**

**DESIGN OF MOTION SIMULATION SOFTWARE WITH DIGITAL FILTERING TECHNIQUES**

R. A. R. ALMEIDA (ABC Teleinformatica, Brazil) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 47-63.

The application of digital filtering techniques to the design of motion simulation software for flight simulators is studied in this work. Some design criteria for three types of filters, used in classical washout schemes, are developed, taking into account the performance specifications of the motion system and the acceleration envelope of the simulated aircraft. The utilization of the methodology is illustrated with the design of three filters, whose responses simulated in a digital computer are presented. Author

**A87-44713**

**MOTION SOFTWARE FOR A RESEARCH FLIGHT SIMULATOR**

B. N. TOMLINSON (Royal Aircraft Establishment, Farnborough, England) IN: Advances in flight simulation - visual and motion systems; Proceedings of the International Conference, London, England, Apr. 29-May 1, 1986 . London, Royal Aeronautical Society, 1986, p. 64-80. refs

The motion software requirements for a flight simulator are discussed. The role of the research simulator at RAE, Bedford, and its motion system are described. The motion software is a suite of complex computer programs which transform aircraft response variables into commands to the motion hardware. The software must (1) generate primary cue demands, (2) coordinate cues, (3) produce special effects, (4) compute and transmit drive signals, and (5) monitor motion activity. The designing of the motion software to allow for alternative cue algorithms and versatility, and software packages for modeling and analyzing the data are examined. I.F.

**A87-45771*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ANALYSIS OF TYPICAL FAULT-TOLERANT ARCHITECTURES USING HARP**

SALVATORE J. BAVUSO (NASA, Langley Research Center, Hampton, VA), JOANNE BECHTA DUGAN, KISHOR S. TRIVEDI, ELIZABETH M. ROTHMANN, and W. EARL SMITH (Duke University, Durham, NC) IEEE Transactions on Reliability (ISSN 0018-9529), vol. R-36, June 1987, p. 176-185. refs

Difficulties encountered in the modeling of fault-tolerant systems are discussed. The Hybrid Automated Reliability Predictor (HARP)

approach to modeling fault-tolerant systems is described. The HARP is written in FORTRAN, consists of nearly 30,000 lines of codes and comments, and is based on behavioral decomposition. Using the behavioral decomposition, the dependability model is divided into fault-occurrence/repair and fault/error-handling models; the characteristics and combining of these two models are examined. Examples in which the HARP is applied to the modeling of some typical fault-tolerant systems, including a local-area network, two fault-tolerant computer systems, and a flight control system, are presented. I.F.

**A87-46365**
**PROJECT FOR AN INTELLIGENT SYSTEM FOR ON-LINE TROUBLE SHOOTING [UN PROJET DE SYSTEME 'INTELLIGENT' POUR L'AIDE AU DEPANNAGE EN LIGNE]**
P. CHANET and J.-P. FOURNIER (Aerospatiale, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 122, 1987, p. 58-61. In French.

The application of onboard artificial intelligence systems for trouble shooting on commercial aircraft is considered. An ideal system should provide 'intelligent' reports, diagnostic information, and action proposals. Constraints imposed on the dialogue between the technician and the system are discussed. The manner of response of the system should be geared to the particular changing situation of the aircraft, and the intelligent system should provide a level of information and a dialogue strategy commensurate with the needs of the technician. The possibilities of communication in natural language and via graphics are also discussed. R.R.

**N87-25771*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SURVEY OF CURRENTLY AVAILABLE HIGH-RESOLUTION RASTER GRAPHICS SYSTEMS**
DENISE R. JONES Jul. 1987 20 p
(NASA-TM-89139; L-16294; NAS 1.15:89139) Avail: NTIS HC A02/MF A01 CSCL 09B

Presented are data obtained on high-resolution raster graphics engines currently available on the market. The data were obtained through survey responses received from various vendors and also from product literature. The questionnaire developed for this survey was basically a list of characteristics desired in a high performance color raster graphics system which could perform real-time aircraft simulations. Several vendors responded to the survey, with most reporting on their most advanced high-performance, high-resolution raster graphics engine. Author

**N87-25786#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Transport Aircraft Div.
**AUTOMATED SYSTEMS FOR THE MANUFACTURE OF AIRBUS VERTICAL STABILIZERS**
RUDOLF BERFRANZ 1986 6 p Presented at the 15th International Council of the Aeronautical Sciences (ICAS) Congress, London, England, 7-12 Sep. 1986
(MBB-UT-17-86; ETN-87-99960) Avail: Issuing Activity

A full series of Airbus vertical stabilizers with spar boxes in CFRP was produced using a module based production process, intended to become fully automatic. With full mechanization and automation, production costs are expected to be similar to those for a comparable all-metal structure. ESA

**N87-25804*#** Connecticut Univ., Storrs. Dept. of Electrical and Systems Engineering.
**DUAL ADAPTIVE CONTROL: DESIGN PRINCIPLES AND APPLICATIONS**
PURUSOTTAM MOOKERJEE, YAAKOV BARSHALOM, and JOHN A. MOLUSIS Jun. 1987 118 p
(Contract NAG2-318)
(NASA-CR-181050; NAS 1.26:181050) Avail: NTIS HC A06/MF A01 CSCL 09B

An adaptive dual control solution was developed for an ARMA MIMO system. This solution captures the dual effect by performing a second order Taylor series expansion of the expected future cost. It modifies the cautious solution by numerator and denominator correction terms. Analysis of the simulation runs has shown that this dual control solution applied to a multi-input multi-output model improves over the cautious controller. The key improvement is in the avoiding of situations like turnoff and slow convergences, typical of the cautious solution. Author

**N87-25806*#** Information and Control Systems, Inc., Hampton, Va.
**A COMBINED STOCHASTIC FEEDFORWARD AND FEEDBACK CONTROL DESIGN METHODOLOGY WITH APPLICATION TO AUTOLAND DESIGN Final Report**
NESIM HALYO Washington NASA Jul. 1987 130 p
(Contract NAS1-16158)
(NASA-CR-4078; NAS 1.26:4078; FR-687102) Avail: NTIS HC A07/MF A01 CSCL 09B

A combined stochastic feedforward and feedback control design methodology was developed. The objective of the feedforward control law is to track the commanded trajectory, whereas the feedback control law tries to maintain the plant state near the desired trajectory in the presence of disturbances and uncertainties about the plant. The feedforward control law design is formulated as a stochastic optimization problem and is embedded into the stochastic output feedback problem where the plant contains unstable and uncontrollable modes. An algorithm to compute the optimal feedforward is developed. In this approach, the use of error integral feedback, dynamic compensation, control rate command structures are an integral part of the methodology. An incremental implementation is recommended. Results on the eigenvalues of the implemented versus designed control laws are presented. The stochastic feedforward/feedback control methodology is used to design a digital automatic landing system for the ATOPS Research Vehicle, a Boeing 737-100 aircraft. The system control modes include localizer and glideslope capture and track, and flare to touchdown. Results of a detailed nonlinear simulation of the digital control laws, actuator systems, and aircraft aerodynamics are presented. Author

**N87-25807*#** Purdue Univ., West Lafayette, Ind. School of Aeronautics and Astronautics.
**OPTIMAL COOPERATIVE CONTROL SYNTHESIS OF ACTIVE DISPLAYS Final Contractor Report**
SANJAY GARY and DAVID K. SCHMIDT Washington NASA Jun. 1987 169 p
(Contract NAG2-228)
(NASA-CR-4058; H-1378; NAS 1.26:4058) Avail: NTIS HC A08/MF A01 CSCL 09B

A technique is developed that is intended to provide a systematic approach to synthesizing display augmentation for optimal manual control in complex, closed-loop tasks. A cooperative control synthesis technique, previously developed to design pilot-optimal control augmentation for the plant, is extended to incorporate the simultaneous design of performance enhancing displays. The technique utilizes an optimal control model of the man in the loop. It is applied to the design of a quickening control law for a display and a simple K/(s squared) plant, and then to an F-15 type aircraft in a multichannel task. Utilizing the closed-loop modeling and analysis procedures, the results from the display design algorithm are evaluated and an analytical validation is performed. Experimental validation is recommended for future efforts. Author

**N87-26006*#** Rockwell International Science Center, Thousand Oaks, Calif.
**DEVELOPMENT AND APPLICATION OF UNIFIED ALGORITHMS FOR PROBLEMS IN COMPUTATIONAL SCIENCE**
VIJAYA SHANKAR and SUKUMAR CHAKRAVARTHY *In* NASA. Ames Research Center, Supercomputing in Aerospace p 87-107 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 09B

A framework is presented for developing computationally unified numerical algorithms for solving nonlinear equations that arise in modeling various problems in mathematical physics. The concept of computational unification is an attempt to encompass efficient

solution procedures for computing various nonlinear phenomena that may occur in a given problem. For example, in Computational Fluid Dynamics (CFD), a unified algorithm will be one that allows for solutions to subsonic (elliptic), transonic (mixed elliptic-hyperbolic), and supersonic (hyperbolic) flows for both steady and unsteady problems. The objectives are: development of superior unified algorithms emphasizing accuracy and efficiency aspects; development of codes based on selected algorithms leading to validation; application of mature codes to realistic problems; and extension/application of CFD-based algorithms to problems in other areas of mathematical physics. The ultimate objective is to achieve integration of multidisciplinary technologies to enhance synergism in the design process through computational simulation. Specific unified algorithms for a hierarchy of gas dynamics equations and their applications to two other areas: electromagnetic scattering, and laser-materials interaction accounting for melting. Author

**N87-26008*#** Northrop Corp., Hawthorne, Calif. Aircraft Div.
**APPLICATION OF COMPUTATIONAL PHYSICS WITHIN NORTHROP**
M. W. GEORGE, R. T. LING, J. F. MANGUS, and W. T. THOMPKINS (Northrop Research and Technology Center, Palos Verdes Peninsula, Calif.) *In* NASA. Ames Research Center, Supercomputing in Aerospace p 125-137 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 09B

An overview of Northrop programs in computational physics is presented. These programs depend on access to today's supercomputers, such as the Numerical Aerodynamical Simulator (NAS), and future growth on the continuing evolution of computational engines. Descriptions here are concentrated on the following areas: computational fluid dynamics (CFD), computational electromagnetics (CEM), computer architectures, and expert systems. Current efforts and future directions in these areas are presented. The impact of advances in the CFD area is described, and parallels are drawn to analagous developments in CEM. The relationship between advances in these areas and the development of advances (parallel) architectures and expert systems is also presented. Author

**N87-26010*#** General Electric Co., Cincinnati, Ohio.
**DESIGN APPLICATIONS FOR SUPERCOMPUTERS**
C. J. STUDERUS *In* NASA. Ames Research Center, Supercomputing in Aerospace p 149-158 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 09B

The complexity of codes for solutions of real aerodynamic problems has progressed from simple two-dimensional models to three-dimensional inviscid and viscous models. As the algorithms used in the codes increased in accuracy, speed and robustness, the codes were steadily incorporated into standard design processes. The highly sophisticated codes, which provide solutions to the truly complex flows, require computers with large memory and high computational speed. The advent of high-speed supercomputers, such that the solutions of these complex flows become more practical, permits the introduction of the codes into the design system at an earlier stage. The results of several codes which either were already introduced into the design process or are rapidly in the process of becoming so, are presented. The codes fall into the area of turbomachinery aerodynamics and hypersonic propulsion. In the former category, results are presented for three-dimensional inviscid and viscous flows through nozzle and unducted fan bladerows. In the latter category, results are presented for two-dimensional inviscid and viscous flows for hypersonic vehicle forebodies and engine inlets. Author

**N87-26021*#** Calspan Field Services, Inc., Arnold AFS, Tenn.
**EXPERIENCE WITH 3-D COMPOSITE GRIDS**
J. A. BENEK, T. L. DONEGAN, and N. E. SUHS *In* NASA. Ames Research Center, Supercomputing in Aerospace p 271-277 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 09B

Experience with the three-dimensional (3-D), chimera grid embedding scheme is described. Applications of the inviscid version to a multiple-body configuration, a wind/body/tail configuration, and an estimate of wind tunnel wall interference are described. Applications to viscous flows include a 3-D cavity and another multi-body configuration. A variety of grid generators is used, and several embedding strategies are described. Author

**N87-26023*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**COMPUTATIONAL CHEMISTRY**
J. O. ARNOLD *In its* Supercomputing in Aerospace p 299-311 Mar. 1987
Avail: NTIS HC A13/MF A01 CSCL 09B

With the advent of supercomputers, modern computational chemistry algorithms and codes, a powerful tool was created to help fill NASA's continuing need for information on the properties of matter in hostile or unusual environments. Computational resources provided under the National Aerodynamics Simulator (NAS) program were a cornerstone for recent advancements in this field. Properties of gases, materials, and their interactions can be determined from solutions of the governing equations. In the case of gases, for example, radiative transition probabilites per particle, bond-dissociation energies, and rates of simple chemical reactions can be determined computationally as reliably as from experiment. The data are proving to be quite valuable in providing inputs to real-gas flow simulation codes used to compute aerothermodynamic loads on NASA's aeroassist orbital transfer vehicles and a host of problems related to the National Aerospace Plane Program. Although more approximate, similar solutions can be obtained for ensembles of atoms simulating small particles of materials with and without the presence of gases. Computational chemistry has application in studying catalysis, properties of polymers, all of interest to various NASA missions, including those previously mentioned. In addition to discussing these applications of computational chemistry within NASA, the governing equations and the need for supercomputers for their solution is outlined. Author

**N87-26523#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
**INDUSTRIAL APPLICATION OF COMPUTER AIDED STRUCTURAL OPTIMIZATION IN AIRCRAFT CONSTRUCTION [INDUSTRIELLER EINSATZ DER RECHNERGESTUETZTEN STRUKTUROPTIMIERUNG IM FLUGZEUGBAU]**
HEINRICH WELLEN and KLAUS HERTEL 1986 11 p In GERMAN Presented at the DGLR-Jahrestagung, Munich, West Germany, 8-10 Oct. 1986
(MBB-UT-273/86; DGLR-86-167; ETN-87-99968) Avail: Issuing Activity

The software package STARS was used for computer aided structural optimization with a view to a weight-optimized design of components with a minimum of time and cost effort. The iterative process of computer aided structural optimization of aircraft components is outlined. The industrial use of STARS is explained by examples of the stress, stiffness, and frequency optimization of components made of metal and composites and of a given geometry. The results show that large and complex components can be weight optimized, that the development costs can be reduced, and that the optimization computer costs per iteration step are one to three times higher than those of a statistical analysis. ESA

**N87-26831** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Fleugzeuge.
**USE OF ARTIFICIAL INTELLIGENCE METHODS [EINSATZ VON METHODEN DER ARTIFICIAL INTELLIGENCE]**
KLAUS HOLLA *In its* Research and Development. Technical-Scientific Publications 1986 p 63-66 1986 In GERMAN Presented at the DGLR-Jahrstagung 1986, Munich, West Germany, 8-10 Oct. 1986 Original language document announced in IAA as A87-36753
(MBB-LKE-434-S/PUB/284; DGLR-86-100) Avail: Issuing Activity

Knowledge-based systems for military aircraft are described. Onboard and ground-based diagnosis and maintenance systems, multisensor systems, and systems development support are discussed. ESA

# 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.

**A87-42736**
**MODEL-BASED KNOWLEDGE-BASED OPTICAL PROCESSORS**
DAVID CASASENT and SUZANNE A. LIEBOWITZ (Carnegie-Melon University, Pittsburgh, PA) Applied Optics (ISSN 0003-6935), vol. 26, May 15, 1987, p. 1935-1942. USAF-DARPA-supported-research. refs

An efficient 3-D object-centered knowledge base is described. The ability to on-line generate a 2-D image projection or range image for any object/viewer orientation from this knowledge base is addressed. Applications of this knowledge base in associative processors and symbolic correlators are then discussed. Initial test results are presented for a multiple degree of freedom object recognition problem. These include new techniques to achieve object orientation information and two new associative memory matrix formulations. Author

**A87-43044*#** California Univ., Irvine.
**VOLUME INTERCHANGE FACTORS FOR HYPERSONIC VEHICLE WAKE RADIATION**
D. K. EDWARDS and D. S. BABIKIAN (California, University, Irvine) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 10 p. refs
(Contract NCA2-119)
(AIAA PAPER 87-1520)

Volume interchange factors are shown to be convenient in modeling the radiative processes in the wake of a hypersonic vehicle. Use of the factors facilitates calculating not just the radiative heating rates on afterbody surfaces but also the radiative de-excitation rates from stimulated emission and re-excitation rates from absorption in rarefied nonequilibrium flows. Sample calculations of volume interchange factors are presented for volume configurations modeling wake elements, and the numerical results are compared to limiting approximations to clarify the operation of the emission, transmission, and absorption processes. Author

**A87-43129*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**HIGH TEMPERATURE TRANSPORT PROPERTIES OF AIR**
E. LEVIN, HARRY PARTRIDGE, and J. R. STALLCOP (NASA, Ames Research Center, Moffett Field, CA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 39 p. refs
(Contract NCC2-387)
(AIAA PAPER 87-1632)

A general computer code was developed to allow calculation of atom-atom and ion-atom transport collision integrals from accurate potential energy curves described by a set of discrete data points for a broad range of scattering conditions. This code is based upon semiclassical approximations that properly account for quantum mechanical behavior such as tunneling effects near a barrier maximum, resonance charge exchange, and nuclear symmetry effects. Transport collision integrals were determined for N-N, O-O, N(+)-N, and O(+)-O interactions from complete sets of accurate potential functions derived from combined experimental and ab initio structure calculations. For the O-O case, this includes results for excited states. The calculated values of the N(+)-N and O(+)-O resonance charge exchange cross section Q(ex) agree well with measurements from beam experiment that are available at high energies where the diffusion cross section Q(d) satisfies Q(d) approximately equal to 2Q(ex). Author

**A87-43383#**
**COMPUTATIONAL AEROACOUSTICS AS APPLIED TO THE DIFFRACTION OF SOUND BY CYLINDRICAL BODIES**
M. M. S. KHAN, W. H. BROWN, and K. K. AHUJA (Lockheed-Georgia Co., Marietta) AIAA Journal (ISSN 0001-1452), vol. 25, July 1987, p. 949-956. Research sponsored by the Lockheed-Georgia Independent Research and Development Program. Previously cited in issue 22, p. 3338, Accession no. A86-45495. refs

**A87-45282*#** Hamilton Standard, Windsor Locks, Conn.
**RESULTS OF ACOUSTIC TESTS OF A PROP-FAN MODEL**
F.B. METZGER and P. C. BROWN (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 8 p.
(Contract NAS3-24222)
(AIAA PAPER 87-1894)

Results of acoustic tests in a low speed open jet anechoic wind tunnel are presented for a counter rotation Prop-Fan model. The model tested had 5 front and 5 rear rotor blades with swept planform. Noise spectra are presented showing the influence of operating and configuration variables such as: (1) power absorption, (2) tip speed, (3) rotor-rotor spacing, (4) power split between the front and rear blade rows, (5) variation of the RPM ratio between front and rear blade rows, (6) tractor versus pusher (pylon effects), and (7) angle of attack. In addition to model scale results, calculated levels derived from test are presented showing the influence of the above variables on Effective Perceived Noise Level of a 13.1 ft diameter Prop-Fan at a flyover distance of 1500 ft. It was found that the strongest effects are caused by tip speed and power absorption. A significant finding was that there is an optimum operating tip speed for minimum noise for a given power absorption. Effects of other parametric variations are generally small but measurable. In order to minimize noise to meet airplane certification limits, operation at moderate tip speeds and power absorption is shown to be desirable. Accuracy of predicted Effective Perceived Noise Level is shown to be good with the best accuracy in the 590 to 670 ft/sec tip speed range. Author

**A87-46753#**
**WIND TUNNEL EXPERIMENTAL STUDY OF OPTICAL BEAM DEGRADATION THROUGH HETEROGENEOUS AERODYNAMIC FLOWS**
RUY DERON, MICHEL PHILBERT, JEAN-LOUIS SOLIGNAC, and JEAN-PIERRE FALENI (ONERA, Chatillon-sous-Bagneux, France) (SPIE, Technical Symposium on Optics, Electro-Optics and Sensors, Orlando, FL, May 17-22, 1987) ONERA, TP, no. 1987-50, 1987, 8 p. refs
(ONERA, TP NO. 1987-50)

This paper deals with the influence of aerodynamic disturbances on the quality of images obtained by an airborne optical system. A wind-tunnel experiment has been carried out in order to simulate aerooptical phenomena in transsonic and supersonic flows. The characterization of such effects is obtained by studying the propagation of a laser beam (of 0.63-micron wavelength) through optical aerodynamic configurations. The influences of turbulent mixing zone and shock waves have been studied. Each

aerodynamical configuration has been qualified by both Schlieren visualization and wall pressure probing test. For each configuration, images are recorded and then processed to obtain point spread functions, optical transfer functions, modulation transfer function, and Wiener spectrum of the images. This study should lead to a match of optical and aerodynamical considerations in designing future airborne imaging systems. Author

**N87-25824#** Aeronautical Research Inst. of Sweden, Stockholm. Aerodynamics Dept.
**MEASUREMENT OF NOISE FROM AIRPLANES TRAVELING AT 3500 TO 11000 M ALTITUDE**
MAGNUS LINDE and STAFFAN MEIJER Mar. 1986 34 p Sponsored by the Swedish National Board for Technical Development
(FFA-TN-1986-21; ETN-87-99779) Avail: NTIS HC A03/MF A01

The noise on the ground from jet and propeller airplanes at heights 3500 to 11000 m was measured. Results are presented as dBA-levels versus flight level. Equivalent noise levels were also calculated. Examples are given for how increased noise generation from airplanes affects the resulting Flight Noise Level (a Swedish noise rating for noise exposure forecast). It is found that Flight Noise Level 55 dBA can easily be exceeded if it is assumed that a certain number of the flights is made with airplanes giving higher equivalent noise level. ESA

**N87-25827*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EFFECT OF SIGNAL JITTER ON THE SPECTRUM OF ROTOR IMPULSIVE NOISE**
THOMAS F. BROOKS Jun. 1987 18 p Submitted for publication
(NASA-TM-100477; NAS 1.15:100477) Avail: NTIS HC A02/MF A01 CSCL 20A

The effect of randomness or jitter of the acoustic waveform on the spectrum of rotor impulsive noise is studied because of its importance for data interpretation. An acoustic waveform train is modelled representing rotor impulsive noise. The amplitude, shape, and period between occurrences of individual pulses are allowed to be randomized assuming normal probability distributions. Results, in terms of the standard deviations of the variable quantities, are given for the autospectrum as well as special processed spectra designed to separate harmonic and broadband rotor noise components. Consideration is given to the effect of accuracy in triggering or keying to a rotor one per revolution signal. An example is given showing the resultant spectral smearing at the high frequencies due to the pulse signal period variability. Author

**N87-26612*#** Missouri Univ., Rolla. Dept. of Mechanical and Aerospace Engineering.
**A COMPARISON OF THE STRUCTUREBORNE AND AIRBORNE PATHS FOR PROPFAN INTERIOR NOISE Final Report**
W. EVERSMAN, L. R. KOVAL, and J. V. RAMAKRISHNAN Oct. 1986 61 p
(Contract NAG1-394)
(NASA-CR-180289; NAS 1.26:180289) Avail: NTIS HC A04/MF A01 CSCL 20A

A comparison is made between the relative levels of aircraft interior noise related to structureborne and airborne paths for the same propeller source. A simple, but physically meaningful, model of the structure treats the fuselage interior as a rectangular cavity with five rigid walls. The sixth wall, the fuselage sidewall, is a stiffened panel. The wing is modeled as a simple beam carried into the fuselage by a large discrete stiffener representing the carry-through structure. The fuselage interior is represented by analytically-derived acoustic cavity modes and the entire structure is represented by structural modes derived from a finite element model. The noise source for structureborne noise is the unsteady lift generation on the wing due to the rotating trailing vortex system of the propeller. The airborne noise source is the acoustic field created by a propeller model consistent with the vortex representation. Comparisons are made on the basis of interior noise over a range of propeller rotational frequencies at a fixed thrust. Author

# 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.

**A87-42859#**
**LIABILITY OF THE UNITED STATES GOVERNMENT IN CASES OF AIR TRAFFIC CONTROLLER NEGLIGENCE**
SETI K. HAMALIAN (McGill University, Montreal, Canada) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 55-85. refs

The requirements for liability of the U.S. government and air traffic controllers for aircraft accidents caused by air traffic controller negligence are considered. The development and objectives of air traffic control, and the duties of air traffic controllers are described. The liability on the U.S. government for controller negligence, and the use of the discretionary function for exclusion from liability are discussed. The liability of the air traffic controller during various phases of the flight is examined. I.F.

**A87-42860#**
**THE NEW ANNEX 17 - THE LATEST CONTRIBUTION BY INTERNATIONAL CIVIL AVIATION TO THE BATTLE AGAINST TERRORISM [LA NOUVELLE ANNEXE 17 - LE DERNIER APPORT DE L'AVIATION CIVILE INTERNATIONALE POUR LA LUTTE CONTRE LE TERRORISME]**
JEAN-LOUIS MAGDELENAT (McGill University, Montreal, Canada) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 87-103. In French. refs

Following a review of the relatively unsuccessful post-facto conventions previously adopted to counter terrorism, preventative security measures for international civil aviation which were added to the Annex 17 by the ICAO following the Air India tragedy in 1985 are discussed. Additions to Annex 17 call for an increase in the number of standards and recommended practices, requesting countries to intensify their procedures for passenger and baggage search, and aircraft inspection. Exchanges of information between the police services of Western Europe, the United States, and Canada concerning international terrorist activity have been undertaken since 1986. Additional proposals are suggested including an international criminal court and an international prison. R.R.

**A87-42861#**
**INTERCEPTION OF CIVIL AIRCRAFT VS. MISUSE OF CIVIL AVIATION**
MICHAEL MILDE (International Civil Aviation Organization, Montreal, Canada) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 105-130. refs

The March 1986 ICAO Council amendment concerned with the identification and interception of civil aircraft is discussed. The Council was concerned with ways to improve the coordination of communications systems between military and civil aircraft and air traffic control services; to abstain from recourse to the use of force against civil aircraft; and to improve procedures for the identification and interception of civil aircraft. The recommendations of the Air Navigation Commission for improving identification and interception of civil aircraft are examined.The objections and alternatives proposed by various states, to the recommendations of the Commission are described. The criminal use of civil aviation, and its potential threat to the security of a state are studied. I.F.

**A87-42862#**
**THE EFFECT OF EUROPEAN LAW ON AIR TRANSPORT [L'EFFET DU DROIT EUROPEEN SUR LE TRANSPORT AERIEN]**
JACQUES NAVEAU (Bruxelles, Universite Libre, Brussels, Belgium) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 131-138. In French. refs

A review of the impact of European law practices on air transport is presented, with emphasis on the need for more regional intergovernmental air transport agreements. Competitive regulations provided for in the 1956 Rome Treaty were stated to apply to air transport by the European Court of Justice in 1986. It is suggested that article 234 of the Rome Treaty, delegating to the Commission the powers of negotiating traffic rights with third parties on behalf of the community, could help establish a European common market for air transport. Measures including the Council Directive of 1983, sponsored by the French Parliament president, to authorize interregional regular air services for passengers, mail, and freight, would result in a juxtaposition of interregional air services which would be approved automatically by the Commission and which would not be subject to governmental approval. R.R.

**A87-42863#**
**AIRLINES ARE EXEMPT FROM LAW ON RIGHTS OF THE DISABLED**
BARBARA REUKEMA (Southwestern University, Los Angeles, CA) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 139-150. refs

The relation between airlines and the law prohibiting discrimination against handicapped persons is examined. Consideration is given to airline deregulation, airline operating certificates, and government assistance to airlines. Court of Appeals and Supreme Court decisions on the Rehabilitation Act of 1973 are discussed. The Supreme Court ruled that section 504 of the Rehabilitation Act of 1973 is not applicable to all commercial airlines; it is limited to those airlines which receive federal financial assistance. I.F.

**A87-42864#**
**THE WARSAW CONVENTION SYSTEM REGARDING AIR CARRIER RESPONSIBILITY - NEW DEVELOPMENTS IN JURISPRUDENCE [LE SYSTEME DE LA CONVENTION DE VARSOVIE EN MATIERE DE RESPONSIBILITE DU TRANSPORTEUR AERIEN - NOUVEAUX DEVELOPPEMENTS JURISPRUDENTIELS]**
HAROLD ROUSSELLE (McGill University, Montreal, Canada) IN: Annals of air and space law. Volume 11 . Montreal, McGill University, 1986, p. 151-167. In French. refs

Recent developments in jurisprudence with respect to the interpretation of the Warsaw Convention in matters regarding air carrier responsibility are reviewed, highlighting the attitude adopted recently by the United States of not wishing to modify the Warsaw Convention. In Darghouth vs. Swissair, it was concluded that a national law stipulating the nonapplicability of the prescription period to a minor is not compatible with Warsaw Convention article 29. In Rush vs. U.S. Air, it was specified that luggage and passengers can have a different destination for the purposes of calculating the period provided for in article 29. In the Korean Airlines Disaster decision, a contractual link was found to exist between a state which has solely ratified the Warsaw Convention and one which has only adhered to the Hague Protocol. R.R.

**A87-44064**
**AVIATION SAFETY AND THE FAA'S QUALITY ASSURANCE PROGRAM**
ALAN ARMSTRONG Air Law (ISSN 0165-2079), vol. 12, April 1987, p. 58-67. refs

The FAA Quality Assurance Program (QAP) aimed at identifying problems in the national airspace system is examined. The implementation and operation of the Snitch program, conflict alert software connected to ATC computers to signal aircraft deviation from ATC clearance or if separation between aircraft is less than a percentage of the prescribed criteria, are described. Recent changes by the FAA in the QAP/Snitch program and pilot certificate actions related to pilot deviations detected by Snitch are identified and analyzed. I.F.

**A87-45265#**
**AIRBREATHING PROPULSION SYSTEM DESIGN AT THE UNITED STATES AIR FORCE ACADEMY - AN INTEGRATED APPROACH**
D. NEAL BARLOW and CHARLES W. WOOD (U.S. Air Force Academy, Colorado Springs, CO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 11 p.
(AIAA PAPER 87-1870)

The philosophy and content of the propulsion curriculum at the United States Air Force Academy are summarized, and a detailed discussion is given of the capstone design course. The course includes engine/aircraft system constraint analysis, preliminary engine/aircraft weight and mission analysis, preliminary aircraft configuration, fuselage design, drag and lift characteristics, engine design and point analysis, and engine off design parameters. The importance of the use of computers in the design sequence is emphasized. V.L.

**N87-25273*#** FWG Associates, Inc., Tullahoma, Tenn.
**MODELING AND IMPLEMENTATION OF WIND SHEAR DATA**
WALTER FROST *In* NASA. Langley Research Center Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification p 49-66 Jul. 1987
Avail: NTIS HC A12/MF A01 CSCL 05B

The problems of implementing the JAWS wind shear data are discussed. The data sets are described from the view of utilizing them in an aircraft performance computer program. Then, some of the problems of nonstandard procedures are described in terms of programming the equations of aircraft motion when the effects of temporal and spatially variable winds are included. Finally, some of the computed effects of the various wind shear terms are shown. Author

## 19

## GENERAL

**A87-46178#**
**THE ORIGINS AND FUTURE POSSIBILITIES OF AIR BREATHING JET PROPULSION SYSTEMS**
HANS VON OHAIN (Dayton, University, OH) IN: International Symposium on Air Breathing Engines, 8th, Cincinnati, OH, June 14-19, 1987, Proceedings . New York, American Institute of Aeronautics and Astronautics, 1987, p. 14-25.

A development history is presented for airbreating jet aircraft propulsion systems, together with a development status evaluation and prospective development projection. The various influences which had a significant bearing on the major breakthoughs and development trends, encompassing those of wartime economies in Germany during WW II, the popular appeal of passenger jet travel at high subsonic speeds, etc. are assessed. The comparative advantages of higher-bypass turbofans for subsonic flight and low-bypass turbofans for supersonic flight are evaluated, and the rationale for hydrogen-fueled supersonic combustion ramjet operating at hypersonic cruise speeds is presented. O.C.

**N87-26826** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensbereich Apparate.
**RESEARCH AND DEVELOPMENT. TECHNICAL-SCIENTIFIC PUBLICATIONS 1986 [FORSCHUNG UND ENTWICKLUNG. TECHNISCH-WISSENSCHAFTLICHE VEROEFFENTLICHUNGEN 1986]**
1986 317 p Partly in GERMAN and ENGLISH
(ETN-87-99713) Avail: Issuing Activity

The evolution of microsystems techniques, the space transportation system SAENGER 2, strategic technology assessment, and the determination of the kinematic parameters of a moving imaging sensor are treated. Trends in intake pressure distortion measurements, artificial intelligence methods, recovery rates of optical fibers, and a Euler solution for air-flow calculations for fighter aircraft; technologies, camber control systems, and a propfan concept for transport aircraft; avionics systems and bearingless rotor systems for helicopters are presented. The TV-SAT antenna, combined spacecraft propulsion systems, the evolution of a serviceable EURECA, Columbus control engineering tasks, and life cycle costs are considered. Acoustics applications, active optics, adaptive preprocessing, streak techniques, and electronic packaging for defense systems are presented.

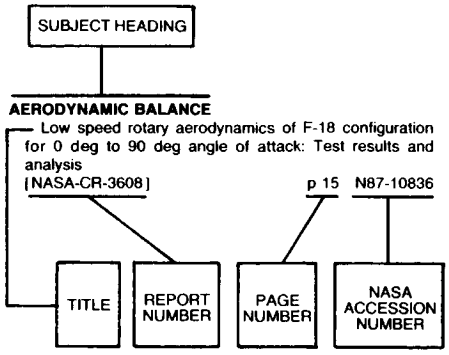
ESA

**N87-26853#** Inter Nationes, Bonn (West Germany).
**GOING BEYOND THE LIMITS. AVIATION IN GERMANY [DIE GRENZEN UEBERWINDEN. LUFTFAHRT IN DEUTSCHLAND]**
GOETZ WANGE, HANNS REDEMANN, and KLAUS MUELLER
1987 28 p In GERMAN
(SO-1-87; ETN-87-99909) Avail: NTIS HC A03/MF A01

The history of 175 years of aviation in Germany is depicted. The work of Hugo Junkers and Claude Dornier is summarized. The beginning of world air traffic, and the evolution from propeller to jet aircraft are depicted. The new start of the German aviation industry after 1945, and the concentration and international cooperation in the aviation industry are presented. Military requirements as a motor for the technological development are treated.

ESA

## Typical Subject Index Listing




The subject heading is a key to the subject content of the document. The title is used to provide a description of the subject matter. When the title is insufficiently descriptive of the document content, the title extension is added, separated from the title by three hyphens. The (NASA or AIAA) accession number and the page number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document. Under any one subject heading, the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

## B



## C

# D

## E

# F

## G

# H

## I



## J

## K



## L



## M

## N

## O



## P

## Q



## R

## S

## T

# U



# V



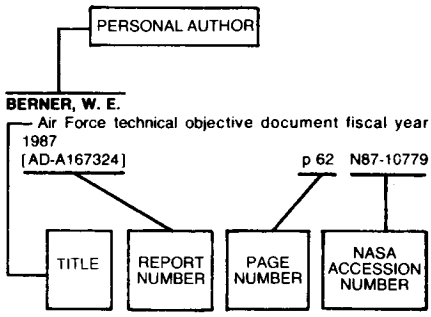
# W

## X



## Y

### Typical Personal Author Index Listing




Listings in this index are arranged alphabetically by personal author. The title of the document provides the user with a brief description of the subject matter. The report number helps to indicate the type of document listed (e.g., NASA report, translation, NASA contractor report). The page and accession numbers are located beneath and to the right of the title. Under any one author's name the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

## A



## B

## C

## D

## E



## F

## G



## H

## I



## J

## K



## L

## M

## N

## O



## P

## Q



## R



## S

## T



## U

## V



## W



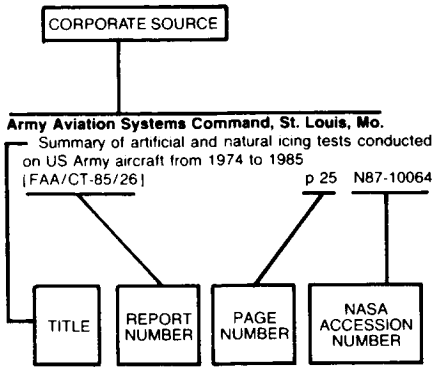
## X

# Y



# Z

## 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.

## G



## H



## I



## K



## L



## M



## N

## O



## P

## Q



## R



## S



## T

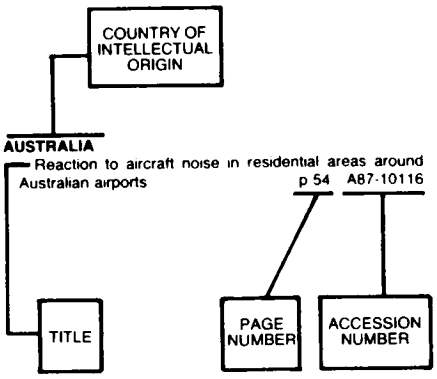


## U



## V

## 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.



FOREIGN

**GERMANY,PEOPLES DEMOCRATIC REPUBLIC OF**



**GREECE**



## I

**INDIA**



**INTERNATIONAL ORGANIZATION**



**ISRAEL**



**ITALY**



## J

**JAPAN**



## K

**KOREA,(SOUTH)**



## N

**NETHERLANDS**



**NORWAY**



## P

**POLAND**



## S

**SOUTH AFRICA, REPUBLIC OF**



**SPAIN**



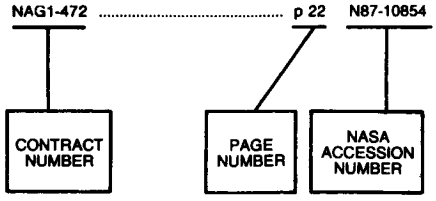
**SWEDEN**



**SWITZERLAND**

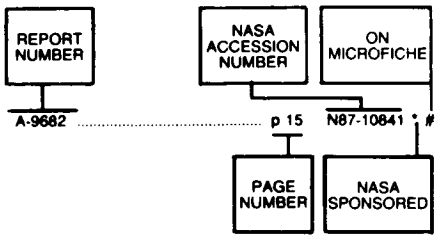
# U

### Typical Contract Number Index Listing



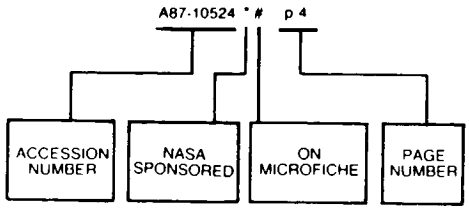

Listings in this index are arranged alpha-numerically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under that contract are arranged in ascending order with the AIAA accession numbers appearing first. The accession number denotes the number by which the citation is identified in the abstract section. Preceding the accession number is the page number on which the citation may be found.

### Typical Report Number Index Listing




Listings in this index are arranged alpha-numerically 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.

### 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.**

# AVAILABILITY OF CITED PUBLICATIONS

## IAA ENTRIES (A86-10000 Series)

Publications announced in *IAA* are available from the AIAA Technical Information Service as follows: Paper copies of accessions are available at $10.00 per document (up to 50 pages), additional pages $0.25 each. Microfiche[1] of documents announced in *IAA* are available at the rate of $4.00 per microfiche on demand. Standing order microfiche are available at the rate of $1.45 per microfiche for *IAA* source documents and $1.75 per microfiche for AIAA meeting papers.

Minimum air-mail postage to foreign countries is $2.50. All foreign orders are shipped on payment of pro-forma invoices.

All inquiries and requests should be addressed to: Technical Information Service, American Institute of Aeronautics and Astronautics, 555 West 57th Street, New York, NY 10019. Please refer to the accession number when requesting publications.

## STAR ENTRIES (N86-10000 Series)

One or more sources from which a document announced in *STAR* is available to the public is ordinarily given on the last line of the citation. The most commonly indicated sources and their acronyms or abbreviations are listed below. If the publication is available from a source other than those listed, the publisher and his address will be displayed on the availability line or in combination with the corporate source line.

Avail: NTIS. Sold by the National Technical Information Service. Prices for hard copy (HC) and microfiche (MF) are indicated by a price code preceded by the letters HC or MF in the *STAR* citation. Current values for the price codes are given in the tables on NTIS PRICE SCHEDULES.

Documents on microfiche are designated by a pound sign (#) following the accession number. The pound sign is used without regard to the source or quality of the microfiche.

Initially distributed microfiche under the NTIS SRIM (Selected Research in Microfiche) is available at greatly reduced unit prices. For this service and for information concerning subscription to NASA printed reports, consult the NTIS Subscription Section, Springfield, Va. 22161.

NOTE ON ORDERING DOCUMENTS: When ordering NASA publications (those followed by the * symbol), use the N accession number. NASA patent applications (only the specifications are offered) should be ordered by the US-Patent-Appl-SN number. Non-NASA publications (no asterisk) should be ordered by the AD, PB, or other *report number* shown on the last line of the citation, not by the N accession number. It is also advisable to cite the title and other bibliographic identification.

Avail: SOD (or GPO). Sold by the Superintendent of Documents, U.S. Government Printing Office, in hard copy. The current price and order number are given following the availability line. (NTIS will fill microfiche requests, as indicated above, for those documents identified by a # symbol.)

(1) A microfiche is a transparent sheet of film, 105 by 148 mm in size containing as many as 60 to 98 pages of information reduced to micro images (not to exceed 26.1 reduction).

Avail: BLL (formerly NLL): British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England. Photocopies available from this organization at the price shown. (If none is given, inquiry should be addressed to the BLL.)

Avail: DOE Depository Libraries. Organizations in U.S. cities and abroad that maintain collections of Department of Energy reports, usually in microfiche form, are listed in *Energy Research Abstracts.* Services available from the DOE and its depositories are described in a booklet, *DOE Technical Information Center - Its Functions and Services* (TID-4660), which may be obtained without charge from the DOE Technical Information Center.

Avail: ESDU. Pricing information on specific data, computer programs, and details on ESDU topic categories can be obtained from ESDU International Ltd. Requesters in North America should use the Virginia address while all other requesters should use the London address, both of which are on the page titled ADDRESSES OF ORGANIZATIONS.

Avail: Fachinformationszentrum, Karlsruhe. Sold by the Fachinformationszentrum Energie, Physik, Mathematik GMBH, Eggenstein Leopoldshafen, Federal Republic of Germany, at the price shown in deutschmarks (DM).

Avail: HMSO. Publications of Her Majesty's Stationery Office are sold in the U.S. by Pendragon House, Inc. (PHI), Redwood City, California. The U.S. price (including a service and mailing charge) is given, or a conversion table may be obtained from PHI.

Avail: NASA Public Document Rooms. Documents so indicated may be examined at or purchased from the National Aeronautics and Space Administration, Public Documents Room (Room 126), 600 Independence Ave., S.W., Washington, D.C. 20546, or public document rooms located at each of the NASA research centers, the NASA Space Technology Laboratories, and the NASA Pasadena Office at the Jet Propulsion Laboratory.

Avail: Univ. Microfilms. Documents so indicated are dissertations selected from *Dissertation Abstracts* and are sold by University Microfilms as xerographic copy (HC) and microfilm. All requests should cite the author and the Order Number as they appear in the citation.

Avail: US Patent and Trademark Office. Sold by Commissioner of Patents and Trademarks, U.S. Patent and Trademark Office, at the standard price of $1.50 each, postage free. (See discussion of NASA patents and patent applications below.)

Avail: (US Sales Only). These foreign documents are available to users within the United States from the National Technical Information Service (NTIS). They are available to users outside the United States through the International Nuclear Information Service (INIS) representative in their country, or by applying directly to the issuing organization.

Avail: USGS. Originals of many reports from the U.S. Geological Survey, which may contain color illustrations, or otherwise may not have the quality of illustrations preserved in the microfiche or facsimile reproduction, may be examined by the public at the libraries of the USGS field offices whose addresses are listed in this Introduction. The libraries may be queried concerning the availability of specific documents and the possible utilization of local copying services, such as color reproduction.

Avail: Issuing Activity, or Corporate Author, or no indication of availability. Inquiries as to the availability of these documents should be addressed to the organization shown in the citation as the corporate author of the document.

## PUBLIC COLLECTIONS OF NASA DOCUMENTS

**DOMESTIC:** NASA and NASA-sponsored documents and a large number of aerospace publications are available to the public for reference purposes at the library maintained by the American Institute of Aeronautics and Astronautics, Technical Information Service, 555 West 57th Street, 12th Floor, New York, New York 10019.

**EUROPEAN:** An extensive collection of NASA and NASA-sponsored publications is maintained by the British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England for public access. The British Library Lending Division also has available many of the non-NASA publications cited in *STAR*. European requesters may purchase facsimile copy or microfiche of NASA and NASA-sponsored documents, those identified by both the symbols # and * from ESA – Information Retrieval Service European Space Agency, 8-10 rue Mario-Nikis, 75738 CEDEX 15, France.

## FEDERAL DEPOSITORY LIBRARY PROGRAM

In order to provide the general public with greater access to U.S. Government publications, Congress established the Federal Depository Library Program under the Government Printing Office (GPO), with 50 regional depositories responsible for permanent retention of material, inter-library loan, and reference services. At least one copy of nearly every NASA and NASA-sponsored publication, either in printed or microfiche format, is received and retained by the 50 regional depositories. A list of the regional GPO libraries, arranged alphabetically by state, appears on the inside back cover. These libraries are *not* sales outlets. A local library can contact a Regional Depository to help locate specific reports, or direct contact may be made by an individual.

## STANDING ORDER SUBSCRIPTIONS

NASA SP-7037 and its supplements are available from the National Technical Information Service (NTIS) on standing order subscription as PB 86-914100 at the price of $7.00 domestic and $14.00 foreign–includes annual index. Standing order subscriptions do not terminate at the end of a year, as do regular subscriptions, but continue indefinitely unless specifically terminated by the subscriber.

# ADDRESSES OF ORGANIZATIONS

American Institute of Aeronautics and Astronautics
Technical Information Service
555 West 57th Street, 12th Floor
New York, New York 10019

British Library Lending Division,
Boston Spa, Wetherby, Yorkshire,
England

Commissioner of Patents and Trademarks
U.S. Patent and Trademark Office
Washington, D.C. 20231

Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

ESA-Information Retrieval Service
ESRIN
Via Galileo Galilei
00044 Frascati (Rome) Italy

ESDU International, Ltd.
1495 Chain Bridge Road
McLean, Virginia 22101

ESDU International, Ltd.
251-259 Regent Street
London, W1R 7AD, England

Fachinformationszentrum Energie, Physik, Mathematik GMBH
7514 Eggenstein Leopoldshafen
Federal Republic of Germany

Her Majesty's Stationery Office
P.O. Box 569, S.E. 1
London, England

NASA Scientific and Technical Information Facility
P.O. Box 8757
B.W.I. Airport, Maryland 21240

National Aeronautics and Space Administration
Scientific and Technical Information Division (NTT-1)
Washington, D.C. 20546

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Pendragon House, Inc.
899 Broadway Avenue
Redwood City, California 94063

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

University Microfilms
A Xerox Company
300 North Zeeb Road
Ann Arbor, Michigan 48106

University Microfilms, Ltd.
Tylers Green
London, England

U.S. Geological Survey Library
National Center - MS 950
12201 Sunrise Valley Drive
Reston, Virginia 22092

U.S. Geological Survey Library
2255 North Gemini Drive
Flagstaff, Arizona 86001

U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

U.S. Geological Survey Library
Box 25046
Denver Federal Center, MS914
Denver, Colorado 80225

# NTIS PRICE SCHEDULES

(Effective January 1, 1987)

## Schedule A
## STANDARD PRICE DOCUMENTS AND MICROFICHE

| PRICE CODE | PAGE RANGE | NORTH AMERICAN PRICE | FOREIGN PRICE |
|---|---|---|---|
| A01 | Microfiche | $ 6.50 | $13.00 |
| A02 | 001-025 | 9.95 | 19.90 |
| A03 | 026-050 | 11.95 | 23.90 |
| A04-A05 | 051-100 | 13.95 | 27.90 |
| A06-A09 | 101-200 | 18.95 | 37.90 |
| A10-A13 | 201-300 | 24.95 | 49.90 |
| A14-A17 | 301-400 | 30.95 | 61.90 |
| A18-A21 | 401-500 | 36.95 | 73.90 |
| A22-A25 | 501-600 | 42.95 | 85.90 |
| A99 | 601-up | * | * |
| NO1 | | 45.00 | 80.00 |
| NO2 | | 48.00 | 80.00 |

## Schedule E
## EXCEPTION PRICE DOCUMENTS AND MICROFICHE

| PRICE CODE | NORTH AMERICAN PRICE | FOREIGN PRICE |
|---|---|---|
| E01 | $ 7.50 | 15.00 |
| E02 | 10.00 | 20.00 |
| E03 | 11.00 | 22.00 |
| E04 | 13.50 | 27.00 |
| E05 | 15.50 | 31.00 |
| E06 | 18.00 | 36.00 |
| E07 | 20.50 | 41.00 |
| E08 | 23.00 | 46.00 |
| E09 | 25.50 | 51.00 |
| E10 | 28.00 | 56.00 |
| E11 | 30.50 | 61.00 |
| E12 | 33.00 | 66.00 |
| E13 | 35.50 | 71.00 |
| E14 | 38.50 | 77.00 |
| E15 | 42.00 | 84.00 |
| E16 | 46.00 | 92.00 |
| E17 | 50.00 | 100.00 |
| E18 | 54.00 | 108.00 |
| E19 | 60.00 | 120.00 |
| E20 | 70.00 | 140.00 |
| E99 | * | * |

*Contact NTIS for price quote.

## IMPORTANT NOTICE

NTIS Shipping and Handling Charges

U.S., Canada, Mexico — ADD $3.00 per TOTAL ORDER

All Other Countries — ADD $4.00 per TOTAL ORDER

Exceptions — Does NOT apply to:

ORDERS REQUESTING NTIS RUSH HANDLING

ORDERS FOR SUBSCRIPTION OR STANDING ORDER PRODUCTS *ONLY*

NOTE: Each additional delivery address on an order requires a separate shipping and handling charge.

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| NASA SP-7037 (219) | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Aeronautical Engineering<br>A Continuing Bibliography (Supplement 219) | November, 1987 |
| | 6. Performing Organization Code |
| 7. Author(s) | 8. Performing Organization Report No. |
| | 10. Work Unit No. |
| 9. Performing Organization Name and Address<br>National Aeronautics and Space Administration<br>Washington, DC 20546 | 11. Contract or Grant No. |
| | 13. Type of Report and Period Covered |
| 12. Sponsoring Agency Name and Address | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

This bibliography lists 586 reports, articles and other documents introduced into the NASA scientific and technical information system in October, 1987.

| 17. Key Words (Suggested by Authors(s)) | 18. Distribution Statement |
|---|---|
| Aeronautical Engineering<br>Aeronautics<br>Bibliographies | Unclassified - Unlimited |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price * |
|---|---|---|---|
| Unclassified | Unclassified | 164 | A08/HC |

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1987