

**NASA SP-7037(246)**

# **AERONAUTICAL ENGINEERING**

**A CONTINUING BIBLIOGRAPHY  
WITH INDEXES**

**(Supplement 246)**

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 November 1989 in

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



National Aeronautics and Space Administration  
Office of Management  
Scientific and Technical Information Division  
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# INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 690 reports, journal articles and other documents originally announced in November 1989 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA)*.

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

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

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

An annual cumulative index will be published.

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

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# TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED  
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 ON MICROFICHE

ACCESSION NUMBER → **N89-10029\***# North Carolina State Univ., Raleigh. Dept. of Mechanical and Aerospace Engineering. ← CORPORATE SOURCE

TITLE → **A TRANSONIC INTERACTIVE BOUNDARY-LAYER THEORY FOR LAMINAR AND TURBULENT FLOW OVER SWEEP WINGS Final Report**

AUTHORS → SHAWN H. WOODSON and FRED R. DEJARNETTE

CONTRACT NUMBER → (Contract NCC1-22) ← PUBLICATION DATE

REPORT NUMBERS → (NASA-CR-4185; NAS 1.26:4185) Avail: NTIS HC A05/MF A01 ← PRICE CODE

COSATI CODE → CSCL 01A ← AVAILABILITY SOURCE

A 3-D laminar and turbulent boundary-layer method is developed for compressible flow over swept wings. The governing equations and curvature terms are derived in detail for a nonorthogonal, curvilinear coordinate system. Reynolds shear-stress terms are modeled by the Cebeci-Smith eddy-viscosity formulation. The governing equations are discretized using the second-order accurate, predictor-corrector finite-difference technique of Matsuno, which has the advantage that the crossflow difference formulas are formed independent of the sign of the crossflow velocity component. The method is coupled with a full potential wing/body inviscid code (FLO-30) and the inviscid-viscous interaction is performed by updating the original wing surface with the viscous displacement surface calculated by the boundary-layer code. The number of these global iterations ranged from five to twelve depending on Mach number, sweep angle, and angle of attack. Several test cases are computed by this method and the results are compared with another inviscid-viscous interaction method (TAWFIVE) and with experimental data.

Author

# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED  
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 ON MICROFICHE

ACCESSION NUMBER → **A89-12562\***# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

TITLE → **EFFICIENT VIBRATION MODE ANALYSIS OF AIRCRAFT WITH MULTIPLE EXTERNAL STORE CONFIGURATIONS**

AUTHOR → M. KARPEL (NASA, Langley Research Center, Hampton, VA; Israel Aircraft Industries, Ltd., Lod) ← JOURNAL TITLE

Journal of Aircraft (ISSN 0021-8669), vol. 25, Aug. 1988, p. 747-751. refs

A coupling method for efficient vibration mode analysis of aircraft with multiple external store configurations is presented. A set of low-frequency vibration modes, including rigid-body modes, represent the aircraft. Each external store is represented by its vibration modes with clamped boundary conditions, and by its rigid-body inertial properties. The aircraft modes are obtained from a finite-element model loaded by dummy rigid external stores with fictitious masses. The coupling procedure unloads the dummy stores and loads the actual stores instead. The analytical development is presented, the effects of the fictitious mass magnitudes are discussed, and a numerical example is given for a combat aircraft with external wing stores. Comparison with vibration modes obtained by a direct (full-size) eigensolution shows very accurate coupling results. Once the aircraft and stores data bases are constructed, the computer time for analyzing any external store configuration is two to three orders of magnitude less than that of a direct solution.

Author

# AERONAUTICAL ENGINEERING

*A Continuing Bibliography (Suppl. 246)*

DECEMBER 1989

01

## AERONAUTICS (GENERAL)

**A89-48164#**

### **THE NATIONAL AERO-SPACE PLANE PROGRAM**

ROBERT R. BARTHELEMY (USAF, National Aero-Space Plane Joint Program Office, Wright-Patterson AFB, OH) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 6 p.  
(AIAA PAPER 89-5053)

The technological, programmatic, and utilitarian, aspects of the NASP program are reviewed. Research to develop the technologies needed to implement the NASP program are considered, focusing on the need for the synergism of technological breakthroughs in various aerospace fields. The management and implementation requirements of the NASP program are evaluated and the military, civil, and commercial systems that would be produced by the program are presented. R.B.

**A89-48166#**

### **LANTIRN APPROACH TO ENHANCE MAINTAINABILITY**

MURRAY W. GARBRICK (Martin Marietta Corp., Orlando, FL) AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 5 p.  
(AIAA PAPER 89-5055)

Three major initiatives now being undertaken which enhance the total system maintainability of LANTIRN (low altitude navigation and targeting infrared for night) are described. LANTIRN provides low altitude night offensive combat operation capability to high-speed tactical fighter aircraft. These initiatives include: (1) simplifying the system, (2) introducing and developing the generic bus interface card for use in the support equipment, and (3) developing the fielded system status/analysis using the data logging module activity. The results of these improvements include an approximate 30 percent reduction of support time, a 28 percent reduction of intermediate level support equipment, and development of an inexpensive, throwaway module storing three months of flight data for fault trend evaluation and isolation of flight environment-induced faults. C.D.

**A89-48171#**

### **MAINTAINABILITY OF NEXT GENERATION AIRCRAFT**

NEAL A. BLAKE AIAA and NASA, Symposium on the Maintainability of Aerospace Systems, Anaheim, CA, July 26, 27, 1989. 5 p.  
(AIAA PAPER 89-5060)

Programs which are being developed to ensure maintainability in the next generation of commercial aircraft are discussed. It is shown how those aircraft will utilize extensive onboard sensing and monitoring systems to provide information automatically on the status of the airframe, engines, and aircraft systems. These systems will identify trends in system and element performance that will provide advanced warning of future failures. R&D programs will address areas of aging in all systems and airframe components, environmental shielding of critical systems, improved and

automated nondestructive testing systems, monitoring systems for airframes, engines, and flight control systems, and technology assessments of new materials, systems, and problems associated with the introduction of new aircraft into the fleet. C.D.

**A89-48550**

### **DEVELOPMENT OF ONBOARD MAINTENANCE SYSTEMS ON BOEING AIRPLANES**

ANTHONY J. MARTIN (Boeing Commercial Airplanes, Seattle, WA) Aerospace (UK) (ISSN 0305-0831), vol. 16, Aug. 1989, p. 16-21.

A major U.S. airliner manufacturer has undertaken a major onboard maintenance system development program on the basis of an evaluation of current tracking methods for in-service R&M performance as unacceptably poor. Efforts are accordingly directed toward MTBF tracking systems encompassing failure confirmation by the BITE record and recognition of design errors. The BITE fault record stored within an LRU is often the only source of useful data for accurately determining whether a failure has occurred, and what its root cause may be. Avionics equipment suppliers must in future maintain a data base of their equipment repair reports and BITE data. Attention is given to the 747-400 airliner's Central Maintenance Computer System. O.C.

**A89-49051**

### **AIAA ATMOSPHERIC FLIGHT MECHANICS CONFERENCE, BOSTON, MA, AUG. 14-16, 1989, TECHNICAL PAPERS**

Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 497 p. For individual items see A89-49052 to A89-49102.

The present conference discusses the control of wing leading-edge vortices, vortex interaction control on a chine forebody/delta-wing configuration at high alpha, modeling of V/STOL aircraft thrust-induced aerodynamics, parameter estimation for highly-augmented aircraft, a standard evaluation maneuver test set for agility and the 'extended flight envelope', coupled static and dynamic stability parameters, the aerodynamics of a family of cone cylinder-flare projectiles, and the unsteady aerodynamics of delta wings with tangential leading-edge blowing. Also discussed are thrust-law effects for aerospace craft long-period modes, aeroassist technology for Martian exploration, passive drag reduction for transonic airfoils, torsional agility in air-to-air combat, the aeroelastic stability of slender spinning missiles, the launch dynamics of fin-stabilized projectiles, and the numerical computation of hypersonic flows with transpiration cooling. O.C.

**A89-49086#**

### **EXPERIMENTAL MEASUREMENT OF THE POWER REQUIRED TO FLY THE DAEDALUS HUMAN POWERED AIRCRAFT**

R. BRYAN SULLIVAN (Orbital Sciences Corp., Fairfax, VA) and THOMAS CLANCY (Aurora Flight Sciences Corp., Alexandria, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 330-337.  
(AIAA PAPER 89-3385)

**A89-49409#**

### **CONFIGURATIONAL REPERCUSSIONS OF NEW TECHNOLOGIES IN DESIGNING A REGIONAL AIRLINER**

BERTRAM FISCHER (Messerschmitt-Boelkow-Blohm GmbH,

## 01 AERONAUTICS (GENERAL)

Hamburg, Federal Republic of Germany) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p.  
(AIAA PAPER 89-2022)

Based on a set of design requirements a target configuration for a new regional airliner is presented together with its capabilities and economics. Trade-off studies into laminar flow, propfan propulsion and CFRP wing are summarized with their configurational repercussions including the snowballing. The effects on total aircraft weight, drag, geometry and thrust are finally evaluated by direct operating cost. It will be shown that fuel efficiency or light weight structures will not sell if extra development and production cost or engine price prohibit any return on investment, the most probable aircraft in the expected economic environment will come as a conclusion. Author

### **A89-49414# OVERVIEW OF THE HELICOPTER INDUSTRY**

JOHN F. ZUGSCHWERT (AHS, Alexandria, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 4 p.  
(AIAA PAPER 89-2029)

Accounts are given of the current economic status and technological development trends of the U.S. helicopter-manufacturing industry. This industry's market, substantially export-oriented, encompasses an important military component as well as a domestic civilian one. Major recent developments, such as Chinese purchases of U.S. military helicopters, and Japanese coproduction of most U.S. helicopter designs, are noted. The industry's best prospects for expansion are seen in the helicopter's attractiveness as a solution to air/airport and surface/highway traffic congestion problems, as well as its demonstrated applicability to emergency medical services and law enforcement functions. C.E.

### **A89-49422# THE DAEDALUS PROJECT - A SUMMARY OF LESSONS LEARNED**

JOHN S. LANGFORD (Atlantic Aircraft Co., Alexandria, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs  
(AIAA PAPER 89-2048)

On April 23, 1988, a three-year program in education and research known as the Daedalus Project culminated with a successful 72-mile flight by the human-powered aircraft Daedalus 88. This paper revisits the feasibility study and updates it based on the experience and data obtained during the conduct of the project. The paper draws together the most significant research results obtained in the areas of physiology, meteorology, aerodynamics, structures, performance, and stability and control. It documents the design characteristics and performance of the Daedalus airframe, as well as the human and financial resources devoted to the Project. Author

### **A89-49427# FAA CONCEPTUAL CHANGES IN MINIMUM EQUIPMENT LIST POLICIES**

D. BRIDGENS (American Airlines, Inc., Flight Academy, Fort Worth, TX) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 8 p.  
(AIAA PAPER 89-2055)

A minimum equipment list concept (MEL) within the FAA, requires that all equipment installed on an aircraft in compliance with either airworthiness standards or the operating rules must be operative all the time. The primary driving force for timely restoration of MEL items was the risk of subsequent failures that could render an aircraft unserviceable. FAA policymakers recognized that it would not always be possible to restore inoperative items within the established time limits and provide an extended restoration plan to certain individual operators. Certain features incorporated into aircraft design are considered as not essential for airplane operation, but become required unless the FAA can be convinced of an acceptable level of safety. Aircraft manufacturers should

develop certification programs that include only the equipment essential to the design type. The FAA would then find it necessary to take a more objective position, considering the alternative to be aircraft with only minimal airworthiness standards. C.E.

**A89-49434\*#** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

### **AEROMECHANICS AND MAN-MACHINE INTEGRATION TECHNOLOGY OPPORTUNITIES FOR ROTORCRAFT OF THE 1990S AND BEYOND**

ANDREW W. KERR (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 18 p. refs  
(AIAA PAPER 89-2065)

Programs related to rotorcraft aeromechanics and man-machine integration are discussed which will support advanced army rotorcraft design. In aeromechanics, recent advances in computational fluid dynamics will be used to characterize the complex unsteady flowfields of rotorcraft, and a second-generation comprehensive helicopter analysis system will be used along with models of aerodynamics, engines, and control systems to study the structural dynamics of rotor/body configurations. The man-machine integration program includes the development of advanced cockpit design technology and the evaluation of cockpit and mission equipment concepts in a real-time full-combat environment. R.R.

**A89-49445\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

### **BEFORE THE HIGH-SPEED CIVIL TRANSPORT**

M. LEROY SPEARMAN (NASA, Langley Research Center, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 8 p. refs  
(AIAA PAPER 89-2081)

Following the cancellation of the U.S. National SST Program in March, 1971, NASA conducted SST propulsion technology and configurational aerodynamics and structures development efforts through what came in the wake of a 1976 conference to be called the Supersonic Cruise Research and Variable Cycle Engine programs. These programs were in turn canceled in 1982. The present historical assessment of major advancements in passenger aircraft technology notes that the flying public has tended to be reluctant in accepting such innovations as swept-wing jet airliners and may be expected to be similarly wary about SST use. O.C.

### **A89-49459# AIRCRAFT DESIGN FOR MAINTAINABILITY**

ANTHONY E. MAJOROS (Douglas Aircraft Co., Long Beach, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. refs  
(AIAA PAPER 89-2101)

The interaction between aircraft structure and equipment and their maintenance personnel can be studied and improved during preliminary configuration design efforts through the use of CAD graphics. The human-model figures employed are based on anthropometric data that have been rendered compatible with the CAD geometric environment. Predictions of maintenance personnel performance can be made on the basis of these graphics simulations, leading to design option validations or the formulation of modifications. O.C.

### **A89-49462# MAINTENANCE LESSONS LEARNED - BLUE TWO VISITS**

WILLIAM H. DEHLER (Boeing Military Airplanes, Wichita, KS) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 17 p.  
(AIAA PAPER 89-2104)

The USAF's 'Blue Two Visits' (BTV) program invites contractor engineering personnel to visit AFBs throughout the world in order to experience the daily work of maintenance personnel by actually performing their tasks over the course of a typical week. The

ultimate purpose of BTV is the identification of inadequate maintainability design features. Attention is presently given to the computer data base compiled by a major military aircraft manufacturer on the basis of its BTV experiences, using questionnaires that are filed by its employees upon their return.

O.C.

**A89-49468#****LIGHT HELICOPTER (LHX) PROGRAM DEMONSTRATION/VALIDATION PROGRAM**

ROBERT HUBBARD and DARREL CALDWELL (U.S. Army, LHX Program Management Office, Saint Louis, MO) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. (AIAA PAPER 89-2115)

The elements of the U.S. Army LHX Demonstration/Validation (DEM/VAL) program are overviewed together with the program's activities. The purpose of the LHX DEM/VAL phase is discussed, and the processes used to identify the critical technology candidates for risk-reduction and the technology developments and demonstration efforts currently underway are examined. Particular attention is given to the design parameters of the LHX concept and the improvements achieved in LHX survivability, dash speed, deployability, reliability and maintainability. Consideration is also given to the airborne adverse weather weapon system of the LHX.

I.S.

**A89-49472#****THE AGING FLEET CHALLENGE**

J. T. ROGERS and U. G. GORANSON (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p.

(AIAA PAPER 89-2125)

Boeing continually reviews reported service data and other firsthand information from customer airlines in order to promote continued safe and economic operation of the worldwide fleet. The active service life of commercial airplanes has increased in recent years as a result of low fuel costs and increasing costs and delivery times for fleet replacements. Air transport industry consensus is that older jet transports will continue in service despite anticipated substantial increase in required maintenance. This presentation is focused on recent initiatives to enhance aging airplane safety. These actions are in addition to standard Boeing practices to support continuing structural integrity through inspection and overhaul recommendations contained in maintenance manuals and service bulletins.

Author

**A89-49575****AGING AIRCRAFT ISSUE PRESENTS MAJOR CHALLENGE TO INDUSTRY**

Aviation Week and Space Technology (ISSN 0005-2175), vol. 131, July 24, 1989, p. 42, 43, 45.

For aging aircraft, corrosion tends to pose a double threat, as it progressively thins structural metal cross-sections and exacerbates fatigue. A major consequence of the problem posed by the aging of airliner fleets is that there may be shortages of facilities, personnel, and replacement parts needed to meet inspection and repair schedules. Continuing backlogs in airliner production make it especially difficult to manufacture spare parts. This situation, fortunately, presents avionics manufacturers with the opportunity to take advantage of the enforced downtime for retrofitting of such equipment as Traffic Alert and Collision Avoidance systems. Considerable interest is being shown by the manufacturers of commercial aircraft in NDI technologies for older-aircraft inspection.

O.C.

**A89-49794****PARACHUTE JUMP TESTING OF PORTABLE GPS RECEIVERS**

PAUL BRAISTED (Trimble Navigation, Sunnyvale, CA) Navigation (ISSN 0028-1522), vol. 36, Summer 1989, p. 205-217.

The results of two series of tests in which portable, 2-channel, C/A-code, slow-sequencing GPS receivers were carried by freefall

parachutists are presented. The accuracy of the satellite tracking and the continuous position and velocity data is demonstrated. It is suggested that the receiver be tracking prior to exit if tracking through freefall is desired or if the jump will be of short duration. Desirable characteristics for a GPS receiver for parachute operations are that it is self-contained, low power, and able to withstand vibration and shock.

R.R.

**A89-50169****VERTICAL FLIGHT PROGRAMS AT HUGHES AIRCRAFT COMPANY**

RICHARD DUMOND (Hughes Aircraft Co., Electro-Optical and Data Systems Group, El Segundo, CA) Vertiflite (ISSN 0042-4455), vol. 35, July-Aug. 1989, p. 6-10.

Advanced electrooptical and data-processing systems for the major U.S. vertical flight aircraft programs, the light helicopter experimental (LHX) and the V-22 Osprey, are discussed together with the upgrades to currently fielded systems. Special consideration is given to the night vision system, which is described in detail, and the upgraded Cobra-Nite (a night-targeting system for Cobra attack helicopters) and the upgraded TOW control system TOW 2B.

I.S.

**A89-50171****SOVIET HELICOPTER TECHNOLOGY**

M. N. TISHCHENKO (Vertoletnyi Zavod, Moscow, USSR) Vertiflite (ISSN 0042-4455), vol. 35, July-Aug. 1989, p. 76-86.

A review of the Soviet helicopter engineering evolution is presented, with special consideration given to the designs developed by the Mil Design Bureau (responsible for the design of the single-rotor Mi-series helicopters) and the Kamov Design Bureau (responsible for the development of the Ka-series rotorcraft, which feature the coaxial rotor design concept). Particular attention is given to the amphibious helicopter Mi-14, the fire support helicopter Mi-24, and the heavy-lift helicopters Mi-26 and Ka-32. It is noted that, at present, Mil helicopters hold 96 world records.

I.S.

**A89-50362****DEVELOPMENT OF AN AIRCRAFT SIDE RUDDER IN A NEW TYPE OF CARBON FIBER COMPOSITE TECHNOLOGY [ENTWICKLUNG EINES FLUGZEUGSEITENRUDERS IN NEUARTIGER KOHLEFASER-VERBUNDTECHNOLOGIE]**

MATTHIAS PIENING and ARNO PABSCH (DLR, Institut fuer Strukturmechanik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0011-4901), June 1989, p. 19-22. In German.

The application of a new fabrication technology for lightly loaded composite structures to the construction of an aircraft side rudder is reported. The production process is described, and the modifications made on the rudder as a result of static tests are addressed. The use of a fiber composite actuating lever with the rudder is briefly examined.

C.D.

**A89-50774****POLYMER COMPOSITES FOR HELICOPTER STRUCTURES**

N. G. MARKS (Westland Helicopters, Ltd., Yeovil, England) Metals and Materials (ISSN 0266-7185), vol. 5, Aug. 1989, p. 456-459.

The state-of-the-art in application of fiber-reinforced thermosetting and thermoplastic polymer composites to helicopter primary structures and rotor blading is presently illustrated for the case of the EH101 military helicopter. By comparison with the epoxy-type thermosetting matrix resins in current use, advanced thermoplastic resins have the advantages of a shorter processing time, superior hot/wet environmental conditions resistance, and greater damage tolerance; higher prepreg costs and higher processing temperatures than are associated with thermosets of comparable mechanical strength, however, as well as greater labor requirements, are noted to remain major drawbacks.

O.C.

**A89-51200#****BEWARE 'OFF-THE-SHELF'**

MARK G. FEUERSTEIN (U.S. Navy, Washington, DC) (Society

## 01 AERONAUTICS (GENERAL)

of Experimental Test Pilots, Mini-Symposium, 19th, San Diego, CA, Apr. 7, 8, 1989) Cockpit (ISSN 0742-1508), Apr.-June 1989, p. 4-8.

Tacamo aircraft, such as the EC-130s currently approaching retirement from service, furnish a continuous, survivable communications link between the U.S. National Command Authority and submerged USN ballistic-missile submarines. An account is presently given of the process by which the economics of 'off-the-shelf' procurement were engaged in the creation of the next-generation Tacamo aircraft, designated the E-6, through the use of CFM-56 turbofan-reengined B707 airframes outfitted with the communications electronics of the EC-130s. Attention is given to the degree of confidence that can justifiably be placed in off-the-shelf programs, and to the testing requirements they entail. O.C.

### **A89-51301 AIRCRAFT SYMPOSIUM, 26TH, SENDAI, JAPAN, OCT. 19-21, 1988, PROCEEDINGS**

Symposium sponsored by the Japan Society for Aeronautical and Space Sciences. Tokyo, Japan Publications Trading Co., 1988, 800 p. In English and Japanese. For individual items see A89-51302 to A89-51316.

Recent advances in aircraft and propulsion systems are discussed in reviews and reports, with an emphasis on developments in Japan. Topics addressed include wind-tunnel tests of gust alleviation and gust-load alleviation for aircraft, a one-equation turbulence model for the laminar separation bubble on airfoils, the feasibility of a long-duration high-altitude communication-relay aircraft, in-flight evaluation of a GPS receiver on an aircraft with a stabilized video-camera system, and the thermodynamic spectrum of airbreathing propulsion. Consideration is given to recent ISAS studies of winged reentry vehicles, a sizing and aerodynamic-design study of the Hope spacecraft, a preliminary weight analysis of a two-stage-to-orbit vehicle, the buckling of composite panels with initial imperfections, numerical simulations of hypersonic flow around an aerospace plane at high angle of attack, and CFD studies of chemically reacting flows around aerospace planes. T.K.

### **A89-51306# SPAIN'S AEROSPACE INDUSTRY - PRESENT AND FUTURE**

RAMON TERRONES DIAZ (Construcciones Aeronauticas, S.A., Madrid, Spain) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 180-183.

The role of Spanish industry in ESA programs and other European aerospace projects is surveyed. Consideration is given to the Spanish contributions to Ariane, Meteosat and Olympus, Hermes, military helicopters, the Airbus commercial transports, and the European Fighter Aircraft. The capabilities of Spanish industry with respect to electronics, engine maintenance and manufacturing, missiles, and airframe manufacturing are reviewed, and particular attention is given to the role of the mainly state-owned company Construcciones Aeronauticas S.A. (CASA). The facilities and major activities of the seven principal CASA centers are listed and briefly characterized. T.K.

### **A89-51329# THE PAST AS PROLOGUE**

R. H. GULCHER (Rockwell International Corp., Downey, CA) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 10 p.  
(AIAA PAPER 89-5004)

The relevance of the development history and progressively greater achievements of the NACA/NASA X-series of experimental and research aircraft to the X-30 design effort associated with the NASA National Aero-Space Plane (NASP) program is discussed. Attention is given to lessons derived from the development and flight testing of the X-1, X-7, X-10, XB-70, X-15, X-20, X-23/24, and Space Shuttle Orbiter. An account is given of the CFD, ramjet/scramjet configurational and functional integration, refractory

airframe materials, and adaptive controls method development requirements of the X-30. O.C.

### **A89-51351 ADVANCED AEROSPACE AERODYNAMICS; PROCEEDINGS OF THE AEROSPACE TECHNOLOGY CONFERENCE AND EXPOSITION, ANAHEIM, CA, OCT. 3-6, 1988**

Conference sponsored by SAE, Warrendale, PA, Society of Automotive Engineers, Inc. (SAE SP-757), 1988, 284 p. For individual items see A89-51352 to A89-51369. (SAE SP-757)

The present conference discusses aerodynamic developments applicable to high-speed civil transports, the low-speed aerodynamics of accelerator vehicle configurations, the development history of laminar flow flight testing, the use of the Eppler (1978, 1979) program in studies of airfoil friction and pressure drag, design aspects of long-range laminar flow control-employing SSTs, vortex-lift fighter configuration forebody aerodynamics at high alpha, and the high-alpha flight dynamics testing of the X-29. Also discussed are a VSAERO analysis of several canard-configured aircraft, an Euler code for nonlinear aerodynamic analysis, Navier-Stokes and Euler computations of the flow field around a complete aircraft, inviscid flow field computations for hypervelocity projectiles, and the status of several American university programs in hypersonic research. O.C.

### **A89-51365 Ohio State Univ., Columbus. HYPERSONIC AERODYNAMICS AT THE OHIO STATE UNIVERSITY**

JOHN D. LEE (Ohio State University, Columbus) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 243-247. Research supported by NASA, USAF, and U.S. Navy. (SAE PAPER 881519)

The development status of hypersonic aerodynamics research at Ohio State University after one year of effort under the guidance of the NASA/USAF/USN Hypersonic Training and Research Grant is evaluated. These graduate-level training activities encompass the use of aerodynamic data-gathering sensor and signal-processing systems associated with hypersonic wind tunnels, pressure and flowfield measurements in 4-inch and 12-inch hypersonic wind tunnels, heat-transfer measurements at high angles-of-attack using phase-change paints, and hypersonic flow phenomena visualizations. O.C.

### **A89-51369\* North Carolina State Univ., Raleigh. HYPERSONIC AERODYNAMICS AT NORTH CAROLINA STATE UNIVERSITY**

FRED R. DEJARNETTE (North Carolina State University, Raleigh) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 269-277. Research supported by the U.S. Navy and USAF. refs  
(Contract NAGW-1072; NAGW-1331)  
(SAE PAPER 881524)

Hypersonic Aerodynamics has attracted outstanding graduate students and faculty at NCSU. It has grown to 6 faculty and 32 graduate students for fall, 1988. A significant feature of the program is that students and faculty spend time at government laboratories which currently include NASA Langley Research Center, Naval Surface Warfare Center at Silver Spring, and the Wright Aeronautical Laboratories. Research projects include analysis, computational and experimental aerodynamics. The combined program produces graduates with the background needed to perform aerodynamics investigations of hypersonic aircraft and spacecraft. The research performed helps advance the state of the art as well as assist government laboratories in meeting their goals. Author

**N89-26807#** Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.

**ACTA AERONAUTICA ET ASTRONAUTICA SINICA, VOLUME 8, NUMBER 12, DECEMBER 1987 (SELECTED ARTICLES)**

15 Feb. 1989 71 p Transl. into ENGLISH from Hangkong Xuebao (Peoples Republic of China), v. 8, no. 12, Dec. 1987 p 8557-8562, 8585-8593, and 8601-8610  
(AD-A206782; FTD-ID(RS)T-0942-88) Avail: NTIS HC A04/MF A01 CSCL 01/2

Aircraft take off and landing gear are studied in order to understand nose wheel shimmy and provide measures to prevent it. It also deals with an analysis of runway dynamics and other such similar areas as nose wheel operation. Semi-Prepared Airfield and Design of Double-Action Shock Absorber: Airfields, in wars of the future, most necessarily suffer damage. To satisfy the peculiar demands of using this type of airfield, the design concepts of double action or double gas chamber shock absorbers. Moreover, as concerns their static and dynamic characteristics as well as the main parameters in the principles for their selection, it makes a relatively detailed comparative analysis. The settlement on standards for the unevenness of airfield runways, is based on the concept of power spectra. It introduces basic methods for measuring random variables from the unevenness of airfield runways. It drafts curves for the power spectra of uneven runways and carries out a preliminary analysis of the dynamic effects in aircraft ground surface taxing. GRA

**N89-26809#** Naval Postgraduate School, Monterey, CA. Dept. of Administrative Sciences.

**ESTIMATING AND EXPLAINING THE PRODUCTION COST OF HIGH-TECHNOLOGY SYSTEMS: THE CASE OF MILITARY AIRCRAFT**

O. DOUGLAS MOSES 17 May 1989 85 p  
(AD-A208391; NPS54-89-07) Avail: NTIS HC A05/MF A01 CSCL 01/3

This study tests relationships between measures of the state-of-the-art of technology and advances in technology with production cost. The analysis is conducted using a sample of military aircraft. Parametric cost estimating models are developed. Actual production costs are compared with estimated production costs predicted from the models to create measure of cost overruns and cost underruns. A set of factors that are associated with instances of cost over/underruns are identified. These factors reflect aspects of the aircraft program, the political and economic environment at the time of commencement of production on the aircraft program, and the financial condition of the prime contractor. GRA

**N89-27632#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.

**BASELINE PERFORMANCE VERIFICATION OF THE 12TH YEAR PRODUCTION UH-60A BLACK HAWK HELICOPTER Final Report, 15 Aug. - 2 Sep. 1988**

JOHN I. NAGATA, JOSEPH L. PIOTROWSKI, CHRISTOPHER J. YOUNG, WILLIAM D. LEWIS, PAUL W. LOSIER, and JOSEPH A. LYLE Jan. 1989 74 p  
(AD-A208671; USAAEFA-87-32) Avail: NTIS HC A04/MF A01 CSCL 01/3

Testing was conducted to establish a performance baseline of the 12th year production UH-60A helicopter. A total of 19.5 productive hours were flown at two different test sites between 15 August and 2 September 1988. The performance of the 12th year production UH-60A Black Hawk was similar to or slightly degraded from the sixth year production UH-60A. At the primary mission gross weight, the performance met the requirement of the Prime Item Development Specification (PIDS). The out-of-ground effect hover gross weight capability was 17,416 pounds for 95 percent intermediate (30 minute limit) rated power available at 4000 feet pressure altitude and 35 C temperature. The vertical rate of climb of the 12th year aircraft exceeded the PIDS requirement by 21 ft/min. The 12th year production aircraft has an increase in equivalent flat plate area over the sixth year

production aircraft. At 4000 ft pressure altitude, 35 C, and maximum continuous power, the cruise airspeed is 139 knots true airspeed, equal to the PIDS requirement. GRA

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## AERODYNAMICS

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

**A89-47626**

**AIAA APPLIED AERODYNAMICS CONFERENCE, 7TH, SEATTLE, WA, JULY 31-AUG. 2, 1989, TECHNICAL PAPERS**

Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 782 p. For individual items see A89-47627 to A89-47694.

The present conference discusses the comparative aerodynamic behavior of half-span and full-span delta wings, TRANAIR applications to engine/airframe integration, a zonal approach to V/STOL vehicle aerodynamics, an aerodynamic analysis of segmented aircraft configurations in high-speed flight, unstructured grid generation and FEM flow solvers, surface grid generation for flowfields using B-spline surfaces, the use of chimera in supersonic viscous calculations for the F-15, and hypersonic vehicle forebody design studies. Also discussed are the aerothermodynamics of projectiles at hypersonic speeds, flow visualization of wing-rock motion in delta wings, vortex interaction over delta wings at high alpha, the analysis and design of dual-rotation propellers, unsteady pressure loads from plunging airfoils, the effects of riblets on the wake of an airfoil, inverse airfoil design with Navier-Stokes methods, flight testing for a 155-mm base-burn projectile, experimental results on rotor/fuselage aerodynamic interactions, the high-alpha aerodynamic characteristics of crescent and elliptic wings, and the effects of free vortices on lifting surfaces. O.C.

**A89-47627#**

**FLOW SEPARATION AND VORTEX BURSTING LOCATIONS ON WINGS PITCHING AT CONSTANT RATES**

L. J. HUDSON (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH), P. I. KING (USAF, Institute of Technology, Wright-Patterson AFB, OH), and M. DAVID (USAF, Hill AFB, UT) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-7. refs  
(AIAA PAPER 89-2160)

Water tunnel flow-separation phenomena data have been obtained for rectangular- and delta-planform, wall-mounted pitching wings. While separation locations were measured on the suction surface of the rectangular wings, vortex-bursting locations were ascertained on deltas of various sweep angles. Separations on the rectangular wings were either forward-moving/upstroke rate-dependent or backward-moving/downstroke rate-dependent; in the 45- and 65-deg delta wings, the forward-moving burst locations mainly depend on the upstroke pitching rate, and the rearward-moving bursts on the downstroke rate. O.C.

**A89-47628#** Notre Dame Univ., IN.

**A COMPARISON OF THE AERODYNAMIC CHARACTERISTICS OF HALF-SPAN AND FULL-SPAN DELTA WINGS**

S. M. WALTON, R. C. NELSON, and S. M. BATILL (Notre Dame, University, IN) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 8-18. Research supported by NASA and University of Notre Dame. refs  
(AIAA PAPER 89-2161)

To determine the implications of using half-span models to

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represent full-span wings, a wind tunnel investigation on 70 deg sweep sharp-edged delta wings was conducted. The half-span model was tested with a platform balance at root chord Reynolds numbers of 250,000 and 322,000. A six-component pyramidal force balance was used to obtain force and moment data on the full-span 70 deg delta wing at a root chord Reynolds number of 322,000. There were no discernible changes in the half-span lift and drag coefficients with variation in the Reynolds number, but there was a definite influence on the pitching moment coefficients. The results from this investigation showed that half-span delta wings are not good substitutes for full-span delta wings when studying their aerodynamic characteristics at high angles of attack, but may be suitable when investigating vortex breakdown location. Author

**A89-47630#**

### **AN INVESTIGATION INTO WEDGE-INDUCED TURBULENT BOUNDARY LAYER SEPARATION ON A UNIFORMLY ROUGHENED SURFACE AT MACH 6.0**

P. J. DISIMILE (Cincinnati, University, OH) and N. E. SCAGGS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 32-41. Research supported by USAF. refs (AIAA PAPER 89-2163)

Compressible turbulent boundary layer characteristics on a roughened surface were studied in the presence of a wedge induced adverse pressure gradient. All tests were conducted at a nominal Mach number of 6 and unit Reynolds numbers of 10, 20 and 30 million/ft. Documentation of the surface pressure distribution confirmed the two-dimensionality of the boundary layer flow throughout the interaction region. A 10 percent change in the upstream extent of the separation was observed when the Reynolds number was increased from 10 to 30 million/ft. Pitot pressure and total temperature profiles of the boundary layer were also acquired. Pitot pressures were found to reach a maximum on the ramp 3.5 times that of the freestream pitot pressure. Similarly, total temperature profiles were also found to peak on the ramp. Further, a bimodal character of the total temperature profiles was observed on the ramp with peak values 5 to 30 percent larger than the stagnation temperature. Author

**A89-47633#**

### **INTEGRAL BOUNDARY LAYER FORMULATION FOR BLUNT TRAILING EDGES**

MARK DRELA (MIT, Cambridge, MA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 59-68. Research supported by MIT. refs (AIAA PAPER 89-2166)

Extensions to a two-equation lag-dissipation closure integral boundary layer formulation are developed. The wake is treated as one viscous layer which is matched to the upper and lower airfoil surface boundary layers at the trailing edge. A special treatment of the near wake behind a blunt trailing edge is employed, consisting of a correction to the shape parameter correlation to account for the highly irregular velocity profile in the near wake. The momentum and displacement thickness distributions on the airfoil surfaces and wake compare very well with experiment for transonic and high subsonic flows. The rapid momentum thickness rise immediately behind the blunt trailing edge, representing 'base drag', is captured particularly well, giving the correct far downstream momentum thickness and hence an accurate overall drag prediction. Further work is necessary to more accurately predict mean trailing edge flows with periodic vortex shedding. Author

**A89-47634\*#** Analytical Methods, Inc., Redmond, WA.

**A ZONAL APPROACH TO V/STOL VEHICLE AERODYNAMICS**  
SUNGYUL YOO and DANIEL J. STRASH (Analytical Methods, Inc., Redmond, WA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and

Astronautics, 1989, p. 69-79. Research supported by Analytical Methods, Inc. refs (Contract NAS2-12166) (AIAA PAPER 89-2168)

A zonal method based on an iterative coupling between an inviscid panel method and two viscous finite difference methods is applied to solve for the region of jets issued from generic V/STOL models in order to assess the influence of the jet upon V/STOL configurations. The low-order panel method, VSAERO, is used to solve for the entire flow region, which includes the V/STOL model and jet boundary. ARC3D, a well known compressible, thin layer Navier-Stokes (NS) code developed at NASA-Ames, and APPL, a parabolized NS code, are used to solve for the jet region subject to the boundary condition provided by the VSAERO calculation. Overlapping boundaries are used for the purpose of coupling. Results are presented with the available experimental data for the jet and V/STOL configurations. Author

**A89-47635#**

### **AERODYNAMIC ANALYSIS OF SEGMENTED CONFIGURATIONS IN HIGH-SPEED FLIGHT**

KLAUS A. HOFFMANN, TING-LUNG CHIANG, and WALTER H. RUTLEDGE (Texas, University, Austin) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 80-87. refs (AIAA PAPER 89-2170)

A computational fluid dynamics scheme is presented to solve the hypersonic chemically reacting flowfield over complex double segmented kinetic energy projectiles. The procedure solves the axisymmetric blunt body problem by numerically marching the unsteady Navier-Stokes equations in time using a first-order implicit scheme. Spatial derivatives are modeled in computational space with a first-order flux-vector splitting technique. The resulting block penta-diagonal system is reduced to successive block tridiagonals using an approximate factorization scheme. Equilibrium chemistry effects are included at hypersonic Mach numbers, however, the current investigation is restricted to laminar flow. Author

**A89-47641#**

### **MULTI-BODY FLOW FIELD CALCULATIONS WITH OVERLAPPING-MESH METHOD**

TAKESHI SAKATA and ANTONY JAMESON (Princeton University, NJ) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 140-149. refs (AIAA PAPER 89-2179)

The efficient overlapping-mesh method for Euler flow solvers presently applied to two-body flowfield problems employs simple procedures to ascertain the interface cells on which the flow quantities are to be transferred from one mesh system to the other, thereby obtaining great flexibility of mesh arrangement. In the case of the transonic flow field around two vertically-laid airfoils with strong mutual interaction, a symmetric flow field is predicted despite the asymmetric configuration of the mesh; in the case of a subsonic flow around a Williams airfoil with a flap, an exact potential solution to which is available for comparison, excellent results are obtained once a minor modification to the meshes is conducted. O.C.

**A89-47642#**

### **APPLICATION OF CHIMERA FOR SUPERSONIC VISCOUS CALCULATIONS OF THE F-15**

D. M. SOMMERFIELD and J. C. WAI (Boeing Advanced Systems, Seattle, WA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 150-156. refs (AIAA PAPER 89-2180)

A supersonic viscous calculation for a complete F-15 configuration employing the CHIMERA grid-embedding technique is described. The technique eases the requirements for



grid-generation by using simply constructed overlapping grids for components of the configuration. Flow field information is passed between grids by interpolation at grid boundaries. For this calculation, the solution is obtained by computing a series of grid blocks in the streamwise direction. The procedure for generating the grids and implementing them in the CHIMERA technique is described. Results from a calculation of an F-15 at a Mach number of 1.5 at zero deg angle-of-attack are presented. Author

**A89-47643#**  
**NONADIABATIC HYPERSONIC BOUNDARY LAYERS WITH**  
**NONSIMILAR PRESSURE GRADIENTS**

G. R. INGER (Iowa State University of Science and Technology, Ames) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 157-164. refs  
 (AIAA PAPER 89-2181)

This paper describes a basic study of hypersonic laminar boundary layers when the external inviscid flow differs from a power law by a small perturbation which itself has a power law behavior of a different exponent. Results are given in a universal nondimensional form for the skin friction, heat transfer and displacement thickness as functions of both the basic and perturbed flow pressure gradient exponents and the wall temperature ratio. Such results shed valuable light on the accuracy and limitations of the local similarity approximation for engineering analysis of highly-cooled hypersonic aerodynamic bodies. Author

**A89-47644#**  
**HYPERSONIC VEHICLE FOREBODY DESIGN STUDIES AND**  
**AERODYNAMIC TRENDS**

H. IDE, J. ARMSTRONG, J. HANEY (Rockwell International Corp., Los Angeles, CA), and K. Y. SZEMA (Rockwell International Science Center, Thousand Oaks, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 165-172. Research supported by Rockwell International Independent Research and Development Program. refs  
 (AIAA PAPER 89-2182)

A systematic examination method of the lift to drag ratio and the massflow rate changes due to different types of hypersonic forebody shapes is introduced. Analysis, using a simple Euler marching code, provides increased understanding of aerodynamic trends and an improved forebody design. Several forebody shapes are constructed mathematically from a basic conical cross sectional shape. The aerodynamic results of perturbed shapes are compared. Concurrently, the massflow rate is computed and is compared with the baseline of the conic cross sectional shape. This trade study indicates that the lift to drag ratio and massflow rate are optimized independently for a given cross sectional forebody shape. Therefore, a key to improving the design seems to depend on a combination of cross sectional shapes and their geometric transition lengths. Author

**A89-47645\*#** Old Dominion Univ., Norfolk, VA.  
**INFLUENCE OF SHOCK-SHOCK INTERACTIONS ON THE**  
**BLUNT BODY FLOW FIELD AT HYPERSONIC FLIGHT**  
**SPEEDS**

D. J. SINGH, S. N. TIWARI (Old Dominion University, Norfolk, VA), and A. KUMAR (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 173-182. refs  
 (AIAA PAPER 89-2184)

The effect of shock impingement on the blunt leading edge of the inlet cowl of a scramjet engine is investigated numerically. The impinging shock is caused by the vehicle forebody. The interaction of this forebody shock with the cowl leading edge shock results in a very complex flowfield containing local regions of high pressure and intense heating. In the present investigation, this

complex flowfield is calculated by solving the full Navier-Stokes equations using a finite-volume flux splitting technique due to Van Leer. Results are also obtained for the downstream effects into the inlet of the leading edge shock-shock interactions. Results of the present numerical investigation are compared with available experimental results. Author

**A89-47648\*#** Eidetics International, Inc., Torrance, CA.  
**FLOW VISUALIZATION STUDY OF DELTA WINGS IN**  
**WING-ROCK MOTION**

T. TERRY NG, GERALD N. MALCOLM, and LIANE C. LEWIS (Eidetics International, Inc., Torrance, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 194-204. refs  
 (Contract NAS2-12787)  
 (AIAA PAPER 89-2187)

Water tunnel flow visualizations have been conducted for the wing-rock phenomenon in the cases of models having different leading-edge sweeps and roundness. Wing rock, which is noted to occur in the absence of asymmetric vortex liftoff, vortex breakdown, and static hysteresis, is seen to be initiated by flowfield asymmetries that are induced by flow disturbances and vortex interactions near the apex region; one vortex is thereby strengthened while the other is weakened, inducing a roll moment. Leading-edge roundness decreases vortex strength and reduces vortex spacing, reducing the tendency to wind rock and coupled vortex motions at higher angles-of-attack. O.C.

**A89-47649#**  
**CALCULATION OF HIGH ANGLE-OF-ATTACK**  
**AERODYNAMICS OF FIGHTER CONFIGURATIONS**

C. EDWARD LAN, H. EMDAD, SUEI CHIN (Kansas, University, Lawrence), P. SUNDARAM, and SUDHIR C. MEHROTRA (Vigyan, Inc., Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 205-217. refs  
 (Contract F33615-87-C-3616)  
 (AIAA PAPER 89-2188)

A computational method for lateral-directional aerodynamics of fighter configurations is developed. The leading-edge vortices are represented by free vortex filaments which are adjusted iteratively to satisfy the force-free condition. The forebody vortex separation, both symmetrical and asymmetrical, is calculated with a slender body theory. Effect of boundary layer separation on lifting surfaces is accounted for by using the effective sectional angles of attack. The latter are obtained iteratively by matching the nonlinear sectional lift with the computed results based on a lifting-surface theory. Results for several fighter configurations are employed for comparison with available data. It is shown that the present method produces reasonable results in predicting sideslip derivatives, while roll- and yaw-rate derivatives do not compare very well with forced-oscillation test data at high angles of attack. Author

**A89-47650#**  
**NUMERICAL SIMULATION OF LEADING-EDGE VORTEX**  
**BREAKDOWN USING AN EULER CODE**

P. J. O'NEIL, R. M. BARNETT, and C. M. LOUIE (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 218-226. refs  
 (AIAA PAPER 89-2189)

Accurate simulation of the breakdown of leading-edge vortices emanating from sharp leading edges of delta wings is demonstrated using an Euler code. A straightforward technique is described which identifies the onset of vortex breakdown within numerical solutions, thereby allowing quantitative comparison with experimental data. Predictions of breakdown progression with angle of attack are shown to be consistent with test data up to  $C(L)_{max}$ , and indicate that the vortex breakdown process is governed primarily by inviscid

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factors. Effects of computational grid characteristics and wing camber effects on breakdown prediction are also noted. Author

**A89-47651#**

### **NAVIER-STOKES SIMULATION OF BURST VORTEX FLOWFIELDS FOR FIGHTER AIRCRAFT AT HIGH INCIDENCE**

JOSEPH VADYAK and DAVID M. SCHUSTER (Lockheed Aeronautical Systems Co., Marietta, GA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 227-237. Research supported by the Lockheed Independent Research and Development Program. refs (AIAA PAPER 89-2190)

A computational study has been conducted to investigate vortex breakdown on a generic fighter configuration operating at high incidence. The flow simulations are based on solutions of the full Reynolds-averaged Navier-Stokes equations using an implicit finite-difference algorithm. Results of the analysis have been correlated with an experimental data base obtained using a three-dimensional Laser Velocimeter system. Good correlation has been obtained between the analysis and the data base in terms of the vortex core path, cross-flow velocity fields and the approximate vortex breakdown onset location. Author

**A89-47652#**

### **VORTEX INTERACTION OVER DOUBLE DELTA WINGS AT HIGH ANGLES OF ATTACK**

P. E. OLSEN and R. C. NELSON (Notre Dame, University, IN) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 238-248. Research supported by the University of Notre Dame. refs (AIAA PAPER 89-2191)

An experimental study of the vortical interaction of a double delta wing having leading edge sweep angles of 80/60 deg is presented. Both flow visualization and laser Doppler velocimetry measurements were used to investigate the complicated interactions that exist between the vortices generated on the forward and aft portions of the double delta wing. Vortex trajectory data and velocity surveys are used to identify the nature and extent of the interaction. Author

**A89-47654\*#** Analytical Services and Materials, Inc., Hampton, VA.

### **SUPERSONIC NAVIER-STOKES SIMULATIONS OF TURBULENT AFTERBODY FLOWS**

KHALED S. ABDOL-HAMID (Analytical Services and Materials, Inc., Hampton, VA) and WILLIAM B. COMPTON, III (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 268-277. refs (Contract NAS1-18599) (AIAA PAPER 89-2194)

Four numerical algorithms and three turbulence models are used to solve the thin layer three-dimensional Reynolds-averaged Navier-Stokes equations for the supersonic flow past a nonaxisymmetric nozzle. The four numerical algorithms evaluated are based on upwind differencing and feature time-dependent, space relaxation, and parabolized schemes. The three different algebraic turbulence models are the Baldwin-Lomax (1978), the nonequilibrium model of Johnson and King (1985), and the Goldberg (1989) modification for the separated flow region. The present investigation was conducted at freestream Mach numbers of 1.2 and 1.3 and at an angle of attack of 0.0 deg. The Reynolds numbers for the investigation ranged from 20.5 million to 21.5 million, based on the model length. The calculations are compared with experimental data. Author

**A89-47655#**

### **NONAXISYMMETRIC BODY, SUPERSONIC, INVISCID DYNAMIC DERIVATIVE PREDICTION**

LEROY DEVAN (U.S. Navy, Naval Surface Warfare Center, Dahlgren, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 278-288. Research supported by the U.S. Navy. refs (AIAA PAPER 89-2195)

A supersonic aerodynamic computational model which is the basis of the NANC code has been extended to compute dynamic derivatives. The extension is to the inviscid contribution of constant angular rates and axial accelerations. The body may be noncircular with planar discontinuities, including inlets, with fins (up to six per fin set), which lie on a cylindrical coordinate ray. For the low Mach number range, the original second-order potential model has been extended for angular rate derivative prediction. For the acceleration rate derivatives, a 'hybrid' first- and second-order model has been developed. For the high Mach number range, an equivalent freestream angle-of-attack vector is defined and combined with local solution models. Computational comparisons are made with experimental data, primarily for pitch and roll damping derivatives. Author

**A89-47656\*#** Analytical Services and Materials, Inc., Hampton, VA.

### **THREE-DIMENSIONAL CALCULATIONS FOR UNDEREXPANDED AND OVEREXPANDED SUPERSONIC JET FLOWS**

KHALED S. ABDOL-HAMID (Analytical Services and Materials, Inc., Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 289-296. refs (Contract NAS1-18599) (AIAA PAPER 89-2196)

A three-dimensional code is developed to simulate the characteristics of the jet exhaust plume issuing from nonaxisymmetric nozzles at different flight conditions. In the present paper, the time-iterative Space Marching Scheme (SMS) is used to simulate the shock-cell structure of underexpanded supersonic jet issued from round and square nozzles. Also, the computational results are compared with the experimental data from underexpanded and overexpanded supersonic round jets. The agreement with the experimental data validates the applicability of the new technique for predicting the shock-cell structure of supersonic jet flows. The computational results reveals that the azimuthal structure of the supersonic square jet changed as the jet progressed downstream of the exit nozzle. Author

**A89-47657\*#** Old Dominion Univ., Norfolk, VA.

### **A PARAMETRIC STUDY OF THREE-DIMENSIONAL SEPARATION AT A WING/BODY JUNCTION FOR SUPERSONIC FREE-STREAM CONDITIONS**

B. LAKSHMANAN, S. N. TIWARI (Old Dominion University, Norfolk, VA), and M. Y. HUSSAINI (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 297-306. refs (Contract NAG1-530) (AIAA PAPER 89-2198)

The problem of three-dimensional separation at a wing/body junction has been investigated numerically using a three-dimensional Navier-Stokes code which employs the MacCormack's time split finite volume technique. An algebraic grid generation technique is used for generating the grid at a wing/body junction. Specific computational results on velocity and pressure distribution in the separated flow region are compared with the experimental results. A parametric study of flow parameters such as Mach number and Reynolds number have been carried out to understand their effect in interaction flow field. The parametric study indicates a strong dependency of the number of vortices at the junction on Mach number and Reynolds number. Author

**A89-47658#****EFFECTS OF RIBLETS ON THE WAKE CHARACTERISTICS OF AN AIRFOIL**

J. M. CARAM and A. AHMED (Texas A & M University, College Station) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 307-321. refs

(AIAA PAPER 89-2199)

Near- and intermediate-wake region boundary layer profile and skin friction coefficient measurements have been conducted for a NACA 0012 airfoil incorporating 0.0229, 0.076, and 0.152 mm symmetric v-groove riblets at a freestream Reynolds number of 250,000. While the growth of the wake was found to be similar for both the clean and the riblet-surfaces airfoils, riblet effectiveness in drag reduction was indicated by a significant decrease in wake turbulence levels. A drag reduction of as much as 13.3 percent was achieved, perhaps due to a combination of skin friction diminution in the riblet valleys and a decrease in turbulent shear stress. O.C.

**A89-47661#****INVERSE AIRFOIL DESIGN USING THE NAVIER-STOKES EQUATIONS**

LARRY BIRKELBAW (Lockheed Aeronautical Systems Co., Marietta, GA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 346-353. refs

(AIAA PAPER 89-2202)

A semi-inverse aerodynamic design technique has been developed which couples the well-known Garabedian-MacFadden procedure with an efficient two-dimensional Navier-Stokes solver to allow the design of airfoil sections under realistic viscous flow conditions. The surface coordinates are obtained from a Bezier curve fitting routine which eliminates discontinuities in slope or curvature. Descriptions are given of the design procedure, the Navier-Stokes solver and the Bezier smoothing technique. The procedure is demonstrated for selected test design problems. Author

**A89-47668#****EXPERIMENTAL STUDY OF AERODYNAMIC INTERACTIONS BETWEEN A ROTOR AND A FUSELAGE**

NAIPEI BI and J. GORDON LEISHMAN (Maryland, University, College Park) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 428-439. refs

(Contract DAAL03-88-C-002)

(AIAA PAPER 89-2211)

The effects of mutual aerodynamic interaction between a small-scale articulated rotor and a body-of-revolution fuselage have been ascertained in wind tunnel tests. The results obtained indicate that large downloads and pitching moments are generated in the fuselage by the rotor wake; these loads are significantly affected by variations in both rotor thrust and advance ratio. It is also noted that the presence of the fuselage produces an increase in rotor thrust over that measured in isolated rotor performance. Unsteady pressure fluctuations on the fuselage due to the periodic rotor blade passages' coupling with rotor wake vortices' impingement were pronounced, and often exceeded mean pressure values. O.C.

**A89-47671#****CALCULATION OF ISOLATED AND INSTALLED MULTIPLE ROTOR FLOWS USING A SURFACE PANEL METHOD**

WALTER O. VALAREZO (Douglas Aircraft Co., Long Beach, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 458-463. refs

(AIAA PAPER 89-2214)

A surface panel method capable of computing the flow on

and about arbitrary multiple rotor propellers is presented. The complex rotor-to-rotor aerodynamic interaction is handled by computing time-averaged flows for each rotor and using a superposition technique to account for all rotor influences. The various features of the method are described and computed results for multiple rotor configurations are presented for both isolated and installed cases. Comparisons to experimental data show good agreement and are presented wherever available. The multiple-rotor/airplane interference solutions presented are a first-in-the-industry. Author

**A89-47672#** Iowa State Univ. of Science and Technology, Ames.**A NUMERICAL STUDY OF A WING AND PROPELLER IN MUTUAL INTERFERENCE**

R. GANESH RAJAGOPALAN (Iowa State University of Science and Technology, Ames) and MARVIN A. MOULTON IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 464-472. Research supported by NSF, NASA, and Iowa State University of Science and Technology. refs

(AIAA PAPER 89-2215)

The aerodynamic interference of a wing and propeller is studied. Steady, laminar, incompressible Navier-Stokes equations are solved in cartesian coordinate system. The wing itself is treated as a solid blocked off region in the computational domain with no slip boundary condition applied on the surface. The propeller is modeled as momentum sources from known geometric and airfoil characteristics of the blades and the computed local flow field. A nonuniform slipstream and all components of the induced velocity are captured by the solution procedure. The thrust and torque developed by the propeller are computed with and without the wing interference and compared. Several cross planes of the flow field are presented to contrast the flow with the wing and propeller to that of the flow through the propeller only. Author

**A89-47674#****MEASUREMENTS OF THE AERODYNAMIC CHARACTERISTICS OF VARIOUS WING-CANARD CONFIGURATIONS AND COMPARISON WITH NLVLM RESULTS**

J. ROM, J. ER-EL, and R. GORDON (Technion - Israel Institute of Technology, Haifa) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 481-490. refs

(AIAA PAPER 89-2217)

Three different close-coupled wing-canard configurations have been tested in a wind tunnel at Mach 0.15 and Re of 5 million, to ascertain their comparative aerodynamic characteristics; the results obtained have been compared with calculation results of the NLVLM program. The aerodynamic characteristics are noted for various canard lateral positions. Reasonably good agreement is found; the calculated values of the lift and induced drag coefficients are in especially good agreement for angles of attack less than that of vortex-breakdown. NLVLM calculation results for pitching moment and pressure distribution do not, however, agree with the experimental data. O.C.

**A89-47676#****COMPUTATION OF THE EULER FLOW FIELD PRODUCED BY A TRANSONIC AIRCRAFT WITH STORES**

J. H. FOX, T. L. DONEGAN, J. L. JACOBS, and R. H. NICHOLS (Calspan Corp., Arnold AFB, TN) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 500-512. refs

(AIAA PAPER 89-2219)

A series of computations solving the Euler equations that model the flow field produced by the F-15E aircraft flying at a Mach number of 0.98 has been completed. The configurations simulated were: wing/body/inlet; wing/body/inlet/pylons/targeting pod; and

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wing/body/inlet/pylons/targeting pod/one guided store. The guided store had four canards and four rear tail-fin gloves. A computational grid was developed that required 29 grids with a total of 1.2 million mesh points. Results were compared with wind-tunnel measurements of surface pressure and with a cone-probe survey of the pressure field proximate to the store carriage positions. Clean aircraft comparisons were excellent, and comparisons using the last configuration (with the store) were good, particularly since inviscid equations were used. Author

**A89-47677#**

### TRANAIR APPLICATIONS TO FIGHTER CONFIGURATIONS

W. TSENG, E. FEINBERG, and A. CENKO (U.S. Navy, Naval Air Development Center, Warminster, PA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 513-518. refs (AIAA PAPER 89-2220)

Initial results obtained using the TRANAIR transonic full potential code for the F-14 configuration are compared with Boppe's small disturbance code and flight test wing pressure data. Results are shown for an existing PANAIR panel model and a refined model where additional panels were added in the wing leading and trailing edge region. These comparisons indicate that the TRANAIR code can use existing PANAIR aircraft panel models, with minor modifications, to give good results at transonic speeds. Author

**A89-47678\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### EXPERIMENTAL INVESTIGATION OF THE F/A-18 VORTEX FLOWS AT SUBSONIC THROUGH TRANSONIC SPEEDS

GARY E. ERICKSON, ROBERT M. HALL, DANIEL W. BANKS (NASA, Langley Research Center, Hampton, VA), JOHN H. DEL FRATE, JOHN A. SCHREINER (NASA, Ames Research Center, Moffett Field, CA) et al. IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 519-594. refs (AIAA PAPER 89-2222)

A subsonic-to-transonic speed wind tunnel study has been conducted to deepen understanding of the nature and possibilities for control of vortical flows associated with wing leading edge extensions (LEXs) on the F/A-18 aircraft; these vortical phenomena encompass vortex breakdown and vortex interactions with vertical stabilizers. Wind tunnel results were correlated with in-flight flow visualizations as well as handling-qualities trend data from a USN F-18 with LEX fences to improve the vertical tail buffet environment. Attention is given to the sensitivity of the vortex flows to Re and Mach numbers, reduced vertical tail excitation due to the presence of a LEX fence, and the interpretation of off-body flow visualizations. O.C.

**A89-47681#**

### VORTEX/WAKE FLOW STUDIES FOR AIRFOILS IN UNSTEADY MOTIONS

Z. X. YAO, P. GARCIA-FOGEDA, D. D. LIU (Arizona State University, Tempe), and GEORGE SHEN (Northrop University, Los Angeles, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 622-636. Research supported by the U.S. Navy. refs (AIAA PAPER 89-2225)

A time-domain method has been developed to account for vortex-airfoil-wake interaction problems. The present method is based on a high-order panel scheme on the airfoil coupling with the discrete vortex tracking technique for treatments of the wake and assigned free vortex. Computation examples include complete checks of classical problems, high angle of attack histogram, and various vortex-airfoil interaction problems. New results for the impulsively-started airfoils in tandem are also presented. The present method is found to be a robust one in handling the vortex-airfoil-wake interaction problems. Finally, issues involving

conservation of vorticity condition and vortex models will be discussed. Author

**A89-47682#**

### WING BOUNDARY LAYER RESPONSE TO AN UNSTEADY TURBULENT FLOWFIELD

RICHARD M. HOWARD (U.S. Naval Postgraduate School, Monterey, CA) and ROBERT W. RENOUD (USCG, Elizabeth City, NC) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 637-644. Research supported by the U.S. Navy. refs (AIAA PAPER 89-2226)

Hot-wire velocity measurements have been made of the nonstationary mean velocity and turbulence intensity profiles, as well as the power spectra and cumulative power spectral plots, of the time-dependent boundary layer response of attached flow over an airfoil in response to a periodic turbulent flowfield. Laminar, transitional, and turbulent conditions are encompassed by the measurements. After initial passage of the highly turbulent pulse, the boundary layer recovers to the undisturbed transitional or turbulent state through a recovery period that is distinguished by reduced thickness, a turbulence level lower than that of the undisturbed state, and a turbulence power level that is orders-of-magnitude lower than that of the undisturbed state. O.C.

**A89-47683#**

### VORTEX FLOWS CREATED BY SINUSOIDAL OSCILLATION OF THREE-DIMENSIONAL WINGS

J. ASHWORTH, W. CRISLER, and M. LUTTGES (U.S. Air Force Academy, Colorado Springs, CO) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 645-654. Research supported by USAF. refs (AIAA PAPER 89-2227)

A study is conducted of the vortex-vortex interactive region generated on a rectangular-planform wing as it oscillates through sinusoidal motions about its quarter-chord, using phase-locked stroboscopic photography as the method of initial data collection followed by hot-wire anemometry and surface-pressure measurements. Flow analyses conducted across the span of the wing exhibit repeatable patterns of leading-edge and wingtip vortex size, development, position, and convection velocity throughout the pitching cycle. There results are applicable to a data base for the validation of computational codes attempting the prediction of forces and moments about a dynamic control surface. O.C.

**A89-47684#**

### UNSTEADY PRESSURE LOADS FROM PLUNGING AIRFOILS

ERIC STEPHEN (USAF, Frank J. Seiler Research Laboratory, Colorado Springs, CO), CHRIS KEDZIE, and MICHAEL C. ROBINSON (U.S. Air Force Academy, Colorado Springs, CO) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 655-662. Research supported by USAF. refs (AIAA PAPER 89-2228)

Forced unsteady flow separation from a dynamically plunging airfoil was investigated using surface mounted pressure transducers. The transient pressure distributions and integrated lift and drag coefficients were plotted for parametric alterations in mean angle of attack, reduced amplitude and reduced frequency. The unsteady loads produced were strongly dependent upon the dynamic stall event. Dynamic similarity for dimensional scaling of plunging motions was shown to be a function of both reduced frequency and amplitude. Author

**A89-47685#**

### UNSTEADY FLOWS PRODUCED BY SMALL AMPLITUDE OSCILLATIONS OF THE CANARD OF AN X-29 MODEL

T. MOUCH, T. MCLAUGHLIN, and J. ASHWORTH (U.S. Air Force

Academy, Colorado Springs, CO) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 663-672. refs  
(AIAA PAPER 89-2229)

This investigation develops previous flow visualization studies by quantifying the flowfield around the tandem wing of an X-29 model in the wake of an oscillating canard. The local velocity above and below the wing was measured with the canard oscillating and compared to the cases with the canard static. A structured disturbance pattern was documented in the wake of the oscillating canard then compared to the random flow pattern behind the static canard. Considering the dual vortex system shed from the oscillating canard, the tip vortex dominates the flowfield, the leading edge vortex passes well above the wing. Author

#### **A89-47686#**

##### **VERTICAL FLOW SOLUTIONS USING A TIME-LAGGED THIN-LAYER NAVIER-STOKES ALGORITHM**

JON S. MOUNTS, DAVE M. BELK (USAF, Armament Laboratory, Eglin AFB, FL), and JAMES E. MILTON (Florida, University, Eglin AFB) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 673-681. refs  
(AIAA PAPER 89-2231)

A multi-block, implicit, steady-state thin-layer Navier-Stokes algorithm is presented and applied to obtain transonic flow solutions about a lifting body of elliptic cross-section. Flow conditions are such that large-scale free vortices develop in the leeside flowfield. The thin-layer Navier-Stokes algorithm is an upwind, finite-volume method that implicitly treats the flux-split convective terms and explicitly handles the diffusive terms, effectively time-lagging the viscous effects. Closure is obtained from the standard algebraic turbulence model. The time-lagged thin-layer Navier-Stokes algorithm has been shown to yield accurate viscous solutions to the transonic vortical flowfield; however, the roll up of the vortex sheet is slow to develop and the vortex is typically placed slightly outboard of experimental results. Author

#### **A89-47687#**

##### **THE ROLE OF THE NUMERICAL DISSIPATION ON THE COMPUTATIONAL EULER-EQUATIONS-SOLUTIONS FOR VORTICAL FLOWS**

J. M. A. LONGO (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 682-691. Research supported by DLR and Messerschmitt-Boelkow-Blohm GmbH. refs  
(AIAA PAPER 89-2232)

The reliability and shortcomings of the numerical solution of the Euler equations to predict vortical flow fields around a sharp leading-edge delta wing at moderate to high angles of attack are analyzed for sub-, trans-, and supersonic flow regimes. The influence of the convergence level, order of accuracy, artificial viscosity, mesh fineness, mesh structure (distribution of points and far field location) and mesh topology are investigated for three different finite-volume schemes for the solution of the Euler equations. The existence of a unique numerical Euler solution for vortical flows is discussed. Computed results are compared with experimental data in order to find the limits of the solution method to predict complicated flow features like vortex breakdown and vortex-shock interaction. The implications due to neglecting viscous effects on practical engineering applications is shown. Author

#### **A89-47688\*#** Old Dominion Univ., Norfolk, VA.

##### **NUMERICAL ANALYSIS OF FLOW ABOUT A TOTAL TEMPERATURE SENSOR**

ERNST VON LAVANTE, RUSSELL L. BRUNS, JR. (Old Dominion University, Norfolk, VA), MARK D. SANETRIK (West Virginia University, Morgantown), and TIM LAM (Weed Instrument Co., Inc.,

Round Rock, TX) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 692-714. Research supported by Weed Instrument Co. refs  
(Contract NAG1-633)  
(AIAA PAPER 89-2233)

The unsteady flowfield about an airfoil-shaped inlet temperature sensor has been investigated using the thin-layer and full Navier-Stokes equations. A finite-volume formulation of the governing equations was used in conjunction with a Runge-Kutta time stepping scheme to analyze the flow about the sensor. Flow characteristics for this configuration were established at Mach numbers of 0.5 and 0.8 for different Reynolds numbers. The results were obtained for configurations of increasing complexity; important physical phenomena such as shock formation, boundary-layer separation, and unsteady wake formation were noted. Based on the computational results, recommendations for further study and refinement of the inlet temperature sensor were made. Author

#### **A89-47689#**

##### **NUMERICAL COMPUTATION OF HYPERSONIC TURBULENT FLOWS USING ZERO- AND ONE-EQUATION MODELS**

S. V. RAMAKRISHNAN, U. C. GOLDBERG, and D. K. OTA (Rockwell International Science Center, Thousand Oaks, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 715-719. refs  
(AIAA PAPER 89-2234)

Calculations of hypersonic turbulent flows over a spherically blunted cone, bicone and a cavity have been carried out using a modified Baldwin-Lomax zero-equation model and a new one-equation K-L model. A detailed evaluation of the models is presented by comparing computed kinematic eddy viscosity, length scale, skin-friction, heat transfer rates and wall pressure distributions with those obtained from experiments. Author

#### **A89-47690\*#** North Carolina State Univ., Raleigh.

##### **EFFECTS OF NOSE BLUNTNESS, ROUGHNESS, AND SURFACE PERTURBATIONS ON THE ASYMMETRIC FLOW PAST SLENDER BODIES AT LARGE ANGLES OF ATTACK**

CARY A. MOSKOVITZ, F. R. DEJARNETTE (North Carolina State University, Raleigh), and ROBERT M. HALL (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 720-732. refs  
(Contract NCC1-46)  
(AIAA PAPER 89-2236)

The effects of such geometric perturbations as variations of model-tip sharpness and roughness, as well as discrete surface perturbations, on the asymmetric flow past slender bodies is experimentally investigated for the cases of a cone/cylinder model having a 10-deg semiapex angle and a 3.0-caliber tangent ogive model. Both models have base diameters of 3.5 inches, and were tested in laminar flow conditions at angles-of-attack in the 30-60 deg range. Single, discrete roughness elements were represented by beads; bead effectiveness was judged on the basis of the extent to which they affected the flowfield in various conditions. O.C.

#### **A89-47692#**

##### **THEORETICAL AND QUALITATIVE ANALYSIS OF THE EFFECT OF FREE VORTICES ON LIFTING SURFACES**

C. J. DIXON (Lockheed Aeronautical Systems Co., Burbank, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 743-752. refs  
(AIAA PAPER 89-2238)

While a lifting surface's leading-edge vortex lift is largely due to the free shear layer from which the free vortex originates, the stable free vortage generated from this shear layer has only modest and indirect effects on lifting surface forces; it has large and direct

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effects, however, on lifting-surface moments. An appropriate model is presently defined for this effect in two-dimensional theory, with a view to the representation of three-dimensional wing cross-sections. It is shown that the local chordwise and normal forces on a delta wing are not greatly affected by the strength and location of the free vortex except near the apex and wingtip.

O.C.

**A89-47693#**

### **TURBULENCE-FLOW CALCULATIONS FOR FLOW OVER WINGS NEAR MAXIMUM LIFT**

J. E. DEESE and R. K. AGARWAL (McDonnell Douglas Research Laboratories, Saint Louis, MO) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 753-762. Research supported by Douglas Aircraft Co. refs  
(AIAA PAPER 89-2239)

Calculation of horizontal-stabilizer flowfields near maximum lift using a three-dimensional Navier-Stokes code is described. Results are presented for two stabilizer configurations with and without elevator deflection. Predicted lift coefficients are within 10 percent of experimental values up to the onset of stall. The code is able to predict the onset of both wing and elevator stall for the two configurations studied. Surface pressure distribution predictions are in good agreement with experimental data. Author

**A89-47694\*#** California Univ., Davis.

### **HIGH-ALPHA AERODYNAMIC CHARACTERISTICS OF CRESCENT AND ELLIPTIC WINGS**

C. P. VAN DAM (California, University, Davis), P. M. H. W. VIJGEN (High Technology Corp., Hampton, VA), and B. J. HOLMES (NASA, Washington, DC) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 763-774. refs  
(Contract NAG1-732; NAS1-18240)  
(AIAA PAPER 89-2240)

Static longitudinal and lateral-directional forces and moments were measured for elliptic- and crescent-wing models at high angles of attack in the NASA Langley 14-by-22-ft Subsonic Tunnel. The forces and moments were obtained for an angle-of-attack range including stall and post-stall conditions at a Reynolds number based on the average wing chord of about 1.8 million. Flow-visualization photographs using a mixture of oil and titanium-dioxide were also taken for several incidence angles. The force and moment data and the flow-visualization results indicated that the crescent wing model with its highly swept tips produced much better high-angle-of-attack aerodynamic characteristics than the elliptic model. Leading-edge separation-induced vortex flow over the highly swept tips of the crescent wing is thought to produce this improved behavior at high angles of attack. The unique planform design could result in safer and more efficient low-speed airplanes.

Author

**A89-47863**

### **COMPUTATIONAL AERODYNAMICS FOR AIRCRAFT DESIGN**

ANTONY JAMESON (Princeton University, NJ) Science (ISSN 0036-8075), vol. 245, July 28, 1989, p. 361-371. refs

This article outlines some of the principal issues in the development of numerical methods for the prediction of flows over aircraft and their use in the design process. These include the choice of an appropriate mathematical model, the design of shock-capturing algorithms, the treatment of complex geometric configurations, and shape modifications to optimize the aerodynamic performance. Author

**A89-47896**

### **EXACT SOLUTION OF THE KARMAN-FAL'KOVICH EQUATION DESCRIBING SEPARATION FROM THE CORNER POINT OF AN AIRFOIL PROFILE [TOCHNOE RESHENIE URAVNENIYA KARMANA-FAL'KOVICHA, OPISYVAIUSHCHEE OTRYV OT UGLOVOI TOCHKI PROFILIA]**

V. N. DIESPEROV (AN SSSR, Vychislitel'nyi Tsent, Moscow, USSR) Akademiia Nauk SSSR, Doklady (ISSN 0002-3264), vol. 306, May 30, 1989, p. 561-565. In Russian. refs

**A89-47926**

### **AERODYNAMIC CHARACTERISTICS OF WINGS WITH ULTRASMALL ASPECT RATIO IN THE ANGLE-OF-ATTACK RANGE 0-90 DEG [AERODINAMICHESKIE KHARAKTERISTIKI KRYL'EV SVERKHMALOGO UDLINENIYA V DIAPAZONE UGLOV ATAKI 0-90 DEG]**

K. P. DANIL'CHENKO and V. I. KULESHOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 3-5. In Russian. refs

Aerodynamic characteristics of a V-wing with ultrasmall aspect ratio and an apex angle of 90 deg, of a thin rectangular plate with sharp edges, and of a trihedral prism formed by filling the inner-wing-angle space were investigated by analyzing flows produced on the leeside of these bodies in a subsonic tunnel at the incoming-flow speed of 45 m/sec. It was found that, for all these models, the coefficients of the normal force,  $C(y)$ , were quantitatively similar and were determined by the flow. I.S.

**A89-47929**

### **APERIODIC WING MOTIONS ABOVE A SOLID BOUNDARY [APERIODICHESKIE DVIZHENIYA KRYL'EV NAD TVERDOI GRANITSEI]**

E. P. LUKASHCHIK Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 14-20. In Russian. refs

The effect of aperiodic turbulence on a finite-aspect-ratio wing was investigated for abrupt and gradual wing entry into a stepped gust located at a random distance from a flat solid boundary. Using the pi-type vortex concept, an integrodifferential equation for an unsteady finite flow about the airfoil was developed. I.S.

**A89-47930**

### **SUBSTANTIATION OF THE VALIDITY OF LINEAR THEORY IN INVESTIGATIONS OF FLOWS PAST BLUNT BODIES ON THE BASIS OF A NUMERICAL EXPERIMENT [OBOSNOVANIE PRIMENIMOSTI LINEINOI TEORII PRI ISSLEDOVANII OBTEKANIYA ZATUPLennykh TEL S POMOSHCH'U VYCHISLITEL'NOGO EKSPERIMENTA]**

S. A. BANNIKOVA and A. N. TSAR'KOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 20-24. In Russian. refs

The use of linear theory for investigating flows past blunt bodies is illustrated. Based on the method of aerodynamic equivalence, numerical calculations were performed to determine the effect of the angle of attack on the gasdynamic parameters and aerodynamic coefficients of a blunt body with a high aspect ratio. Results show that the linear approach to the problem of flow about a blunt body in a supersonic flow can be used only for low values (between 0 and 11 deg) of the angle of attack. I.S.

**A89-47931**

### **INVESTIGATING A CLASS OF LOCAL SOLUTIONS FOR THE PROBLEM OF A FLOW PAST A FLAT WING WITH INJECTION [ISSLEDOVANIE KLASSA CHASTNYKH RESHENII ZADACHI OBTEKANIYA PLOSKOGO KRYLA SO VDUVOM]**

A. M. ANTONOVA and L. I. DZVONIK Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 25-29. In Russian.

This paper investigates the three-dimensional problem of a supersonic flow past a triangular flat wing, with intense mass exchange on the wing surface. An asymptotic solution was derived for local boundary-value problems related to the flow's basic gasdynamic parameters. The shapes of the shock wave and contact discontinuity for a stepped-injection law were determined. I.S.

**A89-47932**

### **SOLUTION OF AN EXTREME-VALUE PROBLEM OF HYPERSONIC AERODYNAMICS [RESHENIE ODNOI EKSTREMAL'NOI ZADACHI GIPERZVUKOVOI AERODINAMIKI]**

V. I. KHOLIIVKO Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 29-34. In Russian.

A solution was obtained for the problem of constructing a slender body with maximal aerodynamic efficiency from given values for the base (the midsection), the height, and the shape of the side surface in a hypersonic viscous flow. Pressure on the surface of the body is calculated using Newton's formula, and the local friction coefficient is given in the form of a power function of the longitudinal coordinate. I.S.

**A89-47933**

**ALGORITHM FOR CALCULATING TRANSONIC VISCOUS-GAS FLOWS NEAR ASYMMETRIC WING PROFILES [OB ALGORITME RASCHETA TRANSZVUKOVYKH TECHENII VIAZKOGO GAZA VOZLE NESIMMETRICHNYKH KRYLOVYKH PROFILE]**

V. I. PINCHUKOV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 34-37. In Russian.

This paper investigates plane laminar viscous-gas flow with local supersonic and circulatory zones near an asymmetric wing. The algorithms for the transonic flow calculations are described in the framework of the scheme developed earlier by Pinchukov (1983). The effects of various boundary conditions on the solution of this problem were investigated. I.S.

**A89-47962**

**CALCULATION OF A FINITE-SPAN CURVED WING [RASCHET IZOGNUTOGO KRYLA KONECHNOGO RAZMAKHA]**

M. V. DEVAEV and T. K. SIRAZETDINOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 44-49. In Russian.

A method is proposed for solving an equation describing circulation distribution over a finite-span curved wing. The method allows for the presence of a sideslip angle and for the nonlinear nature of the angle-of-attack dependence of the lift coefficient. Results of calculations are presented. V.L.

**A89-47964**

**NUMERICAL INVESTIGATION OF THE CHARACTERISTICS OF SUPERSONIC FLOW OF A NONVISCOUS GAS PAST A CIRCULAR CONE WITH PLANE WINGS [CHISLENNOE ISSLEDOVANIE OSOBENNOSTEI SVERKHZVUKOVOGO OBTEKANIIA KRUGOVOGO KONUSA S PLOSKIMI KRYL'IAMI POTOKOM NEVIAZKOGO GAZA]**

V. I. TIMOSHENKO and L. M. FILIPPOVSKAIA Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 53-55. In Russian. refs

The problem of supersonic flow of a nonviscous gas past a blunt cone with thin delta wings at angle of attack is solved in cylindrical coordinates using McCormack's finite difference scheme to solve the system of Euler equations. The dependence of pressure and aerodynamic characteristic distributions on the body geometry and flow parameters is analyzed in qualitative terms. V.L.

**A89-48193**

**AN OPTIMUM METHOD FOR EXTRACTING THE AERODYNAMIC DERIVATIVES OF A HELICOPTER FROM FLIGHT TEST DATA**

SONGSHAN YANG (Flight Test Research Institute, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 2, May 1989, p. 102-109.

This paper describes a method for extracting the aerodynamic derivatives of a helicopter from flight test data by means of the frequency technique, Kalman filter, and Bayesian maximum-likelihood technique. The method can be summarized as follows. First, the high frequency effects from the rotor are eliminated by frequency technique. Then, by using the Kalman filter, the random noise is reduced considerably. Finally, by using the maximum likelihood technique, the random noise is minimized, and the final derivatives are extracted. By using this method, the bias error is minimized, the multiple correlation coefficient will approach 1.0, and the latent roots will approach true values. It is

more accurate than using any technique alone (for example, the least square technique, Kalman filter, or maximum likelihood technique). Author

**A89-48194**

**EXPERIMENTAL STUDY ON APPLICABILITY OF DAMAGE FAILURE CRITERION OF COMPOSITE LAMINATES**

ZHEN SHEN, JUNSHI LIU, XIAODONG TANG (Aircraft Strength Research Institute, Yaoxian, People's Republic of China), QI HUANG, and WEI SHEN (Central China University of Science and Technology, Wuhan, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 2, May 1989, p. 110-113.

The damage strain energy release rate failure criterion developed by Shen et al. (1985, 1986) for composite laminates is described, and the engineering applicability of this criterion is demonstrated using results from a tension damage test on different lay-ups of carbon/648-epoxy laminates. The results verified the validity of the damage failure criterion, as well as of an expression developed for the damage evolution law. I.S.

**A89-48651#**

**COMPUTATIONAL SIMULATION OF VORTEX GENERATOR EFFECTS ON TRANSONIC SHOCK/BOUNDARY-LAYER INTERACTION**

G. R. INGER (Iowa State University of Science and Technology, Ames) and TIMOTHY SIEBERMA Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 697, 698. Previously cited in issue 16, p. 2598, Accession no. A88-40771.

**A89-48652#**

**THREE-SURFACE AIRCRAFT - OPTIMUM VS TYPICAL**

KAMRAN ROKHSAZ and BRUCE P. SELBERG (Missouri-Rolla, University, Rolla) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 699-704. refs

Comparisons of the induced drag for a three-surface general aviation aircraft were made using a vortex lattice method and Prandtl-Munk theory. Substantial differences between the two prediction methods have been shown in the presence of practical nonelliptic spanwise load distributions. At the same time, a parametric study using the vortex lattice method has been carried out to determine the sensitivity of lift to induced-drag ratio to different design variables. Using the resulting trends, a three-surface general aviation aircraft has been modeled and compared with its equivalent canard and conventional configurations. It has been shown that although the three-surface geometry is more efficient than a canard configuration, it remains inferior to a conventional design. Author

**A89-48653#**

**EXPERIMENTAL INVESTIGATION OF WING/FUSELAGE INTEGRATION GEOMETRIES**

M. MAUGHMER (Pennsylvania State University, University Park), D. HALLMAN, R. RUSZKOWSKI (General Dynamics Corp., Fort Worth, TX), G. CHAPPEL (USAF, Minot, ND), and I. WAITZ Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 705-711. Previously cited in issue 03, p. 283, Accession no. A88-14278. refs

**A89-48656\*#** North Carolina State Univ., Raleigh.

**UNSTEADY VISCOUS-INVISCID INTERACTION PROCEDURES FOR TRANSONIC AIRFOILS USING CARTESIAN GRIDS**

CHARLES C. FENNO, JR., H. A. HASSAN (North Carolina State University, Raleigh), and PERRY A. NEWMAN (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 723-730. Research supported by USAF and U.S. Navy. Previously cited in issue 16, p. 2596, Accession no. A88-40757. refs (Contract NGT-34-002-801; NAGW-1072)

**A89-48657#**

**INVESTIGATION OF THE BUFFET CHARACTERISTICS OF TWO SUPERCRITICAL AIRFOILS**

B. H. K. LEE, F. A. ELLIS, and J. BUREAU (National Research



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Council of Canada, Ottawa) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 731-736. refs

The buffet characteristics of two supercritical airfoils were investigated at the high Reynolds number two-dimensional test facility of the National Aeronautical Establishment. The design conditions of these two airfoils were quite similar. The thickness-to-chord ratio differed from each other by approximately 35 percent. The buffet onset boundaries were determined from the divergence of the unsteady balance normal force. They were compared to show the effect of thickness-to-chord ratio on buffet onset. One of the airfoils was instrumented with fast-response pressure transducers on the upper surface. Pressure intensities for shock-induced separation with reattachment as well as fully separated flows were measured. For flow conditions where discrete-frequency shock wave oscillations occurred, ensemble averaging of the unsteady pressure were carried out to determine the propagation of the pressure wave induced by periodic shock motion. Spectral analyses of the pressure and normal force fluctuations were carried out quite deep into the buffet regime. Broadband convection velocities of the turbulent eddies were measured for fully separated flows. Author

**A89-48658#**  
**DEVELOPMENT OF AN ANALYTICAL MODEL OF WING ROCK FOR SLENDER DELTA WINGS**

J. M. ELZEBDA, A. H. NAYFEH, and D. T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 737-743. refs

(Contract AF-AFOSR-85-0158)

Three analytical models of the subsonic wing-rock phenomenon for slender delta wings mounted on free-to-roll stings are compared. The first model was developed earlier by other investigators, the second is a version of the first model that has been modified in the present paper, and the third was developed in an earlier paper by the authors. The differences among the three models lie in the assumed nonlinear form of the roll moment as a function of the roll angle and its derivative. The numerical values of the coefficients in the moment expressions are obtained by fitting them to moments obtained in an earlier numerical simulation. It is shown that the original model, which contains only quadratic terms, does not predict roll divergence. The model is modified by the addition of a cubic term, and the modified version does predict roll divergence. An asymptotic approximation to the solution of the equation of motion is obtained for the modified model, and it is shown that the solution reduces to the one given when the cubic term is dropped. Finally, the two models are compared with a third model developed earlier by the authors. The periods and amplitudes predicted by the asymptotic analysis for all three models are in close agreement with the numerical simulations, which were found in an earlier work to be in good agreement with experimental data. It appears that the authors' model is slightly more accurate and easier to analyze than either the earliest model or the modified version of that model. Author

**A89-48661#**  
**INFLUENCE FUNCTION METHOD APPLICATIONS TO CAVITY FLOWFIELD PREDICTIONS**

A. GENKO, D. CHEN, and R. TURZANSKI (U.S. Navy, Naval Air Development Center, Warminster, PA) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 760-764. Previously cited in issue 09, p. 1282, Accession no. A89-25390. refs

**A89-48662#**  
**MODIFICATIONS TO TRANSONIC FLOW CODES FOR UNSTEADY PERTURBATIONS AROUND AN EXPERIMENTAL MEAN**

L. C. RODMAN, D. NIXON (Nielsen Engineering and Research, Inc., Mountain View, CA), and L. J. HUTTSELL (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 765-771. Previously cited in issue 09, p. 1281, Accession no. A89-25365.

refs  
(Contract F33615-87-C-3211)

**A89-48666#**  
**LIFT-CURVE SLOPE FOR FINITE-ASPECT-RATIO WINGS**

E. V. LAITONE (California, University, Berkeley) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 789, 790. refs

Exact lift-generation solutions for an elliptic-planform flat plate in steady, incompressible potential flow are presently used to improve the commonly used lift curve slope approximations of finite aspect ratio wings; excellent approximation results are thereby obtained for the initial lift-curve slope when the aspect ratio is not greater than 2. In the case of greater aspect ratios, the lift curve slope equation is still significantly improved, and can therefore more accurately determine the corresponding two-dimensional lift-curve slope from finite aspect ratio wing wind tunnel test data. O.C.

**A89-48741#**  
**UNSTEADY AERODYNAMIC THEORY USING CORRECTION BY WIND-TUNNEL MEASUREMENTS**

ROGER DESTUYNDER (ONERA, Chatillon-sous-Bagneux, France) and ROLAND BARREAU (Aerospatiale, Toulouse, France) (European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, Apr. 17-19, 1989) ONERA, TP no. 1989-56, 1989, 10 p. refs  
(ONERA, TP NO. 1989-56)

This paper applies semiempirical corrections to linear calculations, using for example a doublet lattice method with data extracted from a wind tunnel. The significant parameters considered include Mach number, wing incidence, deflection of the control surfaces, and the reduced frequency. Wind tunnel results are modeled and applied at different control surfaces for various aerodynamic problems, including flutter control using a spoiler, gust reduction, and buffeting control using a flaperon. C.D.

**A89-48751#**  
**NUMERICAL OPTIMIZATION OF WINGS IN TRANSONIC FLOW [OPTIMISATION NUMERIQUE DE VOILURES EN REGIME TRANSSONIQUE]**

D. DESTARAC, J. RENEUX (ONERA, Chatillon-sous-Bagneux, France), and D. GISQUET (Aerospatiale, Division Avions, Toulouse, France) (NATO, AGARD, Symposium, 73rd, Gol, Norway, May 8-11, 1989) ONERA, TP no. 1989-67, 1989, 13 p. In French. refs  
(ONERA, TP NO. 1989-67)

The numerical optimization method for wings in transonic flow presented in this paper combines a constrained minimization program, a fast direct aerodynamic code, and a shape modification technique. Possibilities of optimization with regard to the total aerodynamic coefficients of a wing are shown. A method for estimating inviscid drag is proposed. Two application cases of the optimization method in the quasi-inverse mode (aiming at a given pressure distribution) are described. One is the adaptation of the inner part of a transport aircraft wing, a problem to which optimization is a well suited approach, considering the highly three-dimensional phenomena involved and the necessity of respecting constraints related to the aircraft design. Another example, the modification of a four-engined jet aircraft in order to reduce perturbations created by the propulsive system, shows that interference problems between the wing and other components of the aircraft can also be approached by numerical optimization. Author

**A89-48752#**  
**DESIGN OF HELICOPTER AIRFOILS AND BLADES USING NUMERICAL OPTIMIZATION [DEFINITIONS DE PROFILS ET DE PALES D'HELICOPTERE PAR OPTIMISATION NUMERIQUE]**

J. RENEUX (ONERA, Chatillon-sous-Bagneux, France) and M. ALLONGUE (Aerospatiale, Division Helicopteres, Marignane, France) (NATO, AGARD, Symposium, 73rd, Gol, Norway, May



8-11, 1989) ONERA, TP no. 1989-68, 1989, 13 p. In French. refs  
(ONERA, TP NO. 1989-68)

Numerical optimization methods have been successfully applied to airfoil design at ONERA and to helicopter blade design at Aerospatiale. The constrained minimization method chosen is the one developed by Vanderplaats (1973). For the design of helicopter airfoils, the minimization algorithm and a transonic viscous flow analysis method are linked together. The design of a 12-percent-thick airfoil and a 9-percent-thick airfoil for helicopter blades has been carried out for two design points, one corresponding to the advancing blade conditions and the other to the retreating blade conditions in forward flight. Two-dimensional tests performed in the ONERA S3MA wind tunnel confirmed the theoretically predicted gains. The design of helicopter blades is achieved through the association of the minimization method and a rotor performance analysis method using the blade element theory. The optimization of the spanwise locations of airfoils of different thickness-to-chord ratios has been carried out with one or two design points corresponding to different flight conditions. The method has been applied to the rotor design for a helicopter of the 8-10-ton gross weight class. Author

**A89-48754#**

**A FINITE ELEMENT INVERSE METHOD FOR THE DESIGN OF TURBOMACHINERY BLADES**

OLIVIER-PIERRE JACQUOTTE (ONERA, Chatillon-sous-Bagneux, France) (International Conference on Finite Element Methods in Flow Problems, 7th, Huntsville, AL, Apr. 3-7, 1989) ONERA, TP no. 1989-70, 1989, 8 p. Research supported by SNECMA. refs (ONERA, TP NO. 1989-70)

An inverse method for the design of turbomachinery blades corresponding to an arbitrary given velocity distribution is presented. The theoretical aspect of the problem is first investigated; considering the ways chosen to enforce the constraints required to ensure the existence of a solution. The equations governing the quasi-three-dimensional potential model are then reviewed. The inverse method consists of solving the potential equation with Dirichlet boundary condition on the profile and then modifying iteratively the profile until there is no mass flow rate through its surface. To implement the method, a finite-element discretization is used. Several results are shown: they illustrate the behavior of the method in particular its robustness and its efficiency. Author

**A89-48755#**

**AN INVERSE METHOD FOR THE DETERMINATION OF TURBINE BLADES [UNE METHODE INVERSE POUR LA DETERMINATION D'AUBES DE TURBOMACHINES]**

OLIVIER-PIERRE JACQUOTTE (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Meeting, 64th, Loen, Norway, May 22-25, 1989) ONERA, TP no. 1989-71, 1989, 20 p. In French. Research supported by SNECMA. refs (ONERA, TP NO. 1989-71)

An inverse method for the determination of the profiles of turbine blades in transonic flow is presented. The method involves the inverse solution of a scalar potential equation for the absolute velocity of relative points on the blade. The desired profile is obtained following a series of iterations, and the FEM is used to derive a numerical solution. Tests are performed to validate the method. Nonuniqueness is found for a case in which the number of free parameters is not correct. When this difficulty is taken into account, the present method permits, on the one hand, the retrieval of known profiles, and on the other hand, the determination of profiles around which the flow corresponds to an arbitrary velocity distribution. R.R.

**A89-48756#**

**GENERATION, OPTIMIZATION AND ADAPTATION OF MULTIDOMAIN MESHES AROUND COMPLEX CONFIGURATIONS [GENERATION, OPTIMISATION ET ADAPTATION DE MAILLAGES MULTIDOMAINES AUTOUR DE CONFIGURATIONS COMPLEXES]**

OLIVIER-PIERRE JACQUOTTE (ONERA, Chatillon-sous-Bagneux,

France) (NATO, AGARD, Meeting, 64th, Loen, Norway, May 24, 25, 1989) ONERA, TP no. 1989-72, 1989, 14 p. In French. refs (ONERA, TP NO. 1989-72)

A method for the construction, optimization, and adaptation of three-dimensional structured meshes around complex configurations is presented. The first step consists of the algebraic generation of a multidomain mesh by dividing the calculation domain into structured hexahedral subdomains. A variational method is then developed to improve the qualities of the mesh (in particular its metrical properties) and to adapt it to the physical solution to be calculated on the mesh. The method has been used to obtain results for such configurations as a turbine blade, a hollow nacelle, and the Aster missile. R.R.

**A89-48765\*** Office National d'Etudes et de Recherches Aerospatiales, Leclerc (France).

**HYPERSONIC BLUNT BODY COMPUTATIONS INCLUDING REAL GAS EFFECTS**

J.-L. MONTAGNE (ONERA, Chatillon-sous-Bagneux, France), H. C. YEE (NASA, Ames Research Center, Moffett Field, CA), G. H. KLOPFER (NEAR, Inc., Mountain View, CA), and M. VINOKUR (Sterling Software, Inc., Palo Alto, CA) (Nonlinear hyperbolic equations - Theory, computation methods, and applications; Proceedings of the Second International Conference on Nonlinear Hyperbolic Problems, Aachen, Federal Republic of Germany, Mar. 14-18, 1988, p. 413-422) ONERA, TP no. 1989-85, 1989, 12 p. refs (ONERA, TP NO. 1989-85)

Various second-order explicit and implicit TVD shock-capturing methods, a generalization of Roe's approximate Riemann solver, and a generalized flux-vector splitting scheme are used to study two-dimensional hypersonic real-gas flows. Special attention is given to the identification of some of the elements and parameters which can affect the convergence rate for high Mach numbers or real gases, but have negligible effect for low Mach numbers, for cases involving steady-state inviscid blunt flows. Blunt body calculations at Mach numbers of greater than 15 are performed to treat real-gas effects, and impinging shock results are obtained to test the treatment of slip surfaces and complex structures. Even with the addition of improvements, the convergence rate of algorithms in the hypersonic flow regime is found to be generally slower for a real gas than for a perfect gas. R.R.

**A89-48767#**

**EFFECT OF TURBULENCE ON LIFTING SURFACE BOUNDARY LAYER TRANSITION [INFLUENCE DE LA TURBULENCE SUR LA TRANSITION DES SURFACE PORTANTES]**

J. RENEUX and H. BEZARD (ONERA, Chatillon-sous-Bagneux, France) (Journées sur la Turbulence en Altitude, Marseille, France, June 13, 14, 1989) ONERA, TP no. 1989-87, 1989, 7 p. In French. (ONERA, TP NO. 1989-87)

The effect of the coefficient of external turbulence ( $Tu$ ) on the longitudinal and transverse boundary layer transitions of lifting surfaces has been theoretically studied using the method of Arnal et al. (1984) and Arnal (1988). The negative pressure gradients necessary to avoid longitudinal boundary layer transition, along with the limits imposed by transverse instabilities on the concept of natural laminar flow, are found to depend directly on the applied  $Tu$  value. The results demonstrate the importance of  $Tu$  in laminar lifting surface design. R.R.

**A89-48845**

**THERMODYNAMIC CRITERIA OF STABILITY - NUMERICAL SOLUTION OF TRANSONIC FLOW**

FRANTISEK MARSIK (Czechoslovak Academy of Sciences, Institute of Thermodynamics, Prague, Czechoslovakia) Acta Technica CSAV (ISSN 0001-7043), vol. 34, no. 3, 1989, p. 253-266. refs

The limits of stability for constant-volume transonic flows are determined analytically on the basis of the generalized stability criteria of classical thermodynamics. The formulations of the

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entropy-maximum and internal-energy concepts are outlined; the governing equations for isentropic processes are derived; the thermodynamic analysis method for the transonic flowfield is explained; and numerical results for a NACA 0012 profile are compared with published experimental data in graphs. The thermodynamically derived stability limits are shown to be in good agreement with those obtained experimentally or by means of physical stability analysis. T.K.

**A89-48897**

### **AERODYNAMICS: LAMINAR BOUNDARY LAYER [AERODYNAMIQUE: COUCHE LIMITE LAMINAIRE]**

J. COUSTEIX (Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, Toulouse; ONERA, Centre d'Etudes et de Recherches de Toulouse, France) Toulouse, France, Editions Cepadues, 1988, 412 p. In French. refs

The role of laminar boundary layers in aerodynamics is reviewed, with special attention given to the imbrication of the perfect fluid and boundary layer approximations. The present study takes into account viscosity and thermal conductivity, viscous fluid and Reynolds number effects, and the evolution of vortices in viscous fluids. Also considered are two-dimensional boundary-layer equations, the boundary-layer/external flow interaction, boundary-layer equations based on asymptotic developments, the three-layer theory, and self-similar solutions for an incompressible laminar boundary layer. Other topics include numerical solution of the boundary-layer equations, integral methods, perfect-fluid/viscous layer coupling, compressibility effects, and effects related to the dissociation of air. R.R.

**A89-48951#**

### **EULER CALCULATIONS OF FLOW OVER A COMPLETE FIGHTER AIRCRAFT**

RAMESH AGARWAL, JERRY E. DEESE, JERRY G. JOHNSON (McDonnell Douglas Research Laboratories, Saint Louis, MO), and JOHN S. STEINHOFF (Tennessee, University, Tullahoma) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 14 p. Research supported by the McDonnell Douglas Independent Research and Development Program. (AIAA PAPER 89-2221)

The paper describes the development of a three-dimensional, Euler/Reynolds-averaged Navier-Stokes code and its application to the calculation of transonic flow about a complete fighter aircraft (wing, body, and horizontal and vertical tails assembly with fared-in inlets). Steinhoff's blending method of grid-generation is used to generate a global grid about a generic fighter aircraft configuration. Computational results are presented for inviscid transonic flow about a fighter aircraft configuration and comparisons are made with experimental data. Author

**A89-48955\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **NUMERICAL SOLUTION OF PERIODIC VORTICAL FLOWS ABOUT A THIN AIRFOIL**

JAMES R. SCOTT (NASA, Lewis Research Center, Cleveland, OH) and HAFIZ M. ATASSI (Notre Dame, University, IN) AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989. 11 p. Previously announced in STAR as N89-23413. refs (Contract NAG3-732) (AIAA PAPER 89-1691)

A numerical method is developed for computing periodic, three-dimensional, vortical flows around isolated airfoils. The unsteady velocity is split into a vortical component which is a known function of the upstream flow conditions and the Lagrangian coordinates of the mean flow, and an irrotational flow whose potential satisfies a nonconstant-coefficient, inhomogeneous, convective wave equation. Solutions for thin airfoils at zero degrees incidence to the mean flow are presented in this paper. Using an elliptic coordinate transformation, the computational domain is transformed into a rectangle. The Sommerfeld radiation condition is applied to the unsteady pressure on the grid line corresponding to the far field boundary. The results are compared with a Possion solver, and it is shown that for maximum accuracy the grid should

depend on both the Mach number and reduced frequency. Finally, in order to assess the range of validity of the classical thin airfoil approximation, results for airfoils with zero thickness are compared with results for airfoils with small thickness. Author

**A89-49018**

### **THE UNSTEADY AERODYNAMIC RESPONSE TO ARBITRARY MODES OF BLADE MOTION**

J. M. VERDON (United Technologies Research Center, East Hartford, CT) Journal of Fluids and Structures (ISSN 0889-9746), vol. 3, May 1989, p. 255-274. Research supported by the United Technologies Corporate Research Program. refs

Analytical expressions are derived for predicting the unsteady aerodynamic response associated with small-amplitude, harmonic vibrations of the blades of a two-dimensional cascade. These expressions can be applied to predict the aeroelastic behavior of blades undergoing arbitrary, i.e. rigid and/or flexible, motions. In addition, a new local response function, termed the pressure-displacement function, has been identified. This function reveals the positions on a moving blade surface at which the local unsteady loads tend to support or suppress a prescribed blade motion and, hence, contribute to the stability or instability of that motion. Example solutions are presented to illustrate the behavior of the global aerodynamic work per cycle and the local pressure-displacement function for a vibrating compressor-type cascade operating at subsonic and transonic Mach numbers. Author

**A89-49052\*#** Eidetics International, Inc., Torrance, CA.

### **ON LEADING EDGE VORTEX AND ITS CONTROL**

T. T. NG (Eidetics International, Inc., Torrance, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-15. refs (Contract NAS2-12989) (AIAA PAPER 89-3346)

A simple model for the leading edge vortex and a postulation for the existence of a critical vorticity concentration above which a stable leading edge vortex cannot be maintained were proposed. Using the model and postulation, various aspects of vortex control by blowing were discussed. Blowing can be envisioned as a means to control the effective sweep and span of a delta wing by redistributing the vorticity. Mixing between the blowing jet and the vortex has a major effect on the effectiveness of controlling the vortex. Different positioning of one vortex relative to another can either enhance or delay the breakdown of the vortices. Author

**A89-49053\*#** Notre Dame Univ., IN.

### **THE EFFECT OF ASYMMETRIC VORTEX WAKE CHARACTERISTICS ON A SLENDER DELTA WING UNDERGOING WING ROCK MOTION**

A. S. ARENA, JR. and R. C. NELSON (Notre Dame, University, IN) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 16-24. Research sponsored by the University of Notre Dame. refs (Contract NCA2-406) (AIAA PAPER 89-3348)

An experimental investigation into the fluid mechanisms responsible for wing rock on a slender delta wing with 80 deg leading edge sweep has been conducted. Time history and flow visualization data are presented for a wide angle-of-attack range. The use of an air bearing spindle has allowed the motion of the wing to be free from bearing friction or mechanical hysteresis. A bistable static condition has been found in vortex breakdown at an angle of attack of 40 deg which causes an overshoot of the steady state rocking amplitude. Flow visualization experiments also reveal a difference in static and dynamic breakdown locations on the wing. A hysteresis loop in dynamic breakdown location similar to that seen on pitching delta wings was observed as the wing was undergoing the limit cycle oscillation. Author

**A89-49054#****A VIDEO-BASED EXPERIMENTAL INVESTIGATION OF WING ROCK**

STEVEN L. MORRIS and DONALD T. WARD (Texas A & M University, College Station) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 25-35. refs  
(Contract F49620-87-C-0069)  
(AIAA PAPER 89-3349)

Water tunnel measurements have been conducted using the 'ExpertVision' video-based motion analysis system in order to ascertain the relative motions of a model undergoing wing rock and the leading-edge vortices generated by its wings. ExpertVision facilitates analyses at time increments as small as 0.005 sec. The results obtained confirm that wing rock is controlled by leading-edge vortices' dynamic behavior; the alternating separation and reattachment of the vortices leads to vortex-lift asymmetry and generates the rolling-moment increments which initiate and sustain roll oscillations. Attention is given to discrepancies between wind tunnel and water tunnel results. O.C.

**A89-49055\*#** Vigyan Research Associates, Inc., Hampton, VA.  
**FEASIBILITY STUDY OF VORTEX INTERACTION CONTROL ON A CHINE FOREBODY/DELTA WING CONFIGURATION AT HIGH ANGLES OF ATTACK**

DHANVADA M. RAO (Vigyan, Inc., Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 36-42. Research supported by NASA.  
(AIAA PAPER 89-3350)

The feasibility of controlling vortex interactions or merger on a blended chine forebody and delta wing configuration was experimentally investigated. Low-speed wind tunnel diagnostics using smoke visualizations and wing upper-surface pressure measurements were performed on a generic 60 deg delta and chine forebody model, to assess chine modifications and leading edge flaps. Both techniques were shown to promote uncoupled vortex flows at high angles of attack and sideslip, with significant influence on the wing flow field, indicating potential for alleviating adverse high-alpha characteristics of blended chine swept wing configurations. Author

**A89-49076#****SUPPRESSION OF ASYMMETRY OF THE VORTEX FLOW BEHIND A CIRCULAR CONE AT HIGH INCIDENCE**

WOLFGANG STAHL (DLR, Goettingen, Federal Republic of Germany) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 231-236. Research supported by DLR and King Fahd University of Petroleum and Minerals. refs  
(AIAA PAPER 89-3372)

A water-tunnel visualization of the flow past a slender circular cross-section cone at high alpha has shown that the addition of a fin on the lee side, in the incidence plane, substantially suppressed the asymmetry of the lee-side vortex flow. The results of an inviscid analysis of the stability of impulsively-originated vortex positions behind a two-dimensional circular cylinder suggest that the suppression or reduction of flow asymmetry by means of the fin allows only a small side-force to act upon the combined elements. O.C.

**A89-49077\*#** Old Dominion Univ., Norfolk, VA.**THICKENING OSCILLATION OF A DELTA WING USING NAVIER-STOKES AND NAVIER-DISPLACEMENT EQUATIONS**

HSIN-KUNG A. CHUANG and OSAMA A. KANDIL (Old Dominion University, Norfolk, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 237-244. refs

(Contract NAG1-648; NAS1-18584)

(AIAA PAPER 89-3373)

The problem of unsteady, supersonic, locally conical, vortical flow around a delta wing undergoing thickening oscillation is solved using the unsteady, thin-layer Navier-Stokes equations and the unsteady linearized Navier-displacement equations. The unsteady, thin-layer Navier-Stokes equations are solved using the implicit approximate-factorization finite-volume scheme to compute the conservative components of the flow vector field. With the conservative components known at any time step, the linearized, Navier-displacement equations are solved using the alternating, direction-implicit scheme to obtain the grid points displacements due to known displacement boundary conditions. A grid-displacements limiter, in the form of a low mesh Reynolds number, is used to limit grid-folding in regions of highly reversed flow. Author

**A89-49078#****UNSTEADY AERODYNAMICS AND CONTROL OF DELTA WINGS WITH TANGENTIAL LEADING-EDGE BLOWING**

ILAN KROO (Stanford University, CA) and ZEEV MITTELMAN (Rafael Armament Development Authority, Haifa, Israel) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 245-255. refs  
(Contract F49620-86-K-0020)  
(AIAA PAPER 89-3374)

An unsteady, low-order panel method was developed and coupled with a nonlinear dynamic simulation to study the dynamics and control of low aspect ratio wings at moderate to high angles-of-attack. The aerodynamic prediction code is capable of simulating flows with leading-edge and side-edge separation, including the unsteady rolling-up of vortex wake sheets. Results of the aerodynamic analysis for wings in steady and maneuvering conditions are presented. The coupled aerodynamics/nonlinear dynamics analysis was used to study direct manipulation of the vortical flow field through tangential leading-edge blowing to control the dynamic motion of delta wings. The wing rock motion of an aspect ratio = 0.7 delta wing, and the dutch-roll motion of the HP-115 aircraft, were simulated using the coupled code. Closed-loop simulations have shown that these oscillatory motions can be successfully controlled by applying asymmetrical tangential leading-edge blowing. Author

**A89-49080\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.**EXPERIMENTAL AND COMPUTATIONAL RESULTS FOR 5 DEGREE BLUNT CONES WITH SHOCK GENERATORS AT HIGH VELOCITY**

A. W. STRAWA, G. A. MOLVIK, L. A. YATES, and C. CORNELISON (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 267-277. refs  
(AIAA PAPER 89-3377)

Experiments and computations have been performed under laminar conditions in air on 5-deg blunt cones at velocities of 5 km/s and 6 km/s and at Reynolds numbers of 100,000 and 1 million. The computations were performed using ideal-, equilibrium- and nonequilibrium-chemistry models for air. At the conditions of the tests, the aerodynamic coefficients are sensitive to the real-gas effects present, and both experimental and computational aerodynamic coefficients show real-gas and nonlinear effects. The nonequilibrium computations show that a large amount of oxygen is dissociated in the blunt nose region of the flow and much of the oxygen remains dissociated over the entire length of the body, providing an insight into the source of the observed effects in the aerodynamic coefficients. The experimental and computational shock-shapes are in good agreement. Author

**A89-49083#****THEORETICAL STUDY OF PASSIVE DRAG-REDUCTION ON TRANSONIC AIRFOILS**

## 02 AERODYNAMICS

W. B. BROWER, JR. (Rensselaer Polytechnic Institute, Troy, NY) and B. Y. KIM IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 304-313. refs  
(AIAA PAPER 89-3382)

A solution is given of the full potential equation for transonic flow over an airfoil using the passive-drag scheme which employs a cavity covered by a perforated skin, using the NASA-Ames TAIR inviscid code, and the BL2D boundary-layer code. The objective is to obtain a solution using a new, semiempirical theory for the transpiration flow through the region of porosity. The results confirm, under appropriate conditions, that a porous skin permits significant drag reduction. It is also shown that the most effective design condition is a cavity over which the shock is located near the center of the porous region, and such that the cavity pressure is equal to the critical pressure associated with the supersonic flow immediately upstream of the shock. Typical cases show the effect of the porous region on the surface-pressure distribution for both the inviscid and viscous cases, compared to that of the solid body. Examples are also given of the drag decrease and the lift increase due to the secondary flow through the cavity.

Author

**A89-49085#**

### **AERODYNAMIC IMPROVEMENT OF A CURRENT ATTACK AIRCRAFT THROUGH NUMERICAL WING DESIGN**

MICHAEL K. WORTHEY (LTV Aircraft Products Group, Dallas, TX) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 320-329. refs  
(AIAA PAPER 89-3384)

The application of modern wing design technology to improve the performance and maneuverability of current aircraft by optimizing wing planform parameters based on new design requirements is explored. 'TWING/QNM1', a transonic wing-optimization code, was used as the principal design tool in this study. Initial attempts using the L/D ratio as the optimization objective function proved unworkable. Alternatively, designing to a specified pressure distribution allowed both flow quality and wing efficiency to be increased. Analysis of the baseline aircraft incorporating the optimized wing shows both range and maneuverability enhancements.

Author

**A89-49097\*#**

### **NAVIER-STOKES COMPUTATIONS OF SYMMETRIC AND ASYMMETRIC VORTEX SHEDDING AROUND SLENDER BODIES**

OSAMA A. KANDIL, TIN-CHEE WONG (Old Dominion University, Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 433-443. refs  
(Contract NAS1-18584)  
(AIAA PAPER 89-3397)

The unsteady, compressible Reynolds-averaged thin-layer Navier-Stokes equations are used to solve for symmetric and asymmetric vortical flows around slender pointed bodies of revolution. The modified Baldwin and Lomax algebraic two-layer turbulent model is used for the eddy viscosity calculation in prescribed turbulent regions. The implicit, upwind flux-difference splitting finite-volume scheme is used to obtain the solutions. Computational results are presented for a low-speed symmetrical vortical flow around a 3.5-caliber tangent-ogive cylinder for fully laminar flow. Computed results are presented for a high-speed asymmetric vortex-shedding flow around a cone at 3.286 relative incidence, using a fine computational grid. The asymmetric vortex-shedding flow has been produced through a small asymmetric transitional perturbation in the cross-flow plane.

Author

**A89-49098#**

### **EULER SOLUTIONS FOR DELTA WINGS**

A. B. WARDLAW, JR. and S. F. DAVIS (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 444-455. Research supported by the U.S. Navy. refs  
(AIAA PAPER 89-3398)

Separated and attached Euler solutions are obtained for thin delta wings. On zero-thickness wings, attached solutions occur at low incidence and high Mach number. Separated solutions arise from a transient shock which coalesces on the leeside of the delta wing. A vortex forms on the downstream side of this shock and the resulting shock-vortex interaction displaces the crossflow shock to the wing tip, leaving the separated flow field. Numerical experiments on smooth bodies without sharp wing tips exhibit similar shock-vortex interactions, but the separated solution does not occur. Errors in the tip region increase the strength of the vortex which forms downstream of the shock, while errors near the crossflow shock decrease it. The separated solution is a product of a shock-vortex interaction, but is also strongly influenced by numerical error. Only by considering these two factors is it possible to account for the conditions under which attached and separated solutions form.

Author

**A89-49099#**

### **THE POTENTIAL HAZARD OF AIRCRAFT WAKE VORTICES IN GROUND EFFECT AND CROSSWIND**

ROBERT E. ROBINS and DONALD P. DELISI (Northwest Research Associates, Inc., Bellevue, WA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 456-461. refs  
(AIAA PAPER 89-3400)

Aircraft trailing vortices, evolving close to the ground in a crosswind, are a potential hazard to aircraft landing or taking off on the same or parallel runways. Numerical simulation is here used to study the effect of aerodynamic and environmental conditions on the generation and transport of such vortices, using a computer code, which solves the two-dimensional, time-dependent, incompressible Navier-Stokes equations to study trailing vortices in ground effect and in a crosswind. Numerical model results are compared with laboratory and field data. Simulation results have shown that, even after evolution times and cross-runway transport distances on the order of 3 min and 500 meters, vortices generated by large aircraft close to the ground in a crosswind can carry sufficient average circulation to be a potential hazard to smaller aircraft.

Author

**A89-49100#**

### **A MULTIBLOCK APPROACH TO SOLVING THE THREE-DIMENSIONAL UNSTEADY EULER EQUATIONS ABOUT A WING-PYLON-STORE CONFIGURATION**

ABDOLLAH ARABSHAH and DAVID L. WHITFIELD (Mississippi State University, Mississippi State) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 462-474. refs  
(AIAA PAPER 89-3401)

The objective of this study is the development of a numerical method which can accurately and economically solve the unsteady Euler equations for three-dimensional flowfields around complex configurations, particularly a generic aircraft with a store in the captive and vertical launch positions. A finite volume, multiblock implementation of a high accuracy, total variation diminishing formulation is used to solve the unsteady Euler equations. A multiblock grid approach is used for calculating the flowfield around a complex aircraft configuration. Calculated results compared with experimental data indicate that the present Euler solver can calculate transonic flowfields efficiently and accurately over complex geometries, and demonstrate how CFD can be used to

accurately simulate steady and unsteady fluid flow over a complete wing-pylon-store configuration with the store in the captive and vertical launch positions. Author

**A89-49101#**  
**NAVIER-STOKES COMPUTATIONS OF THE SUPERSONIC FLOWS ABOUT A SPACE-PLANE**

KISA MATSUSHIMA (Fujitsu, Ltd., Tokyo, Japan), SUSUMU TAKANASHI (National Aerospace Laboratory, Tokyo, Japan), and KOZO FUJII (Institute of Space and Astronautical Science, Sagami, Japan) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 475-483. refs (AIAA PAPER 89-3402)

Three-dimensional flow fields about a Space-plane flying at a supersonic speed are simulated using the Reynolds-averaged Navier-Stokes equations. To realize better performance not only in cruising but also in flying at critical conditions, interest is concentrated on the nonlinear aerodynamic phenomena, including flow separations and vortices due to high angles of attack. Since the Space-Plane is geometrically complicated, the flow field also becomes complicated, and the computational approach with the aid of flow visualization helps understand flow physics as well as provides the aerodynamic coefficients to decide vehicle performance. Author

**A89-49102#**  
**THE CONTROL OF ASYMMETRIC VORTICAL FLOWS OVER DELTA WINGS AT HIGH ANGLES OF ATTACK**

N. J. WOOD, L. ROBERTS, and Z. CELIK (Stanford University, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 484-491. refs

(Contract F49620-86-K-0020)  
 (AIAA PAPER 89-3347)

Results from a wind tunnel experiment are used to confirm that tangential leading edge blowing is capable of controlling the vortical flow over a delta wing to very high angles of attack. The production of significant rolling moments and the ability to unburst a vortex has been demonstrated to 55 deg angle of attack. Strain gauge balance measurements and upper-surface pressure distributions are presented which illustrate the various modes of operation and which, in particular, identify the uncoupled/coupled nature of the vortex control at pre- and poststall angles of attack. At angles of attack beyond 40 deg, rolling moments are produced that exceed those produced by 20 deg of aileron deflection at 0 deg angle of attack. Author

**A89-49107#**  
**AN EFFICIENT MULTIGRID FINITE ELEMENT METHOD FOR TRANSONIC FLOWS WITH SHOCK**

HUILI SHEN and XIAOQING ZHENG (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, July 1989, p. 309-320. In Chinese, with abstract in English. refs

A hybrid FEM Euler solver for steady transonic flow with shock waves is developed analytically and demonstrated. The approach involves locally adapted weight functions, the sweep solution procedure of Shen et al. (1984), direct derivation of the element equations from the governing equations, and a novel multigrid scheme in which only the residuals at the grid points need to be stored; a least-squares conjugate-gradient method is used to treat the strong nonlinearity of the Euler equations. Numerical results for typical nozzle and external flow problems are presented in graphs and briefly characterized; good agreement with published experimental data and/or numerical results is found. T.K.

**A89-49108#**  
**ON FORWARD-SWEPT WING'S AERODYNAMIC CHARACTERISTICS**

BINQIAN ZHANG and B. LASCHKA (Northwestern Polytechnical

University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, July 1989, p. 321-328. In Chinese, with abstract in English. refs

The flow on a NACA 64A 010 forward-swept wing (FSW) or wing-body configuration at angles of attack 0-35 deg and Reynolds number 620,000 is characterized on the basis of oil-flow visualizations and vortex measurements. The results are presented graphically and discussed in detail. It is shown that the development and breakup of leading-edge and trailing-edge vortices (LEVs and TEVs) affects the aerodynamic behavior of the FSW more strongly than that of a similar backward-swept wing, with the appearance of TEVs at higher angles of attack secondary to the LEVs. The FSWs generally possess excellent lift, drag, moment, poststall, and roll-control performance, suggesting their applicability to high-maneuverability aircraft. T.K.

**A89-49141**  
**ON THE MODELLING OF LOSSES WITH DISTRIBUTED FORCES FOR CALCULATING TRANSONIC FLOW FIELDS IN RADIAL DIFFUSERS [EIN VERLUSTMODELL MIT VERTEILTEN KRAEFTEN ZUR BERECHNUNG**

**TRANSSONISCHER STROEMUNGEN IN RADIALDIFFUSOREN]** INGOLF TEIPEL and ALEXANDER WIEDERMANN (Hannover, Universitaet, Hanover, Federal Republic of Germany) Forschung im Ingenieurwesen (ISSN 0015-7899), vol. 55, July 1989, p. 97-104. In German. Research supported by DFG. refs

For calculating viscous flows in diffusers of high-loaded centrifugal compressors, an empirical model has been derived which is based on the polytropic change of state. Suitable force terms are added to the momentum equation which are assumed to vary locally and are able to give some qualitatively correct information about viscous effects on the entire flow field. A comparison of results obtained with three different formulations of the energy equation is carried out. By recalculating the flow fields it is shown how the empirical parameters of the present loss model can be optimized. If the adjustment to a certain operating point has been completed one can obtain results for the remaining points of the characteristic which agree reasonably well with experimental data. On the whole, the present code is proved to be a valuable tool for engineers for efficiently carrying out design studies efficiently to optimize radial diffuser geometries. Author

**A89-49203**  
**VARIATIONAL PROBLEMS IN RADIATIVE GAS DYNAMICS IN THE CASE OF SURFACE GAS INJECTION [VARIATIONNYE ZADACHI RADIATIONNOI GAZODINAMIKI PRI NALICHII VDUVA GAZA S POVERKHNOSTI]**

N. N. PILIUGIN and L. A. PROKOPENKO PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), May-June 1989, p. 49-54. In Russian. refs

An approach to the solution of variational problems in radiative gas dynamics is proposed. First, approximate expressions for radiative heat transfer and pressure are used which are based on analytical and numerical solutions to radiative gas dynamics equations. Once the corresponding variational problem has been solved, more accurate calculations of the gasdynamic and aerodynamic characteristics are performed using the known numerical methods, with allowance made for the spectral properties of the gas. Preliminary results obtained in this manner provide a way to reduce thermal loads on flight vehicles by appropriately selecting their aerodynamic shape and gas injection distribution. V.L.

**A89-49271**  
**EXPERIMENTAL MODELING OF A BOUNDARY LAYER ON A SLIDING WING IN THE SECONDARY FLOW FORMATION REGION [EKSPERIMENTAL'NOE MODELIROVANIE**

**POGRANICHNOGO SLOIA NA SKOL'ZIASHCHEM KRYLE V OBLASTI FORMIROVANIIA VTORICHNOGO TECHENIIA]** I. U. S. KACHANOV, O. I. TARARYKIN, and A. V. FEDOROV (AN SSSR, Institut Teoreticheskoi i Prikladnoi Mekhaniki, Novosibirsk; Moskovskii Fiziko-Tekhnicheskii Institut, Moscow, USSR)

## 02 AERODYNAMICS

Akademiia Nauk SSSR, Sibirskoe Otdelenie, Izvestiia, Seriya Tekhnicheskii Nauki (ISSN 0002-3434), June 1989, p. 44-53. In Russian. refs

The experimental modeling of flow on a sliding wing using a flat plate with an induced pressure gradient is demonstrated to be an efficient method for studying the characteristics of three-dimensional boundary layer flows, particularly, flow stability and the laminar-turbulent transition. The method provides adequate (within experimental uncertainty) modeling of the potential flow and boundary layer structure, with the exception of the slight gradual deviation of the spanwise velocity component from the exact sliding condition, an effect typically observed in wind tunnel tests on sliding wings. V.L.

**A89-49272**

### **A STUDY OF THE STRUCTURE OF SEPARATED FLOW ON A DELTA WING [ISLEDOVANIE STRUKTURY POTOKA V OTRYVNOM TECHENII NA TREUGOL'NOM KRYLE]**

S. P. BARDAKHANOV, A. V. KEINO, and V. V. KOZLOV (AN SSSR, Institut Teoreticheskoi i Prikladnoi Mekhaniki, Novosibirsk, USSR) Akademiia Nauk SSSR, Sibirskoe Otdelenie, Izvestiia, Seriya Tekhnicheskii Nauki (ISSN 0002-3434), June 1989, p. 54-59. In Russian. refs

Subsonic wind tunnel experiments were conducted to investigate the evolution of controlled perturbations in a three-dimensional separated flow formed on the upper surface of a delta wing at large angles of attack. Preliminary results indicate that, in a turbulent separated flow on a delta wing, external perturbations may be transformed to coherent structures. The approach described here contributes to a better understanding of instability evolution and vortex breakdown in swirling flows. V.L.

**A89-49443#**

### **INTEGRATED DESIGN OF AERODYNAMICS AND STRUCTURES**

K. B. BOWMAN (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH), R. V. GRANDHI (Wright State University, Dayton, OH), and F. E. EASTEP (Dayton, University, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p. refs

(AIAA PAPER 89-2079)

In this study, integrated design of aerodynamics and structures was performed. Static aeroelastic considerations like divergence velocity for forward swept wings, control reversal speed for aft swept wings, and lift effectiveness are considered. The design variables were structural members cross-sectional dimensions, and the sweep angle of the wing structure. A vortex lattice generated aerodynamic model is coupled with a structural finite element representation of the wing, leading to a design process that results in a minimum weight structure with enhanced aeroelastic performance. Numerical results are presented for a typical aircraft wing structure. Author

**A89-49595**

### **AIRFOIL WING THEORY FOR ROTATING CYLINDERS OF FINITE WIDTH ENCOUNTERING LATERAL FLOWS [TRAGFLUEGELTHEORIE FUER QUER ANGESTROMTE, ROTIERENDE ZYLINDER ENDLICHER SPANNWEITE]**

DIETER GEROPP (Siegen, Universitaet-Gesamthochschule, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 567-T 569. In German.

A simple new airfoil wing theory based on Prandtl theory is developed to address the forces involved when rotating cylinders of finite width encounter lateral flows. The theory can be used to find the aerodynamic lift forces and their moments which occur in wind generators or in rotating wing flaps, rockets, or projectiles. The theory is restricted to steady, incompressible flows with friction effects. C.D.

**A89-49598**

### **EVALUATION OF DIFFERENT BOUNDARY ALGORITHMS USING THE EXAMPLE OF A TRANSONIC FLOW FIELD IN THE WHEEL OF A RADIAL COMPRESSOR [AUSWERTUNG VERSCHIEDENER RANDALGORITHMEN AM BEISPIEL DES TRANSSONISCHEN STROEMUNGSFELDES IM LAUFRAD EINES RADIALVERDICHTERS]**

J. BOHN (Hannover, Universitaet, Hanover, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 583-T 585. In German.

Highly-loaded radial compressors are used primarily in propulsion technology to charge combustion engines and in shaft power engines of small and medium capacity. Time step procedures are generally used today to numerically handle transonic flow processes in these compressors. The balance equations contain terms which remain unchanged over compressive shocks. These partial differential equations are of the hyperbolic type for both subsonic and supersonic ranges and the same procedures can be used to solve in both ranges. Difference methods involve a computational network over the whole balance; the MacCormack procedure can be used only for network points which are not located at the network boundary. C.D.

**A89-49600**

### **A NUMERICAL METHOD FOR CALCULATING STEADY TRANSONIC FLOWS WITH RELAXATION AND HEAT INPUT [EIN NUMERISCHES VERFAHREN ZUR BERECHNUNG STATIONAERER TRANSSONISCHER STROEMUNGEN MIT RELAXATION UND WAERMEZUFUHR]**

GUENTER SCHNERR and ULRICH DOHRMANN (Karlsruhe, Universitaet, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 588-T 591. In German. refs

The condensation processes which can occur in steady transonic two-dimensional flows after homogeneous nucleus formation are investigated. The Euler differential equation is coupled with the classical nucleus formation theory and a simple model of droplet growth. Perpendicular density shocks with extended local subsonic regions in the relaxation regime are calculated. C.D.

**A89-49601**

### **PROFILES IN SUPERSONIC SOURCE FLOW [PROFILE IM UEBERSCHALLQUELLSTROEMUNG]**

J. ZIEREP (Karlsruhe, Universitaet, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 591-T 593. In German.

The treatment of flows about profiles in the near-sonic supersonic, the supersonic, and the hypersonic source flow regimes is of practical significance. The most significant parameters and coefficients involved in this problem are examined. Some basic differences are found for the case of constant flow. C.D.

**A89-49604**

### **NUMERICAL SIMULATION OF TOLLMIE-SCHLICHTING WAVES IN TRANSONIC COMPRESSIBLE PLATE BOUNDARY LAYERS [NUMERISCHE SIMULATION VON TOLLMIE-SCHLICHTING-WELLEN IN TRANSSONISCHEN KOMPRESSIBLEN PLATTENGRENZSCHICHTEN]**

ANDREAS THUMM, WERNER WOLZ, and HERMANN FASEL (Stuttgart, Universitaet, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 598-T 600. In German. refs

The downstream development of Tollmien-Schlichting waves



in compressible plate boundary layers is numerically simulated by numerical solving the full, compressible Navier-Stokes equations. The quality of the procedure is evaluated by making a quantitative comparison with results from compressible, linear stability theory. The results are illustrated with two examples. C.D.

**A89-49607**

**NUMERICAL SIMULATION OF FLOW AROUND A PROFILE WITH EDDIES [NUMERISCHE SIMULATION DER WIRBELBEHAFTETEN PROFILUMSTROMUNG]**

H. SCHUETZ, R. SCHUSTER, and F. THIELE (Berlin, Technische Universitaet, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 6, 1989, p. T 607-T 609. In German.

The steady flow around a flat airfoil profile has a strongly eddied wake flow which depends on the angle of attack, the Reynolds number, and the profile geometry. The numerical simulation of such a flow was undertaken by Metha and Levan (1975) for a NACA 0009 profile for  $\alpha = 15$  deg. In this paper, the authors apply their previously published method to unsteady profile flows by solving the Navier-Stokes equations in a flow function formulation, and the results are compared with those of Metha and Levan. C.D.

**A89-49677\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**A NATURAL FLOW WING DESIGN EMPLOYING 3-D NONLINEAR ANALYSIS APPLIED AT SUPERSONIC SPEEDS**

STEVEN X. S. BAUER, RICHARD M. WOOD (NASA, Langley Research Center, Hampton, VA), and S. MELISSA BROWN AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 14 p. refs (AIAA PAPER 89-2167)

A wing-design study has been conducted on a 65-deg-swept leading-edge delta wing in which a near-conical geometry was employed to take advantage of the naturally occurring conical flow which arises over such a wing in a supersonic flow field. Three-dimensional nonlinear analysis methods were used in the study. In preliminary design, wing planform, design conditions, and near-conical concept were derived and a baseline standard wing (conventional airfoil distribution) and a baseline near-conical wing were chosen. During the initial analysis, a full-potential solver was employed to determine the aerodynamic characteristics of the baseline standard delta wing and the near-conical delta wing. Modifications due to airfoil thickness, leading-edge radius, and camber were then applied to the baseline near-conical wing. The final design employed a Euler solver to analyze the best wing configurations found in the initial design, and to extend this study to develop a more refined wing. Benefits due to each modification are discussed, and a final natural flow wing geometry is chosen and its aerodynamic characteristics are compared with the baseline wings. Author

**A89-49679\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**PREDICTION OF HIGH-SPEED AERODYNAMIC CHARACTERISTICS USING THE AERODYNAMIC PRELIMINARY ANALYSIS SYSTEM (APAS)**

CHRISTOPHER I. CRUZ and ALAN W. WILHITE (NASA, Langley Research Center, Hampton, VA) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 11 p. refs (AIAA PAPER 89-2173)

An exercise was performed which illustrates the prediction of high-speed aerodynamic coefficients using the Aerodynamic Preliminary Analysis System. Two generic transatmospheric vehicle configurations are used as examples on which various inviscid and viscous estimation techniques are applied. As a means of evaluating the reliability of the Aerodynamic Preliminary Analysis System results, comparisons of predictions using this preliminary-level approach are compared with Shuttle-derived data, hypersonic helium tunnel data for several configurations, and

computational fluid dynamics results. Overall, predictions using the Aerodynamic Preliminary Analysis System agree well with the other calculations and data. Author

**A89-49680\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**AN EULER ANALYSIS OF A HIGH-SPEED CIVIL TRANSPORT (HSCT) CONCEPT AT MACH 3**

JAMES L. PITTMAN, DARYL L. BONHAUS, SAMUEL M. DOLLYHIGH (NASA, Langley Research Center, Hampton, VA), and MICHAEL J. SICLARI (Grumman Aerospace Corp., Bethpage, NY) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 9 p. refs (AIAA PAPER 89-2174)

A marching Euler solver, GEM3D, was used to predict the Mach 3 flow field for the wing and body of a High-Speed Civil Transport concept. The analysis focused on a typical cruise lift coefficient of 0.1 at  $\alpha = 3$  deg. The Euler solution indicated that embedded shocks formed on the upper surface of the inboard wing panel and at the leading-edge of the outboard wing panel, due to its supersonic leading edge condition. According to a simple static-pressure criterion, the embedded wing upper-surface shocks were sufficiently strong to separate a turbulent boundary layer. Comparison of aerodynamic coefficients from the Euler solver with those from linear theory shows that the linear theory estimates of lift and drag are optimistic, which would lead to optimistic estimates of cruise range. Author

**A89-49682#**

**AN IMPLICIT CELL-VERTEX SCHEME FOR SOLUTION OF THE EULER EQUATIONS**

C. B. ALLEN and S. P. FIDDES (Bristol, University, England) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs (AIAA PAPER 89-2235)

An implicit cell-vertex method for the solution of the Euler equations is described. Examples are given for quasi-one-dimensional duct flows and two-dimensional hypersonic intake flows. The method is shown to be robust and fast. It is an excellent candidate for use in conjunction with a multiblock or zonal scheme. Author

**A89-49827#**

**AN EXPERIMENTAL STUDY OF SUPERSONIC MIXING PROCESS BY USING SHOCK TUNNEL USING QUICK-ACTION VALVES AND QUICK-MASS-SAMPLING PROBE TECHNIQUE**

MASAHIRO HATAKEYAMA, KATSUSHI FUNABIKI, and TAKASHI ABE Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 425, 1989, p. 278-284. In Japanese, with abstract in English. refs

In order to examine the supersonic mixing process in a high enthalpy supersonic flow, a shock tunnel using quick-action valves has been developed and operated. The present shock tunnel generates a high enthalpy flow without contamination. The nozzle is designed to make parallel supersonic flows which are comprised of a high-enthalpy air stream and a helium stream. Mach numbers of the air and helium flows are 3.4 and 4.2, respectively. The structure of mixing region of parallel supersonic flows thus obtained was examined by means of a mass-sampling probe which enables direct examination of the concentration ratio of the mixture gases. The measurement shows that the mixing region almost agrees with the region observed by Schlieren photography. Author

**A89-49829#**

**PREDICTION OF THE INDUCED DRAG BY LIFTING SURFACE THEORIES**

MASAMI ICHIKAWA and SHIGENORI ANDO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 425, 1989, p. 293-299. In Japanese, with abstract in English. refs

The use of a new numerical lifting surface method, the box-in-strip (BIS) method, to calculate induced drag is discussed.

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The BIS method leads to excellent agreement with analytical solutions for both the near- and far-field methods on elliptic platform wings. K.K.

### A89-49830

#### A SEMI-EMPIRICAL MODEL FOR DYNAMIC STALL

J. G. LEISHMAN and T. S. BEDDOES (Westland Helicopters, Ltd., Aerodynamics Dept., Yeovil, England) American Helicopter Society, Journal (ISSN 0002-8711), vol. 34, July 1989, p. 3-17. Research supported by the Ministry of Defence Procurement Executive. refs  
(Contract DAAL03-88-C-002)

A semi-empirical model is formulated to represent the unsteady lift, drag, and pitching moment characteristics of an airfoil undergoing dynamic stall. The model is presented in a form which is consistent with an indicial formulation for the unsteady aerodynamics under attached flow conditions. The onset of vortex shedding during dynamic stall is represented using a criterion for leading edge or shock induced separation based on the attainment of a critical leading edge pressure. The induced vortex lift is represented empirically along with the associated pitching moment which is obtained by allowing the center of pressure to move in a time dependent manner during dynamic stall. Significant nonlinearities in the airfoil behavior associated with trailing edge separation are represented using a Kirchhoff flow model in which the separation point is related to the airfoil behavior. These effects are represented in such a way as to allow progressive transition between the dynamic stall and the static stall characteristics. It is shown how the above features may be implemented as an algorithm suitable for inclusion within rotorcraft airloads or aeroelasticity analyses. Validation of the model is presented with force and moment data from two-dimensional unsteady tests on the NACA 0012, HH-02, and SC-1095 airfoils. Author

### A89-49831

#### MODELING SWEEP EFFECTS ON DYNAMIC STALL

J. G. LEISHMAN (Maryland, University, College Park) American Helicopter Society, Journal (ISSN 0002-8711), vol. 34, July 1989, p. 18-29. Research supported by the U.S. Army. refs

A semiempirical procedure is described to represent the effects of blade sweep angle on the airloads during dynamic stall of an airfoil. The procedure is consistent with a previously derived unsteady aerodynamic model for lift-, pitching moment, and drag prediction of a blade section within the context of helicopter rotor aeroelasticity and performance analyses. It has been concluded from the present study that sweep angle primarily affects the nonlinear airloads by modifying the local development of trailing edge flow separation; the subsequent behavior of the airloads, under both steady and unsteady conditions, appears as a consequence. Justification of the modeling is conducted with experimentally obtained dynamic stall data for a NACA 00121 airfoil oscillating in pitch at a Mach number of 0.4 with steady sweep angles of 0 and 30 deg. Excellent correlations were obtained with the test data, and these provide increased confidence in the validity of the unsteady aerodynamic model for the helicopter rotor environment. A preliminary method is also suggested to account for time dependent sweep effects. Author

A89-49854\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### NEW INSTABILITY MODES FOR BOUNDED, FREE SHEAR FLOWS

MICHELE G. MACARAEG and CRAIG L. STREETT (NASA, Langley Research Center, Hampton, VA) Physics of Fluids A (ISSN 0899-8213), vol. 1, Aug. 1989, p. 1305-1307. refs

A class of highly amplified supersonic disturbances are found for high-speed, bounded mixing layers at high values of streamwise wavenumber. Their amplification is an order of magnitude greater than the most amplified modes, which occur at 60-65 deg at low streamwise wavenumber. These disturbances are stabilized by increasing Mach number, viscosity, and sweep; however, the effect of sweep on the most amplified mode is not significant until the wave propagation angle reaches 30 deg. The maximum growth

rate of the unstable disturbances decreases as the temperature of the higher Mach number stream is increased. The structure of these disturbances is such that the phase speed with respect to the mean flow is subsonic in a small region in the center of the shear layer, and supersonic on either side of this region. Author

A89-49899\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

#### THE MINIMUM DRAG OF THIN WINGS AT SUPERSONIC SPEED ACCORDING TO KOGAN'S THEORY

ROBERT T. JONES (NASA, Ames Research Center, Moffett Field, CA) Theoretical and Computational Fluid Dynamics (ISSN 0935-4964), vol. 1, no. 2, 1989, p. 97-103. refs

In the theory of thin lifting surfaces the minimum drag consistent with a given total lift occurs when the downwash, averaged between forward and reversed motion of the wing, has the same value at all points of the wing planform. In Kogan's theory the conditions for minimum drag are determined on the forward sloping characteristic surface touching the trailing edge of the wing and it is shown that such a surface plays the role of the Trefftz plane familiar in subsonic wing theory. This paper shows how Kogan's theory may be applied to determine the drag of elliptic wings at supersonic speed. It appears that such wings have lower drag than the conventional 'delta' wing. Author

### A89-49947#

#### ONE-EQUATION TURBULENCE MODEL FOR THE LAMINAR SEPARATION BUBBLE ON AIRFOILS

KENICHI RINOIE (National Aerospace Laboratory, Chofu, Japan) (Japan Society for Aeronautical and Space Sciences, Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 32, May 1989, p. 1-12. refs

A one-equation turbulence model was made using the experimental results in order to represent the turbulent characteristics inside a laminar separation bubble on the airfoil. An inverse numerical method was used to solve the boundary layer equations coupled with the present turbulence model. The laminar separation bubbles formed on two airfoils which were used to make the present model, and the short bubble formed on the NACA laminar flow airfoil were obtained numerically. Their overall characteristics agreed closely with the ones observed experimentally on airfoils. Author

### A89-49948#

#### NEWTONIAN FLOW OVER AXISYMMETRIC BODIES

HAMDI T. HEMDAN (King Saud University, Riyadh, Saudi Arabia) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 32, May 1989, p. 13-25. refs

The problem of steady Newtonian flow past pointed nose axisymmetric slender bodies at zero angles of attack is considered. Another formulation of the hypersonic small disturbance theory is developed and used to derive a first-order Newtonian theory. The work presents a counterpart of recent papers on two-dimensional flow in the case of axisymmetric flow. Like the two-dimensional case a first integral is obtained and simple closed-form results for the Newtonian flow are obtained. Results for the surface pressure and the shock wave for circular cones as well as other axisymmetric bodies are presented. Author

### A89-50004

#### OBSERVATIONS OF SUPERSONIC FREE SHEAR LAYERS

D. PAPAMOSCHOU and A. ROSHKO (California Institute of Technology, Pasadena) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 57-70. Research supported by Rockwell International Corp. refs

Visual spreading rates of turbulent shear layers with at least one stream supersonic were measured using Schlieren photography. The experiments were done at a variety of Mach number-gas combinations. The spreading rates are correlated with a compressibility-effect parameter called the convective Mach number. It is found that for supersonic values of the convective



Mach number, the spreading rate is about one quarter that of an incompressible layer at the same velocity and density ratio. The results are compared with other experimental and theoretical results. Author

**A89-50008**

**FLAT PLATE REDUCTION BY TURBULENCE MANIPULATION**

R. NARASIMHA (National Aeronautical Laboratory; Indian Institute of Science, Bangalore, India) and K. R. SREENIVASAN (Yale University, New Haven, CT) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 113-128. Research supported by USAF and Ministry of Science and Technology of India. refs

The conditions under which a turbulent boundary layer manipulated by the insertion of a passive object may lead to a lower overall drag than in the unmanipulated flow are discussed. Experimental data are presented which show that almost any device inserted in the boundary layer will lead to a lower skin friction drag. It is shown that any possible reduction in drag due to the manipulator can only be achieved for certain limited downstream lengths behind the manipulator. K.K.

**A89-50010**

**SHOCK-WAVE-TURBULENCE-BOUNDARY-LAYER INTERACTION AND ITS CONTROL - A SURVEY OF RECENT DEVELOPMENTS**

P. R. VISWANATH (National Aeronautical Laboratory, Bangalore, India) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 143-202. refs

This paper presents an overview of some of the recent developments that have taken place in the understanding, prediction and control of two-dimensional shock-wave-turbulent-boundary-layer interaction at high speeds. Following a brief description of the upstream influence phenomena, detailed discussions of incipient and fully separated flows at supersonic and transonic speeds are presented. A brief account of certain gross unsteady features of shock-separated flows is given next. Typical examples demonstrating the current ability to predict these complex flows are also included. Finally, a review of techniques using suction and tangential blowing for controlling shock-separated flows is presented. Author

**A89-50011**

**CHARACTERISTICS OF A TYPICAL LIFTING SYMMETRIC SUPERCRITICAL AIRFOIL**

M. A. RAMASWAMY (Indian Institute of Science, Bangalore, India) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 203-216.

The theoretical aerodynamic characteristics of a typical lifting symmetric supercritical airfoil demonstrating its superiority over the NACA 0012 airfoil from which it was derived are presented in this paper. Further, limited experimental results confirming the theoretical inference are also presented. Author

**A89-50012**

**MONTE CARLO SIMULATION FOR MOLECULAR GAS DYNAMICS**

S. M. DESHPANDE (Indian Institute of Science, Bangalore, India) and P. V. SUBBA RAJU (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 217-235. Research supported by ISRO. refs

The Direct Simulation Monte Carlo method of Deshpande (1981, 1982, 1983) is studied for mono as well as multicomponent gases. This method is a statistical particle-in-cell method and is based on the Kac-Prigogine master equation which reduces to the Boltzmann equation under the molecular chaos hypothesis. The proposed Markoff model simulating the collisions uses a Poisson distribution for the number of collisions allowed in cells into which the physical space is divided. K.K.

**A89-50060\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**STUDY OF A CIRCULATION CONTROL AIRFOIL WITH LEADING/TRAILING-EDGE BLOWING**

B. G. MCLACHLAN (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 817-821. Previously cited in issue 12, p. 1738, Accession no. A87-31104. refs

**A89-50062\*#** Purdue Univ., West Lafayette, IN.

**AERODYNAMIC INTERACTION BETWEEN PROPELLERS AND WINGS**

DAVE P. WITKOWSKI, ALEX K. H. LEE, and JOHN P. SULLIVAN (Purdue University, West Lafayette, IN) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 829-836. Previously cited in issue 07, p. 940, Accession no. A88-22495. refs (Contract NSG-3134)

**A89-50063#**

**NUMERICAL AND EXPERIMENTAL INVESTIGATION OF ISOLATED PROPELLER WAKES IN AXIAL FLIGHT**

D. FAVIER, C. MARESCA (Aix-Marseille II, Universite, Marseille, France), and A. ETTAOUIL (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 1, p. 602-616) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 837-846. Previously cited in issue 03, p. 257, Accession no. A89-13560. refs (Contract DRET-85-115; DRET-87-095)

**A89-50065\*#** Northrop Corp., Hawthorne, CA.

**EVALUATION OF THE CONSTANT PRESSURE PANEL METHOD FOR SUPERSONIC UNSTEADY AIRLOADS PREDICTION**

KARI APPA and MICHAEL J. C. SMITH (Northrop Corp., Hawthorne, CA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 550-562) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 854-862. Previously cited in issue 12, p. 1819, Accession no. A88-32235. refs (Contract NAS2-12597)

**A89-50066\*#** Naval Postgraduate School, Monterey, CA. **TIME-DEPENDENT BOUNDARY-LAYER RESPONSE IN A PROPELLER SLIPSTREAM**

RICHARD M. HOWARD (U.S. Naval Postgraduate School, Monterey, CA) and STAN J. MILEY (Texas A & M University, College Station) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 863-869. refs (Contract NAG1-344)

The time-dependent behavior of a wing boundary layer immersed in a propeller slipstream has been studied experimentally in wind-tunnel tests and in flight. Hot-wire anemometer measurements were made through the boundary layer for time-dependent, ensemble-average velocity and turbulence-intensity profiles at various chord locations. The boundary layer has a coherent, time-dependent cycle of transitional behavior, varying from a laminar to a turbulent-transitional state. Local drag coefficients determined from the velocity profiles for the freewheeling propeller case in flight show that the time-dependent drag in the propeller slipstream varies from the undisturbed laminar value to a value less than that predicted for fully turbulent flow. Local drag coefficients determined from the thrusting propeller case in the wind tunnel indicate that the effects of the slipstream are to enhance the stability of the boundary layer and to reduce the drag coefficient in the laminar portion of the cycle below its undisturbed laminar value. Author

**A89-50067\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**TRANSONIC REGION OF HIGH DYNAMIC RESPONSE ENCOUNTERED ON AN ELASTIC SUPERCRITICAL WING**

DAVID A. SEIDEL, CLINTON V. ECKSTROM, and MAYNARD C. SANDFORD (NASA, Langley Research Center, Hampton, VA)

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(Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A, p. 66-75) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 870-875. Previously cited in issue 14, p. 2102, Accession no. A87-33662. refs

**A89-50069#**

### COMMENTS ON THE LAWRENCE EQUATION FOR LOW-ASPECT-RATIO WINGS

RAJENDRA K. BERA (National Aeronautical Laboratory, Bangalore, India) and G. SURESH Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 883-885.

A faster and more accurate algorithm is presented for solving the Lawrence (1951) equation for chordwise lift distribution in low aspect ratio wings, and the results thus obtained are compared with Lawrence's original ones. A tabulation is made of various wing incidence values for a range of aspect ratios in both delta and rectangular wing planforms. It is found that one of Lawrence's plots was grossly in error for both types of wing, due to computational errors. O.C.

**A89-50084#**

### A METHOD FOR COMPUTING TRANSONIC FLOWS AROUND COMPLETE AIRCRAFT CONFIGURATIONS

F. KAFYEKE and F. MAVRIPLIS (Canadair, Inc., Montreal, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 35, June 1989, p. 76-85. Research supported by DND and National Aeronautical Establishment. refs

A computer code called KTRAN, providing accurate and cost-effective predictions of inviscid transonic flows around three-dimensional aircraft configurations, is being developed at Canadair. The computation scheme uses the Transonic Small Disturbance Equation discretized in simple rectangular coordinates, and a grid embedding technique. The flow field equations are solved iteratively, using successive line overrelaxation. The method is described and comparisons between computed and measured results are given for a Wing/Body and a Wing/Body/Pylon and Store test configuration as well as for the Challenger Wide Body Turbofan aircraft. The potential of the method for analyzing complex three-dimensional configurations at low cost is indicated in this paper, showing that the code is a practical tool for parametric studies and that it can be used as lead program for sophisticated investigations. The program is being further developed under a National Defense contract to permit calculations on the CF-18 aircraft with stores. Author

**A89-50173#**

### MULTIGRID CALCULATION OF TRANSONIC FULL POTENTIAL FLOWS OVER AIRFOIL AND CASCADE

KUEN-CHUAN WU and PONG-JEU LU (National Cheng Kung University, Tainan, Republic of China) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731), vol. 10, April 1989, p. 81-92. refs

A multigrid method is presented to accelerate the iterative convergence of calculations associated with the transonic potential flow over two-dimensional configurations. The steady full-potential equation is discretized by a full-conservative finite difference approximation, with appropriate addition of artificial viscosity to provide a mechanism for the capturing of shock waves. The multigrid scheme is constructed using successive line over-relaxation as iterative procedure for each grid level. Full approximation storage mode of the multigrid algorithm is adopted to treat the nonlinearity inherent in the full-potential equation. The smoothness of the residuals before being transferred down to the coarser grids and the uniformity of meshes are found essential for the fast convergence of the multigrid algorithm. All computations are performed on C-type, body-fitted grids which are generated by a sequence of conformal and shear transformations. Multigrid computations using NACA 0012 profiles for either isolated airfoil or cascade flows are illustrated, in which substantial improvement on the convergent rate is seen. Author

**A89-50528\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### NUMERICAL SIMULATION OF VORTICAL FLOWS OVER A STRAKE-DELTA WING

KOZO FUJII and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1153-1162. Previously cited in issue 19, p. 2940, Accession no. A87-44913. refs

**A89-50532\*#** Iowa State Univ. of Science and Technology, Ames.

### UPWIND ALGORITHM FOR THE PARABOLIZED NAVIER-STOKES EQUATIONS

SCOTT L. LAWRENCE, JOHN C. TANNEHILL (Iowa State University of Science and Technology, Ames), and DENNY S. CHAUSSEE (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1175-1183. Research supported by the U.S. Army and Iowa State University of Science and Technology. refs (Contract NCA2-IR-340-501)

A new upwind algorithm based on Roe's scheme has been developed to solve the two-dimensional parabolized Navier-Stokes equations. This method does not require the addition of user-specified smoothing terms for the capture of discontinuities such as shock waves. Thus, the method is easy to use and can be applied without modification to a wide variety of supersonic flowfields. The advantages and disadvantages of this adaptation are discussed in relation to those of the conventional Beam-Warming (1978) scheme in terms of accuracy, stability, computer time and storage requirements, and programming effort. The new algorithm has been validated by applying it to three laminar test cases, including flat-plate boundary-layer flow, hypersonic flow past a 15-deg compression corner, and hypersonic flow into a converging inlet. The computed results compare well with experiment and show a dramatic improvement in the resolution of flowfield details when compared with results obtained using the conventional Beam-Warming algorithm. Author

**A89-50540#**

### ANALYSIS OF THE EXPANSION-FAN FLOWFIELD FOR HOLES IN A HYPERSONIC CONFIGURATION

JOHN J. BERTIN (Texas, University, Austin), WILLIAM J. TEDESCHI, DANIEL P. KELLY, ALBINO C. BUSTAMANTE, and ERIC W. REECE (Sandia National Laboratories, Albuquerque, NM) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1241-1248. Previously cited in issue 07, p. 934, Accession no. A88-22275. refs

**A89-50548#**

### STEADY, SHOCK-CAPTURING METHOD APPLIED TO ONE-DIMENSIONAL NOZZLE FLOW

S. PARAMESWARAN (Texas Tech University, Lubbock) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1292-1295. refs

In the present consideration of the steady, inviscid, quasi-one-dimensional flow of a perfect gas through a duct of variable area, the steady Euler equations are modeled by an upwind difference scheme and solved by means of a modified version of the SIMPLE algorithm. All three conservation laws are satisfied within the 'shock cell' in which flow transitions from supersonic to subsonic velocity through an adjustment of the shock position within the cell. This approach can locate the shock position accurately within two mesh points without imposing the Rankine-Hugoniot relationships across the shock. O.C.

**A89-50549#**

### INVISCID, UNSTEADY, TRANSONIC AXISYMMETRIC FLOW IN NOZZLES WITH SHOCK WAVES

CARLOS FREDERICO EST ALVES (Centro Tecnico Aeroespacial, Instituto de Atividades Espaciais, Sao Jose dos Campos, Brazil) and DEMETRIO BASTOS-NETTO (Instituto de Pesquisas Espaciais, Sao Jose dos Campos, Brazil) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1295-1298. refs

Messiter and Adamson's (1975) application of the asymptotic-expansions method to the analysis of an axisymmetric nozzle's transonic flow is presently expanded to include unsteady conditions, thereby obviating complex numerical solutions for transport equations. The approach is for flows across nozzles characterized by smooth cross-sectional changes; the applied perturbation should not possess a very high frequency, since the adopted solution is concerned with slow time variation regimes. A characteristic time of the order of 0.01-0.001 sec is chosen.

O.C.

**A89-50586**

**FORWARD FACING SPIKE EFFECTS ON BODIES OF DIFFERENT CROSS SECTION IN SUPERSONIC FLOW**

G. R. HUTT and A. J. HOWE (Southampton, University, England) *Aeronautical Journal* (ISSN 0001-9240), vol. 93, June-July 1989, p. 229-234. refs

The results of an experimental program conducted in the University of Southampton's induced flow supersonic wind tunnel are presented. The pitch static force coefficient and center of pressure data relate to a series of bodies with a blunt cone nose forebody with afterbodies comprising circular, square and triangular cross section. The blunt cone nose forebody has a forward located, body axis, aerodynamic spike system. The data presented reveal the well known benefits of aerospikes with blunt nosed axisymmetric vehicles. This is then used as a base to explore the coupled flowfield effects on force coefficients due to spike deployment on bodies of nonaxisymmetric cross section. Author

**A89-50658#**

**A FULL 3-D ITERATIVE SOLUTION ON S1/S2 STREAM SURFACES IN CAS TRANSONIC COMPRESSOR ROTOR**

XIAOLU ZHAO, LISEN QIN, and CHUNG-HUA WU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) *Journal of Engineering Thermophysics* (ISSN 0253-231X), vol. 10, May 1989, p. 140-145. In Chinese, with abstract in English. refs

As a part of the research program for a CAS research transonic compressor, a full three-dimensional iterative solution procedure has been set up which consists of the calculation of the transonic flowfields along a number of arbitrary twisted S1 stream surfaces and a number of S2 stream surfaces. Based on a previously obtained quasi-three-dimensional solution, a converged full three-dimensional iterative solution to analyze the detailed transonic flowfield within the CAS axial compressor rotor has been obtained after seven iterative calculation of the S1 and S2 stream surfaces were performed using the present procedure. The characteristics of a full three-dimensional flowfield are discussed in detail.

Author

**A89-50659#**

**ON THE IMPROVEMENT OF THE ROTOR BLADE LOSS MODEL OF AXIAL FLOW FAN AND COMPRESSOR INCLUDING THE EFFECT OF ROTATION AND ITS APPLICATION**

FANGYUAN ZHONG and JUN WEI (Shanghai Jiaotong University, People's Republic of China) *Journal of Engineering Thermophysics* (ISSN 0253-231X), vol. 10, May 1989, p. 146-151. In Chinese, with abstract in English. refs

Through the theoretical analysis of the three-dimensional flow in the rotor blade boundary layer of an axial flow fan and proper mathematical deduction, a simple method for predicting the wake width of rotor blade has been obtained which includes the effect of blade rotation. Based on this method, a rotor spanwise aerodynamic loss distribution model, including the effects of blade passage secondary flow and radial mass migration in the rotor blade boundary layer induced by rotation, was developed. The aerodynamic and noise calculation using the above theory agrees well with experimental data. The error of efficiency is less than 1.3 percent, and noise (total sound pressure level) is less than 1 dB.

Author

**A89-50660#**

**NUMERICAL SIMULATION FOR UNSTEADY FLOW IN OSCILLATING CASCADE WITH PROPAGATING STALL USING DISCRETE VORTEX METHOD**

F. SISTO (Stevens Institute of Technology, Hoboken, NJ) and WENQUAN WU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) *Journal of Engineering Thermophysics* (ISSN 0253-231X), vol. 10, May 1989, p. 152-157. In Chinese, with abstract in English.

The unsteady flow in an oscillating cascade with propagating stall was simulated numerically with the discrete vortex method. Owing to the employment of the piecewise linearization and recorrection technique, the needed computational time has been decreased. A series of numerical tests were performed for the study of the quantitative effect of incidence, propagation of the stall, and the frequency and amplitude of vibration. Author

**A89-50806\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**ON THE STRUCTURE, INTERACTION, AND BREAKDOWN CHARACTERISTICS OF SLENDER WING VORTICES AT SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS**

GARY E. ERICKSON (NASA, Langley Research Center, Hampton, VA), JOHN A. SCHREINER (NASA, Ames Research Center, Moffett Field, CA), and LAWRENCE W. ROGERS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989. 114 p. refs

(AIAA PAPER 89-3345)

Slender wing vortex flows at subsonic, transonic, and supersonic speeds were investigated in a 6 x 6 ft wind tunnel. Test data obtained include off-body and surface flow visualizations, wing upper surface static pressure distributions, and six-component forces and moments. The results reveal the transition from the low-speed classical vortex regime to the transonic regime, beginning at a freestream Mach number of 0.60, where vortices coexist with shock waves. It is shown that the onset of core breakdown and the progression of core breakdown with the angle of attack were sensitive to the Mach number, and that the shock effects at transonic speeds were reduced by the interaction of the wing and the lead-edge extension (LEX) vortices. The vortex strengths and direct interaction of the wing and LEX cores (cores wrapping around each other) were found to diminish at transonic and supersonic speeds. R.R.

**A89-50807#**

**AEROELASTIC CHARACTERISTICS OF NACA 0012 AIRFOIL AT ANGLE OF ATTACK**

L. J. HUTTSELL (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) and F. E. EASTEP (Dayton, University, OH) AIAA, Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989. 9 p. refs

(AIAA PAPER 89-3375)

Accurate unsteady aerodynamic calculations are essential for aeroelastic predictions. Since the unsteady aerodynamics are usually a perturbation about a steady solution, the aeroelastic predictions can be improved if a more accurate steady mean is used. In this paper, aeroelastic predictions are presented for the NACA 0012 airfoil at various angles of attack using two different approaches to calculate the unsteady aerodynamics. One approach uses a correction procedure to improve the steady mean flow for the unsteady aeroelastic analyses. In this approach the mean steady pressure distribution is obtained from experiment or calculated using an efficient CFD code. The second approach couples a Euler code with a linear structural model for an aeroelastic solution. Aerodynamic data and flutter trends are presented for several Mach numbers and angles of attack.

Author

**A89-50808\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**LOW-SPEED WIND TUNNEL PERFORMANCE OF HIGH-SPEED COUNTERROTATION PROPELLERS AT ANGLE-OF-ATTACK**

## 02 AERODYNAMICS

CHRISTOPHER E. HUGHES (NASA, Lewis Research Center, Cleveland, OH) and JOHN A. GAZZANIGA (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989. 46 p. Previously announced in STAR as N89-25121. refs  
(AIAA PAPER 89-2583)

The low-speed aerodynamic performance characteristics of two advanced counterrotation pusher-propeller configurations with cruise design Mach numbers of 0.72 were investigated in the NASA Lewis 9- by 15-Foot Low-Speed Wind Tunnel. The tests were conducted at Mach number 0.20, which is representative of the aircraft take-off/landing flight regime. The investigation determined the effect of nonuniform inflow on the propeller performance characteristics for several blade angle settings and a range of rotational speeds. The inflow was varied by yawing the propeller mode to angle-of-attack by as much as plus or minus 16 degrees and by installing on the counterrotation propeller test rig near the propeller rotors a model simulator of an aircraft engine support pylon and fuselage. The results of the investigation indicated that the low-speed performance of the counterrotation propeller configurations near the take-off target operating points were reasonable and were fairly insensitive to changes in model angle-of-attack without the aircraft pylon/fuselage simulators installed on the propeller test rig. When the aircraft pylon/fuselage simulators were installed, small changes in propeller performance were seen at zero angle-of-attack, but fairly large changes in total power coefficient and very large changes of aft-to-forward-rotor torque ratio were produced when the propeller model was taken to angle-of-attack. The propeller net efficiency, though, was fairly insensitive to any changes in the propeller flowfield conditions near the take-off target operating points. Author

**A89-50810\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **NUMERICAL ANALYSIS OF SUPERSONIC FLOW THROUGH OSCILLATING CASCADE SECTIONS BY USING A DEFORMING GRID**

DENNIS L. HUFF (NASA, Lewis Research Center, Cleveland, OH) and T. S. R. REDDY (Toledo, University, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989. 16 p. Previously announced in STAR as N89-25119. refs  
(AIAA PAPER 89-2805)

A finite difference code was developed for modeling inviscid, unsteady supersonic flow by solution of the compressible Euler equations. The code uses a deforming grid technique to capture the motion of the airfoils and can model oscillating cascades with any arbitrary interblade phase angle. A flat plate cascade is analyzed, and results are compared with results from a small-perturbation theory. The results show very good agreement for both the unsteady pressure distributions and the integrated force predictions. The reason for using the numerical Euler code over a small-perturbation theory is the ability to model real airfoils that have thickness and camber. Sample predictions are presented for a section of the rotor on a supersonic throughflow compressor designed at NASA Lewis Research Center. Preliminary results indicate that two-dimensional, flat plate analysis predicts conservative flutter boundaries. Author

**A89-50844**

### **MATHEMATICAL MODELING OF THE FALL OF AN INFINITE-SPAN PLATE IN A FLUID [MATEMATICHESKOE MODELIROVANIE PADENIIA V ZHIDKOSTI PLASTINY BSKONECHNOGO RAZMAKHA]**

V. A. APARINOV, M. I. NISHT, and G. N. STRELKOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela (ISSN 0572-3299), May-June 1989, p. 179-184. In Russian. refs

The motion of an infinite-span thin plate during a free fall in a liquid medium is analyzed on the basis of a combined solution to equations of dynamics and nonlinear nonstationary aerodynamics. The plate is assumed to have a certain finite mass; separated flow is considered, with fixed separation points at the plate edges.

The problem is solved numerically, with an analysis of the plate motion and evolution of the vortex wake. The transition to autorotation and its principal characteristics are discussed. V.L.

**A89-50856**

### **CALCULATION OF THE EXTREME AERODYNAMIC CHARACTERISTICS OF POROUS BODIES WITH INJECTION IN HYPERSONIC FLOW [RASCHET EKSTREMAL'NYKH AERODINAMICHESKIKH KHARAKTERISTIK PORISTYKH TEL SO VDUVOM V GIPERZVUKOVOM POTOKE]**

L. A. PROKOPENKO Kosmicheskaiia Nauka i Tekhnika (ISSN 0321-4508), no. 3, 1988, p. 39-43. In Russian. refs

The problem of optimal control of injection through the porous surface of plane and axisymmetric bodies is stated using an approximate approach. Two functionals, the wave resistance and the lift/drag ratio, are considered as the control objectives. Such problems are solved using a special algorithm based on the unconditional minimization method developed by Pshenichnyi (1973). V.L.

**A89-50928**

### **THE FLOW RATE MAXIMUM PRINCIPLE AND VORTEX CHAMBER AERODYNAMICS [PRINTSIP MAKSIMUMA RASHKODA I AERODINAMIKA VIKHREVOI KAMERY]**

M. A. GOL'DSHTIK, A. V. LEBEDEV, and M. KH. PRAVDINA Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 49-55. In Russian. refs

The paper is concerned with the calculation of the free surface radius in the case of flow of an incompressible fluid out of a centrifugal nozzle. It is shown that the flow rate maximum principle permits an equivalent formulation in the context of the Lagrangian formalism and therefore can be readily extended to the case of a compressible gas. The analytical results are compared with experimental data. V.L.

**A89-50931**

### **STRUCTURE OF FLOW PAST THE WINDWARD SIDE OF V-SHAPED WINGS IN THE PRESENCE OF TURBULENT BOUNDARY LAYER SEPARATION [O STRUKTURE OBTAKANIIA NAVETRENNOI STORONY V-OBRAZNYKH KRYL'EV PRI NALICHII OTRYVA TURBULENTNOGO POGRANICHNOGO SLOIA]**

M. A. ZUBIN and N. A. OSTAPENKO (Moskovskii Gosudarstvennyi Universitet, Moscow, USSR) Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 68-76. In Russian. refs

The qualitative characteristics of shock layer flow associated with the presence of a turbulent boundary layer separation produced by one or several consecutively incident shock waves were investigated experimentally and analytically for the case of flow past V-shaped wings. Experimentally observed and calculated flow patterns for V-wings with angles of 30, 45, and 90 degrees are examined, and some flow singularities are identified. In general, the integral of experimentally observed pressure forces is close to the calculated value. It is concluded that the real normal force acting on the wing in the presence of turbulent boundary layer separation can be estimated from the normal force calculated in the context of ideal gas theory. V.L.

**A89-50933**

### **STRUCTURE OF ARTIFICIAL PERTURBATIONS GENERATED BY AN EXTERNAL ACOUSTIC SOURCE IN A SUPERSONIC BOUNDARY LAYER [STRUKTURA ISKUSSTVENNYKH VOZMUSHCHENII, VYZVANNYKH VNESHNIM AKUSTICHESKIM POLEM V SVERKHZVUKOVOM POGRANICHNOM SLOE]**

A. A. MASLOV and N. V. SEMENOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 82-86. In Russian. refs

The wave structure of artificial perturbations produced by an external acoustic field in a supersonic boundary layer were investigated experimentally at Mach 2 and  $Re_1 = 5 \times 10$  to the 6th/m. A classification of the perturbations based on phase

velocities is presented. Perturbations with a phase velocity in the flow direction greater than unity and waves at the boundary between the discrete and continuous spectra are identified. V.L.

**A89-50934**  
**BOUNDARY LAYER TRANSITION ON THE SURFACE OF A DELTA WING IN SUPERSONIC FLOW [O PEREKHODE POGRANICHNOGO SLOIA NA POVERKHNOSTI TREUGOL'NOGO KRYLA PRI SVERKHZVUKOVOM OBTEKANII]**

V. N. BRAZHKO, N. A. KOVALEVA, L. A. KRYLOVA, and G. I. MAIKAPAR Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 87-92. In Russian. refs

The laminar-turbulent transition on the surface of a delta wing was investigated experimentally in a supersonic wind tunnel at Mach 3-5. It is found that, at Mach 3,  $Re_L = 6.5 \times 10$  to the 6th, and  $\alpha = -5.5$  deg, a wedge-shaped region of turbulent flow extends over most of the upper wing surface near the symmetry line. The heat fluxes in this region reach values equal to those of the heat transfer maxima due to separation flows and may exceed the turbulent level of heat fluxes at the windward wing surface. A change in the shape of the lower wing surface from planar to pyramidal is shown to accelerate the boundary layer transition. V.L.

**A89-50937**  
**CHARACTERISTICS OF THE SPECTRA OF PRESSURE FLUCTUATIONS IN FRONT OF A STEP IN SUPERSONIC TRANSITION FLOW [OSOBENOSTI SPEKTRON PUL'SATSHI DAVLENIIA PERED USTUPOM V SVERKHZVUKOVOM PEREKHODNOM TECHENII]**

V. N. BIBKO, B. M. EFIMTSOV, and V. B. KUZNETSOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 170-173. In Russian. refs

Results of an experimental study of wall pressure fluctuations in front of an axisymmetric step on an ogival cylinder are reported. A new phenomenon, which has not been previously observed in flows with a free separation line, is identified. The phenomenon involves the formation, evolution, and decay of well defined high-intensity peaks in the pressure fluctuation spectra with changes in Reynolds number corresponding to the separation of the transition boundary layer. V.L.

**A89-50938**  
**DETERMINATION OF FLOW FIELD INHOMOGENEITY IN A SUPERSONIC WIND TUNNEL AND ESTIMATION OF ITS EFFECT ON MODEL CHARACTERISTICS [OPREDELENIE NERAVNOMERNOSTI POLIA POTOKA V SVERKHZVUKOVOI AERODINAMICHESKOI TRUBE I OTSENKA EE VLIANIIA NA KHARAKTERISTIKI MODELII]**

V. V. EREMIN, S. E. FILIPPOV, and M. A. SHULAKOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 187-189. In Russian. refs

Flow of a gas in the nozzle and test section of a wind tunnel is investigated numerically using equations for an ideal compressible gas. This approach makes it possible to estimate the quality of the ideal flow core in terms of the inhomogeneity contributions to the forces and moments acting on the model. In particular, this method provides a way to evaluate changes in the aerodynamic characteristics of models due to the inhomogeneity resulting from the replacement of the working gas in the wind tunnel. V.L.

**A89-50995**  
**THE REYNOLDS NUMBER DEPENDENCE OF THE DRAG COEFFICIENT OF CONVEX BODIES IN A RAREFIED GAS [O ZAVISIMOSTI KOEFFITSIENTA SOPROTVLENIIA VYPUKLYKH TEL V RAZREZHENNOM GAZE OT CHISLA REINOL'DSA]**

R. N. MIROSHIN Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia (ISSN 0024-0850), April 1989, p. 48-51. In Russian. refs

A simple analytical approximation (with two empirical parameters) is proposed which describes the drag coefficient of convex bodies in a rarefied gas as a function of the Reynolds number. Details of the analysis are presented, and the comparative advantages and disadvantages of several different formulas are discussed. V.L.

**A89-51017**  
**IMPINGEMENT OF A SONIC JET ON WEDGE-SHAPED OBSTACLES [O NATEKANII ZVUKOVOI STRUI NA KLINOVIDNYE PREPIATSTVIIA]**

A. N. KRAIKO and S. A. MUNIN Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 53, May-June 1989, p. 413-417. In Russian. refs

The paper is concerned with the problem of a symmetrical plane sonic jet of an ideal (nonviscous and non-heat-conducting) gas impinging on wedge-shaped obstacles. The characteristic properties of such flows are briefly reviewed, and some specific examples are presented. The accuracy of the solutions presented here is evaluated. V.L.

**A89-51024**  
**CALCULATION OF AN AXISYMMETRIC STREAM AND ANALYSIS OF FLOW IN AXIAL-FLOW TURBINE STAGES [RASCHET OSESIMMETRICHNOGO POTOKA I ANALIZ TECHENIIA V STUPENIAXH OSEVYKH TURBIN]**

F. P. BORISOV and M. IA. IVANOV Akademiia Nauk SSSR, Izvestiia, Energetika i Transport (ISSN 0002-3310), May-June 1989, p. 89-97. In Russian. refs

A method for calculating axisymmetric flow in a stage of an axial-flow gas turbine is proposed which makes it possible to allow for losses and ejection of the cooling air. A nonstationary system of Euler equations, averaged along the circular coordinate, is integrated using Godunov's explicit difference scheme. A stationary solution is obtained using a finite difference scheme in terms of time; the results are compared with experimental data. It is shown that the approach proposed here can be used for solving the inverse problem of the design of axial-flow turbine rings. V.L.

**A89-51310#**  
**ANALYSIS OF FLUCTUATING PRESSURES ON A NOSE-CYLINDER BODY MEASURED IN THE NAL 2MX2M TRANSONIC WIND TUNNEL**

MASAO EBIHARA (National Aerospace Laboratory, Chofu, Japan), HIROTOSHI MINAKUCHI, YASUHIKO AIHARA (Tokyo, University, Japan), and YUKIO FUKUSHIMA (National Space Development Agency of Japan, Tokyo) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 196-199. refs

Measurements are made of unsteady pressures on the surface of a nose cone-cylinder in a Mach number range of 0.7 to 1.2 at 19 locations along generator of the body. Characteristics of the pressure fluctuations are studied with the help of surface static pressure measurements and Schlieren photographs of the flowfield. By examining the variation of the flow characteristics as either the free-stream Mach number or the angle of attack is changed, it can be shown how the relative significance of the two major sources of pressure fluctuation, i.e., the shock oscillation itself and the separated-flow unsteadiness behind the shock, depends on the combination of the Mach number and the angle of attack. Effects of the test section-wall perforation on the measured fluctuating pressure levels are also studied as the perforation generates edge-tones that are the predominant components of the tunnel background noise. Author

**A89-51314#**  
**NUMERICAL SIMULATION OF HYPERSONIC FLOW AROUND A SPACE PLANE AT HIGH ANGLES OF ATTACK USING IMPLICIT TVD NAVIER-STOKES CODE**

YUKIMITSU YAMAMOTO (National Aerospace Laboratory, Chofu, Japan) and SHIN KUBO (Total Systems, Inc., Tokyo, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988,

## 02 AERODYNAMICS

Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 216-219. refs

A flux-split upwind TVD scheme has been applied to the hypersonic flow around a space plane proposed by National Aerospace Laboratory (NAL). Thin layer Navier-Stokes equations in a finite volume formulation are solved by using an implicit approximately factored ADI algorithm. Numerical computations are performed for the conditions of Mach number of 7.0 and Reynolds number of  $4.4 \times 10^6$  at angles of attack up to 50 degrees. Numerical results are compared with experimental data obtained from the hypersonic wind tunnel tests at NAL. Author

### **A89-51315# COMPUTATIONAL FLUID DYNAMICS ON CHEMICALLY-REACTING EXTERNAL FLOWS AROUND SPACEPLANES**

TORU SHIMADA and KAZUNORI KAWASAKI (Nissan Motor Co., Ltd., Aerospace Div., Tokyo, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 220-223. refs

Various classes of existing computational methods for the solution of chemically reacting external flow around reentry vehicles like spaceplanes are outlined and their critical features are summarized. The methods considered are: equilibrium air techniques, inviscid-viscous approaches, viscous shock-layer methods, and simultaneous solutions of conservation equations. Author

### **A89-51316# TWO-DIMENSIONAL NAVIER-STOKES COMPUTATION OF HIGH LIFT DEVICES**

EIJI SHIMA and TAKUJI KISIMOTO (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kakamigahara, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 224-227. refs

This paper deals with the analysis of multiple-element, high-lift devices by solving the Navier-Stokes equations. In order to generate a computational grid around the multiple element airfoils automatically, the grid generator using the elliptic method, in which Poisson equations are solved by the finite difference method combined with two-dimensional panel method is developed. As to the flow solver, some improvements are added to the TVD scheme to calculate low Mach number flows efficiently. Numerical calculations about the flap gap optimization of the single slotted flap configuration and the flow visualization of complicated multiple slotted flaps are shown. Author

**A89-51338\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **NASP AERODYNAMICS**

ALLEN H. WHITEHEAD, JR. (NASA, Langley Research Center, Hampton, VA) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 11 p. refs (AIAA PAPER 89-5013)

This paper discusses the critical aerodynamic technologies needed to support the development of a class of aircraft represented by the National Aero-Space Plane (NASP). The air-breathing, single-stage-to-orbit mission presents a severe challenge to all of the aeronautical disciplines and demands an extension of the state-of-the-art in each technology area. While the largest risk areas are probably advanced materials and the development of the scramjet engine, there remains a host of design issues and technology problems in aerodynamics, aerothermodynamics, and propulsion integration. The paper presents an overview of the most significant propulsion integration problems, and defines the most critical fluid flow phenomena that must be evaluated, defined, and predicted for the class of aircraft represented by the Aero-Space Plane. Author

**A89-51354\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **WIND-TUNNEL INVESTIGATION OF THE LOW-SPEED AERODYNAMICS OF SLENDER ACCELERATOR-TYPE CONFIGURATIONS**

GREGORY M. GATLIN (NASA, Langley Research Center, Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 27-44. (SAE PAPER 881356)

The NASA-Langley 14x22-ft subsonic wind tunnel has been used to ascertain the low speed aerodynamics of a conical-forebody/annular conformal propulsion system/truncated conical afterbody hypersonic-accelerator configuration with delta-planform wing. Six-component force-and-moment data were obtained over the -4 to +30 deg alpha range and + or - 20 deg sideslip. Flow visualization diagnostics were used to characterize configuration aerodynamics. Vortex flows from the conical forebody created large values of local inflow angles at the engine inlet locations on the lee side of the model, at the moderate-alpha values associated with takeoff and landing. O.C.

**A89-51356\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **STUDIES OF FRICTION DRAG AND PRESSURE DRAG OF AIRFOILS USING THE EPPLER PROGRAM**

WILLIAM H. PHILLIPS (NASA, Langley Research Center, Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 71-86. refs (SAE PAPER 881396)

Most previous studies of the drag and two-dimensional airfoils consider only the total drag. The present report gives results of a study of three airfoils, using the Eppler program, to determine the distribution of friction drag along the chord and to obtain relative values of friction drag and pressure drag over a wide range of angle of attack and Reynolds number. The effects of boundary-layer suction in the turbulent region of the boundary layer of two of the airfoils are also investigated. The pressure drag is found to be an important component of the total drag, reaching values of 60 to 80 percent of the total drag near the stall. The use of suction producing a uniform inflow in the turbulent region of the boundary layer results in large increases in maximum lift, and increases the skin-friction drag but reduces or even changes the sign of the pressure drag. Author

**A89-51357\*#** Analytical Services and Materials, Inc., Hampton, VA.

### **DESIGN ASPECTS OF LONG RANGE SUPERSONIC LFC AIRPLANES WITH HIGHLY SWEEP WINGS**

WERNER PFENNINGER and CHANDRA S. VEMURU (Analytical Services and Materials, Inc., Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 87-100. refs (Contract NAS1-18235; NAS1-18599) (SAE PAPER 881397)

The achievement of natural LFC in SST configurations featuring externally braced, very highly swept, high structural aspect ratio wing planforms results in outstandingly high cruise L/D ratios while maintaining low sonic-boom overpressures. A conceptual design study has been conducted with a view to range capability maximization in SSTs. A three-body configuration employing a highly swept, strut-braced planform, in which a central fuselage and two smaller outboard bodies alleviate structural wing bending and torsion, is noted to allow further increases in wingspan and aspect ratio which commensurately reduce lift-induced wave-plus-vortex drag and volume-induced wave drag. O.C.

**A89-51358\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**WIND-TUNNEL INVESTIGATION OF THE FOREBODY AERODYNAMICS OF A VORTEX-LIFT FIGHTER CONFIGURATION AT HIGH ANGLES OF ATTACK**

DANIEL W. BANKS (NASA, Langley Research Center, Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 101-123. refs

(SAE PAPER 881419)

Results of a recent low-speed wind-tunnel investigation conducted to define the forebody flow on a 16-percent scale model of the NASA High Angle-of-Attack Research Vehicle, an F-18 configuration, are presented with analysis. Measurements include force and moment data, oil-flow visualizations, and surface pressure data taken at angles of attack near and above maximum lift (36 to 52 deg) at a Reynolds number of one million (based on mean aerodynamic chord). The results presented identify the key flow-field features on the forebody including the wing-body strake.

Author

**A89-51360**

**HIGH ANGLE OF ATTACK AERODYNAMICS OF EXCITATION OF THE LOCKED LEESIDE VORTEX**

A. D. VAKILI, J. M. WU, and M. K. BHAT (Tennessee, University, Tullahoma) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 147-157. Research supported by USAF. refs

(SAE PAPER 881424)

The control of flow over a multicomponent wing at large incidence has been investigated. At large incidence angles flow over the wing upper surface becomes fully separated. The wing geometry was considered critical in management of flow energy through organization of vorticity and controlling its shedding on the wing upper surface. A flat plate wing, with the planform of a F-15 wing, was reconfigured to accommodate the locked vortex. Spanwise blowing was used to initiate and/or to increase the strength of the vortical flow. It was found that the presence of the locked vortex favorably changed the flow pattern over the wing. Force measurements indicated moderate improvements on most configurations. One configuration, however, demonstrated significant improvements.

Author

**A89-51363**

**AN EULER CODE FOR NONLINEAR AERODYNAMIC ANALYSIS - ASSESSMENT OF CAPABILITIES**

P. RAJ (Lockheed Aeronautical Systems Co., Burbank, CA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 215-230. Research supported by Lockheed Aeronautical Systems Co. refs

(SAE PAPER 881486)

Capabilities of the Three-dimensional Euler Aerodynamic Method (TEAM) for simulating nonlinear aerodynamics associated with transonic flows and leading-edge vortex flows are assessed. TEAM is based on a cell-centered finite-volume, multistage time-stepping algorithm. It accommodates patched zonal grids of arbitrary topologies with matched as well as mismatched grid distributions at the interfaces. Its ability to handle complex geometries, robustness, accuracy, and parametric sensitivity are used as the assessment criteria. Sensitivity of solutions to three numerical dissipation schemes and grid-density variations is investigated. Transonic-flow solutions for NLR 7301 airfoil, Wing C, and a canard-wing-body, and low-speed leading-edge vortex-flow solutions for a delta wing, a cropped-delta wing, and a double-delta wing-body are presented. The solutions are correlated with experimental data and other numerical solutions as applicable. The results provide a good measure of TEAM's capabilities.

Author

**A89-51364**

**NAVIER-STOKES AND EULER COMPUTATIONS OF THE FLOW FIELD AROUND A COMPLETE AIRCRAFT**

CHARLES R. OLLING and K. KURIAN MANI (Lockheed Aeronautical Systems Co., Burbank, CA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 231-242. Research supported by Lockheed Aeronautical Systems Co. refs

(SAE PAPER 881488)

The flowfield around a complete supersonic V/STOL configuration was computed by solving the Euler and thin-layer Navier-Stokes equations with a multizone finite-volume explicit Runge-Kutta time-stepping method. The Navier-Stokes equations were solved in specified zones and the Euler equations were solved in the remaining zones. The Baldwin-Lomax turbulence model was applied for the Navier-Stokes computations. A global grid for the complete aircraft configuration was generated with an optimization method and divided into a multizone grid. The computed lift coefficients and pressure on the wing surface were compared with experimental data.

Author

**A89-51367\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**HYPERSONIC RESEARCH AT STANFORD UNIVERSITY**

GRAHAM CANDLER (NASA, Ames Research Center, Moffett Field, CA) and ROBERT MACCORMACK (Stanford University, CA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 257-265. refs

(Contract NAGW-965)

(SAE PAPER 881521)

The status of the hypersonic research program at Stanford University is discussed and recent results are highlighted. The main areas of interest in the program are the numerical simulation of radiating, reacting and thermally excited flows, the investigation and numerical solution of hypersonic shock wave physics, the extension of the continuum fluid dynamic equations to the transition regime between continuum and free-molecule flow, and the development of novel numerical algorithms for efficient particulate simulations of flowfields.

Author

**A89-51532**

**DEVELOPMENTS IN THE CALCULATION OF UNSTEADY TURBOMACHINERY FLOW**

MICHAEL B. GILES (MIT, Cambridge, MA) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 45-63. Research supported by Rolls-Royce, PLC. refs

(Contract F49620-78-C-0084)

Three different advances in the calculation of unsteady flows in turbomachinery are discussed. The first is the development of a unified approach to nonreflecting boundary conditions for the Euler equations. Numerical examples demonstrate the effectiveness of the steady-state boundary conditions for both subsonic and supersonic conditions. The second development is the concept of 'time-inclined' computational planes as a computational technique for solving the problem associated with the lagged periodic boundary condition in unsteady flow situations where the stator and rotor pitches are unequal. The approach is validated by a test case of sinusoidal wakes interacting with an unloaded flat plate cascade. The third advance is a new approach to the calculation of unsteady stator/rotor interactions through the simple use of shearing cells in an interface region between one grid fixed to the stator and another fixed to the rotor. Results are presented which show the method's capability to calculate complex shock dynamics in a highly unsteady transonic turbine stage.

C.D.



A89-51534

**A STRATEGY FOR THE USE OF HYBRID STRUCTURED-UNSTRUCTURED MESHES IN COMPUTATIONAL FLUID DYNAMICS**

N. P. WEATHERILL (Swansea, University College, Wales) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 101-116. Research supported by the Aircraft Research Association, Ltd., Ministry of Defence Procurement Executive, and Royal Aircraft Establishment. refs

It is investigated whether the advantages of the unstructured method of mesh generation in computational fluid dynamics can be combined with the advantages of the structured method. Two strategies are considered, one encompassing mesh enrichment/flow adaptivity and the other utilizing the suitability of unstructured meshes to produce a discretization of complex geometrical regions. Both these strategies generally result in meshes with regions of triangular and quadrilateral cells. Thus it is necessary to construct flow algorithms which can be used on mixed structured-unstructured meshes. C.D.

A89-51539

**NUMERICAL GRID GENERATION IN 3-D EULER-FLOW SIMULATION**

J. W. BOERSTOEL (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 187-213. refs

Technical problems of grid generation in CFD are sketched, and a brief overview is given of proposed solutions. A simple example is used to illustrate that the core of the grid generation problem is a topology problem. The usefulness of various numerical grid generation techniques for aerodynamic work is shown. C.D.

A89-51540

**AN APPROACH TO GEOMETRIC AND FLOW COMPLEXITY USING FEATURE-ASSOCIATED MESH EMBEDDING (FAME) - STRATEGY AND FIRST RESULTS**

C. M. ALBONE (Royal Aircraft Establishment, Farnborough, England) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 215-235. refs

An attempt is made to unify the treatment of geometric and flow features through a more flexible approach to mesh generation called feature-associated mesh embedding (FAME). The elements of this approach are outlined and its implementation is illustrated for two-dimensional meshes. Examples of meshes for multielement airfoils are shown. It is suggested how FAME might be generalized by proposing treatments for two further types of feature. Flow-algorithm requirements are discussed and a novel second-order accurate Euler algorithm is briefly described. C.D.

A89-51547\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**A STREAMWISE UPWIND ALGORITHM FOR THE EULER AND NAVIER-STOKES EQUATIONS APPLIED TO TRANSONIC FLOWS**

P. M. GOORJIAN (NASA, Ames Research Center, Moffett Field, CA) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 318-324. Previously announced in STAR as N88-29751.

A new algorithm was developed for the Euler and Navier-Stokes equations that uses upwind differencing based on the streamwise direction. This algorithm is time accurate and can be used in codes for calculating unsteady transonic flows over wings. Such codes can be used for the flutter analysis of wings. In this algorithm, the coordinate system is locally rotated to align with the streamwise direction. For differencing the convective terms in the streamwise direction, a new form of flux splitting is employed, in which the

biasing depends on the local Mach number. In the plane perpendicular to the stream direction, the new flux splitting uses the condition of no flow in that local plane. By using a locally rotated coordinate system, the convective flux vector biasing depends on the total Mach number. Hence, the switching of the flux vector biasing occurs across shock waves and the proper domain of dependence is used in supersonic regions. For comparison, many other upwind methods switch differencing based on Mach number of shock wave in multidimensional flows. The formulas for the convective flux vector differencing do not contain any user specified parameters. So, the amount of numerical dissipation is automatically determined. Author

A89-51550

**SOME EXPERIENCES WITH GRID GENERATION ON CURVED SURFACES USING VARIATIONAL AND OPTIMISATION TECHNIQUES**

C. R. FORSEY and C. M. BILLING (Aircraft Research Association, Ltd., Bedford, England) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 341-352. Research supported by British Aerospace, PLC. refs

Two methods of grid generation based on optimization are investigated. Modifications of these methods to generate grids on nonplanar surfaces, decoupled from the surface geometry definition, are developed and tested. A fast multigrid solution algorithm is successfully devised for one of the methods. The method is planned to be incorporated into an existing multiblock grid generation system for complex aircraft configurations. C.D.

A89-51553

**MULTIBLOCK TECHNIQUES FOR TRANSONIC FLOW COMPUTATION ABOUT COMPLEX AIRCRAFT CONFIGURATIONS**

S. E. ALLWRIGHT (British Aerospace, PLC, Civil Aircraft Div., Hatfield, England) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 367-374. refs

A method is presented which enables a user to utilize interactive graphics to generate a schematic of the multiple-block grid structure required for a complex aircraft configuration and also to associate labels to this schematic to achieve control of the resulting Multiblock grid. This description of the Multiblock grid is processed by a generalized integrate that generates the surface grids for arbitrary configurations. This capability is illustrated by the grid and flowfield solutions presented for an executive jet with aft-fuselage mounted turbofan engine installation. C.D.

A89-51562

**A TOTAL VARIATION DIMINISHING SCHEME FOR COMPUTATIONAL AERODYNAMICS**

D. M. CAUSON (Manchester Polytechnic, England) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 449-457. refs

An improved Euler method for computing steady, high-speed external aerodynamic flows is presented. The method is pseudo-time-dependent and uses operator-splitting in conjunction with a finite-volume formulation. The resolution of captured shock waves is improved by the use of total variation diminishing version of the well-known MacCormack scheme and artificial compression techniques. Existing production code implementation of MacCormack's method can be updated quickly and easily by the addition of a simple subroutine. C.D.

N89-26810\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**WIND-TUNNEL INVESTIGATION OF AERODYNAMIC CHARACTERISTICS AND WING PRESSURE DISTRIBUTIONS OF AN AIRPLANE WITH VARIABLE-SWEEP WINGS MODIFIED FOR LAMINAR FLOW**



JAMES B. HALLISSY and PAMELA S. PHILLIPS Washington  
Aug. 1989 222 p  
(NASA-TM-4124; L-16493; NAS 1.15:4124) Avail: NTIS HC  
A10/MF A01 CSCL 01/1

A wind tunnel test was conducted to evaluate the aerodynamic characteristics and wing pressure distributions of a variable wing sweep aircraft having wing panels that are modified to promote laminar flow. The modified wing section shapes were incorporated over most of the exposed outer wing panel span and were obtained by extending the leading edge and adding thickness to the existing wing upper surface forward of 60 percent chord. Two different wing configurations, one each for Mach numbers 0.7 and 0.8, were tested on the model simultaneously, with one wing configuration on the left side and the other on the right. The tests were conducted at Mach numbers 0.20 to 0.90 for wing sweep angles of 20, 25, 30, and 35 degrees. Longitudinal, lateral and directional aerodynamic characteristics of the modified and baseline configurations, and selected pressure distributions for the modified configurations, are presented in graphical form without analysis. A tabulation of the pressure data for the modified configuration is available as microfiche. Author

**N89-26813#** Coleman Research Corp., Huntsville, AL.  
**EXPENDABLE AIR VEHICLES/HIGH ALTITUDE BALLOON TECHNOLOGY Final Report, 13 Jul. 1988 - 28 Feb. 1989**  
ROBERT L. HAWKINS 28 Feb. 1989 100 p  
(Contract DAAH01-88-C-0581; ARPA ORDER 5916)  
(AD-A206972; CHR/89-1909) Avail: NTIS HC A05/MF A01  
CSCL 01/3

Coleman Research Corporation demonstrates a capability to produce drift patterns for high-altitude zero-pressure and super-pressure balloons. A simplified balloon dynamics model and a highly detailed, statistical wind model are integrated into a proprietary flight simulation framework to enable the production of balloon drift patterns. The worldwide, time-dependent wind model in conjunction with the data-configurable balloon model allow the production and analysis of drift patterns for balloons launched from any point on the earth's surface at any time of year. Sample drift patterns are produced for a zero-pressure balloon floating at 70,000 feet for 24 hours and for a super-pressure balloon floating at 120,000 feet for one year. GRA

**N89-26815\*#** Stewart (V. R.), Columbus, OH.  
**AN EXPERIMENTAL INVESTIGATION OF THE GROUND VORTEX CREATED BY A MOVING JET**  
V. R. STEWART Jul. 1989 124 p  
(Contract NASA ORDER L-29341-C)  
(NASA-CR-181841; NAS 1.26:181841; VS-1-88) Avail: NTIS HC  
A06/MF A01 CSCL 01/1

A 1 inch circular jet moving over a fixed ground board was studied in the NASA Langley Research Center Vortex Research Center. The jet passing over the ground board at a height of three nozzle diameters creates a ground vortex which was measured by a pattern of Endevco high response pressure transducers. The results are compared to existing data to determine the effect of the ground boundary eliminated by the moving jet. The penetration of the vortex both forward of and latterly to the impact point of the jet on the ground. The resulting ground vortex penetration forward of the impact point is reduced by approximately 30 percent and the lateral penetration is reduced by 50 percent over that experienced from a stationary jet over a stationary ground board with a free stream velocity. Author

**N89-26817#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.  
**TECHNICAL STATUS REVIEW ON DRAG PREDICTION AND ANALYSIS FROM COMPUTATIONAL FLUID DYNAMICS: STATE OF THE ART**  
Jun. 1989 156 p In ENGLISH and FRENCH Review held in Lisbon, Portugal, 5 May 1988  
(AGARD-AR-256; ISBN-92-835-0516-6) Avail: NTIS HC A08/MF A01

The papers presented at the AGARD Fluid Dynamics Panel

Technical Status Review on, Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art, are contained. Speakers presented a state of the art review from their individual nation. The Program Chairman summarized the key conclusions from all the papers presented. It is recommended that the Fluid Dynamics Panel consider possibilities for further stimulation of progress in the field of CFD-based drag prediction and analysis.

**N89-26819#** Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

**DRAG PREDICTION AND ANALYSIS FROM CFD STATE-OF-THE-ART IN GERMANY**

WOLFGANG SCHMIDT and PETER SACHER  
(Messerschmitt-Boelkow G.m.b.H., Munich, Germany, F.R.) In  
AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 22 p Jun. 1989

Avail: NTIS HC A08/MF A01

Consistent and accurate prediction of absolute drag for aircraft configurations is currently beyond reach computationally as well as experimentally using wind tunnel model testing. This is attributed to several elements ranging from lack of physical understanding up to limitations in numerical methods and scaling laws. To access drag by computational methods, drag components and the overall drag built-up have to be specified. For the individual drag component semi-empirical as well as theoretical estimates are discussed. Problems and limitations in drag estimates using computational fluid mechanics (CFD) are demonstrated for different types of flowfields. Within the scope of the present conference, our survey over the state-of-the-art in Germany will cover industrial aspects for commuter and transport aircraft, trainer, as well as fighter configurations, missiles, and space vehicles. Author

**N89-26820#** National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.

**SOME RESULTS ON FLOW CALCULATIONS INVOLVING DRAG PREDICTION**

K. D. PAPAILIOU In AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 24 p Jun. 1989

Avail: NTIS HC A08/MF A01

Different calculation methods were developed in the Thermal Turbomachinery Lab. of the Athens National Technical University concerning drag prediction. A Navier-Stokes solver, based on a fractional step method, was developed in order to solve viscous incompressible flow in ducts. A second Navier-Stokes solver was developed for transonic flow using, again, a fractional step method, but this time for quasi-three dimensional cascade flow. Integral methods were developed as well in order to predict secondary flows in compressors and shear layer development on blades. High speed laminar and turbulent flow is predicted, attached and separated. Viscous inviscid interaction techniques were developed for the stabilization of the separated flow calculation. Phenomena such as transitional flow, laminar separation bubbles and shock/shear layer interaction for turbulent flow are predicted with good accuracy. The general methods will be reviewed briefly and results will be presented. Author

**N89-26821#** Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.

**STATE-OF-THE-ART OF AIRCRAFT DRAG PREDICTION IN ITALY BY MEANS OF THEORETICAL METHODS**

G. BUCCIANINI and M. BORSI In AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 12 p Jun. 1989

Avail: NTIS HC A08/MF A01

The state-of-the-art in Italy on the aerodynamic drag prediction, based on theoretical methods, is presented and discussed. A brief description of the methods used is given, with examples of application for typical aircraft configurations. A survey of critical areas is provided, together with present research activities to improve the drag prediction capabilities and accuracy. Author

## 02 AERODYNAMICS

**N89-26822#** National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.

### **AIRCRAFT DRAG PREDICTION FOR TRANSONIC POTENTIAL FLOW**

J. VANDERVOOREN *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 17 p Jun. 1989 Sponsored in part by Netherlands Agency for Aerospace Programs (NIVR)  
Avail: NTIS HC A08/MF A01

The state-of-the-art on computational drag prediction and diagnostics in The Netherlands for transport aircraft in the transonic flight regime is described. Subsequently, a method is discussed that is currently being developed at NLR to calculate wave drag in transonic potential flow. The method is a generalization and extension of Garabedian's and McFadden's idea of determining wave drag by volume-integration of the artificial viscosity. The generalization involves the introduction of a reference artificial viscosity which provides a solid theoretical basis. At the same time this ensures that calculated wave drag is to a certain extent independent of the specific details of the artificial viscosity in different codes. The extension accounts for the fact that artificial viscosity does not smear out supersonic/subsonic shock waves completely, but leaves room for a truly discontinuous sonic/subsonic shock remainder that contributes substantially to the wave drag. A number of first results that illustrate the potential of the method are presented and discussed. Author

**N89-26823#** Royal Aircraft Establishment, Bedford (England).  
**CFD METHODS FOR DRAG PREDICTION AND ANALYSIS CURRENTLY IN USE IN UK**

P. R. ASHILL *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 19 p Jun. 1989  
Avail: NTIS HC A08/MF A01

Computational methods developed in UK for the prediction of the drag of aircraft components at subsonic and supersonic speeds are critically reviewed. In many cases, the flow modeling is found to be lacking in certain respects. Despite this, however, the review suggests that these methods have a useful function both in the early stages of aircraft design, when they may be used to study differences in the drag of various shapes, and later in support of wind-tunnel tests as a diagnostic tool and also to extrapolate the data to full scale. Author

**N89-26824\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. Applied Computational Fluids Branch.

### **COMPUTATIONAL FLUID DYNAMICS DRAG PREDICTION: RESULTS FROM THE VISCOUS TRANSONIC AIRFOIL WORKSHOP**

TERRY L. HOLST *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 12 p Jun. 1989 Previously announced as N88-22009

Avail: NTIS HC A08/MF A01 CSDL 01/1

Results from the Viscous Transonic Airfoil Workshop held in January 1987, are compared with each other and with experimental data. Test cases used include attached and separated transonic flows for the NACA 0012 airfoil. A total of 23 sets of numerical results from 15 different author groups are included. The numerical methods used vary widely and include: 16 Navier-Stokes methods, 2 Euler/boundary-layer methods, and 5 potential/boundary-layer methods. The results indicate a high degree of sophistication among the numerical methods with generally good agreement between the various computed and experimental results for attached or moderately separated cases. The agreement for cases with larger separation is only fair and suggests additional work is required in this area. Author

**N89-26825#** Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.

### **CFD DRAG PREDICTION FOR AERODYNAMIC DESIGN**

CHARLES W. BOPPE *In* AGARD, Technical Status Review on

Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 28 p Jun. 1989

Avail: NTIS HC A08/MF A01

Consistent and accurate Computation Fluid Dynamics (CFD) prediction of absolute drag level for aircraft configurations is currently beyond reach. This is attributed to several elements characterizing state-of-the-art computer algorithms and hardware. With considerable research focused on the 2-D airfoil analysis problem, an exercise is conducted to quantify the implications for 3-D wings. Recent highlights in the U.S.A. which have advanced drag prediction capabilities or improved understanding of the problem are described. Examples are taken from the areas of computational physics, viscous airfoil simulation, component analysis, hypersonics, and conceptual design/configuration optimization. Primary attention is concentrated on aircraft but helicopter, missile, and automobile cases are also included. A near term solution to the CFD drag prediction problem can not be identified. Instead, means based on CFD's strengths are discussed which make computational methods valuable for drag reduction/prediction during aerodynamic design processes. Author

**N89-26826\*#** Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.

### **NUMERICAL STUDY OF THREE-DIMENSIONAL SEPARATION AND FLOW CONTROL AT A WING/BODY JUNCTION**

**Progress Report, period ended 30 Apr. 1989**

ROBERT L. ASH and BALAKRISHNAN LAKSHMANAN *Autg.*  
1989 214 p

(Contract NAG1-530)

(NASA-CR-185819; NAS 1.26:185819) Avail: NTIS HC A10/MF A01 CSDL 01/1

The problem of three-dimensional separation and flow control at a wing/body junction has been investigated numerically using a three-dimensional Navier-Stokes code. The numerical code employs an algebraic grid generation technique for generating the grid for unmodified junction and an elliptic grid generation technique for filleted fin junction. The results for laminar flow past a blunt fin/flat plate junction demonstrate that after grid refinement, the computations agree with experiment and reveal a strong dependency of the number of vortices at the junction on Mach number and Reynolds number. The numerical results for pressure distribution, particle paths and limiting streamlines for turbulent flow past a swept fin show a decrease in the peak pressure and in the extent of the separated flow region compared to the laminar case. The results for a filleted juncture indicate that the streamline patterns lose much of their vortical character with proper filleting. Fillets with a radius of three and one-half times the fin leading edge diameter or two times the incoming boundary layer thickness, significantly weaken the usual necklace interaction vortex for the Mach number and Reynolds number considered in the present study. Author

**N89-26827#** Technische Univ., Delft (Netherlands).

### **A NONLINEAR MULTIGRID METHOD FOR THREE-DIMENSIONAL TRANSONIC POTENTIAL FLOW Ph.D. Thesis**

A. J. VANDERWEES 1988 163 p Sponsored by the Netherlands Agency for Aerospace Programs, Delft  
(ETN-89-94802) Avail: NTIS HC A08/MF A01

The application of the nonlinear multigrid method to three-dimensional transonic potential flow is discussed. The flow is described by the full potential equation, which is discretized using a finite volume method. The smoothing algorithm in the multigrid method is a combination of Incomplete Lower Upper decomposition and Strongly Implicit Procedure. In general this algorithm is a faster smoothing algorithm than the often used successive line relaxation, while it is also more robust, because it is uniformly stable in the supersonic regions of the flow. The influence of computational grid properties, such as grid aspect ratio and grid skewness, on the multigrid convergence speed is investigated theoretically and experimentally. The usefulness of

the method for practical applications is demonstrated for the transonic flow about the DFVLR-F4 and ONERA-M6 wing. ESA

**N89-27633#** Vigyan Research Associates, Inc., Hampton, VA.  
**LOW DENSITY FLOW EFFECTS FOR HYPERVELOCITY VEHICLES Final Report, Aug. 1986 - Jul. 1987**

ROOP N. GUPTA Mar. 1989 41 p  
 (Contract F33615-86-C-3009)  
 (AD-A206218; WRDC-TR-89-3034) Avail: NTIS HC A03/MF A01  
 CSDL 20/4

This work presents results for the surface pressure, drag, heat transfer and skin-friction coefficients for hyperboloids and sphere-cone shaped slender and wide-angle bodies under varying degrees of low-density flow conditions. Recently obtained surface-slip and the corrected shock-slip conditions are employed to account for the low-density effects. The flow cases analyzed include highly cooled and very long slender bodies in high Mach number flows. The present method (limited to the analysis of a perfect gas here) is found to predict various flow field quantities quite accurately when compared with the experimental data.

GRA

**N89-27634\*#** National Aeronautics and Space Administration,  
 Langley Research Center, Hampton, VA.

**STATIC INTERNAL PERFORMANCE OF A NONAXISYMMETRIC VANED THRUST REVERSER WITH FLOW SPLOY CAPABILITY**

LINDA S. BANGERT and LAURENCE D. LEAVITT Washington  
 Sep. 1989 89 p  
 (NASA-TP-2933; L-16552; NAS 1.60:2933) Avail: NTIS HC  
 A05/MF A01 CSDL 01/1

An investigation was conducted in the Static Test Facility of the Langley 16-Foot Transonic Tunnel on a dual-port, nonaxisymmetric, block-and-turn type thrust reverser model with vane cascades in the reverser ports which turned the flow in the splay direction and aided in turning the flow in the reverse direction. Splaying reverser flow is a method of delaying to lower landing ground roll speeds the reingestion of hot exhaust flow into the inlets. Exhaust flow splay can also help prevent the impingement of hot exhaust gases on the empennage surfaces when the reverser is integrated into an actual airframe. The vane cascades consisted of two sets of perpendicular vanes with a variable number of turning and splay vanes. A skewed vane box was also tested which had only one set of vanes angled to provide both turning and splay. Vane cascades were designed to provide different amounts of flow splay in the top and bottom ports. Inner doors, trim tabs, and an orifice plate all provided means of varying the port area for reverser flow modulation. The outer door position was varied as a means of influencing the flow reverse angle. Nozzle pressure ratio was varied from 1.75 to approximately 6.00.

Author

**N89-27635#** Pacific-Sierra Research Corp., Los Angeles, CA.  
**AEROSTAT COLD WEATHER STUDY Technical Report, 6 Mar. - 31 Dec. 1988**

DENNIS L. KANE 13 Mar. 1989 59 p  
 (Contract MDA903-88-C-0020)  
 (AD-A207299; PSR-1925) Avail: NTIS HC A04/MF A01 CSDL  
 04/2

The arctic environment and its potential impact on Aerostat design and operations are discussed. Predictive meteorological resources available are summarized. Results of previous Aerostat operations in cold climates are reviewed and potential solutions discussed for the problems encountered.

GRA

**N89-27636#** Air Force Armament Lab., Eglin AFB, FL.  
**HYPERSONIC PREDICTION COMPARISONS WITH EXPERIMENTAL DATA FOR A CONE-CYLINDER AT MACH 6.86 Final Report, Oct. 1988 - Jan. 1989**

MONTGOMERY C. HUGHSON and CHARLES J. COTTRELL Mar. 1989 10 p  
 Previously announced in IAA as A89-25419  
 (AD-A207583; AFATL-TP-89-04) Avail: NTIS HC A02/MF A01  
 CSDL 20/4

Comparisons of computed flowfield predictions to experimental data for a cone-cylinder configurations at Mach 6.86 and angles of attack of 0, 6.7, 14, and 20 degrees are presented. The two inviscid computer codes used were EAGLE and ZEUS, which represent a time-iterative and a space-marching approach, respectively. Specific comparisons were made between the predicted and the experimental pressure distributions along the body at various circumferential locations, as well as aerodynamic characteristics of normal force coefficient and the location of the center of pressure. The inviscid calculations compare well with experimental data where viscous effects are minimal.

GRA

**N89-27637#** National Aeronautical Lab., Bangalore (India).  
 Computational and Theoretical Fluid Dynamics Div.

**COMPUTATION OF TRANSONIC POTENTIAL FLOW PAST RAE-WING-A AND BODY-B2 COMBINATION**

SUNIL KUMAR CHAKRABARTTY Jun. 1989 122 p  
 (PD-CF-8921) Avail: NTIS HC A06/MF A01

A simple approach has been developed to use the two dimensional grid generation method by solving elliptic partial differential equations to generate the three dimensional grid for wing-fuselage configurations. This simple method can be applied to generate grids for an arbitrary fuselage fitted with any swept wing with dihedral. A three dimensional transonic analysis code TWING, with an approximate factorization (AF2) scheme has been suitably used as a flow solver. As an example, RAE-WING-A with body-B2 configuration has been considered. The results obtained have been compared with available numerical and experimental results. It has been observed in the present computations that AF2 scheme is not sensitive to grid stretching.

Author

**N89-27638#** General Dynamics Corp., Fort Worth, TX.  
**SMALL SCALE MODEL TESTS IN SMALL WIND AND WATER TUNNELS AT HIGH INCIDENCE AND PITCH RATES. VOLUME 3: WATER TUNNEL (HFF) DATA BASE Final Report, Sep. 1985 - Sep. 1988**

ATLEE M. CUNNINGHAM, JR., TODD BUSHLOW, JOHN R. MERCER, TIM A. WILSON, and STEVE N. SCHWOERKE Apr. 1989 179 p  
 (Contract N00014-85-C-0419)  
 (AD-A208690) Avail: NTIS HC A09/MF A01 CSDL 01/1

The force testing of small scale models in either a small wind tunnel or a water tunnel was investigated as an inexpensive and quick means to obtain meaningful dynamic force and moment data representative of rapidly maneuvering full scale aircraft. Force tests of flatplate semispan models were conducted in the General Dynamics Aerodynamic Development Facility (ADF) which is a small 14x14 sq in. low speed wind tunnel. Oscillatory model motions up to 48 deg (peak to peak) amplitude were tested at frequencies of 1 to 3 Hz. Force tests of flat and three-dimensional full span models were conducted in the General Dynamics Hydroflow Facility (HFF) which is a horizontal flow water tunnel with a 24x24 sq in. test section.

GRA

**N89-27639#** Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

**NUMERICAL SIMULATION OF CONTROL OF SUPERSONIC SHEAR LAYERS Semiannual Progress Report, 1 Dec. 1988 - 31 May 1989**

L. N. SANKAR and TANG WEI 31 May 1989 33 p  
 (Contract N00014-89-J-1319)  
 (AD-A209703) Avail: NTIS HC A03/MF A01 CSDL 20/4

The objective of the present research is to investigate the stability and growth characteristics of 2-D and 3-D supersonic free shear layers through direct numerical solution of the 3-D compressible viscous flow equations. An explicit time marching method, patterned after the well known MacCormack scheme is used to integrate the 2-D and 3-D Navier-Stokes equations in time, on a stretched Cartesian grid. The flow being studied consists of shear layers formed at the juncture of two parallel streams at different Mach numbers, densities and temperatures. Assuming an initial velocity, density and temperature distribution at an upstream location, the mean steady flow characteristics of the

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shear layer are first computed. This is done by marching in time, until an asymptotically steady state solution for the mean flow is obtained. Next, acoustic disturbances composed of streamwise, normal or spanwise sinusoidal velocity perturbations at known frequencies are imposed on the shear layer. The limit cycle behavior of the shear layer is then computed by carrying out the calculations for several cycles of the imposed disturbance. The computed flow field properties are post-processed using standard graphics, techniques to obtain vorticity, pressure and density plots, velocity and Mach numbers of eddies, the Fourier spectrum of the velocity, and pressure field at a number of locations within the shear layer. GRA

**N89-27640#** McDonnell-Douglas Research Labs., Saint Louis, MO. Dept. of Flight Sciences.

### **TERMINAL SHOCK RESPONSE IN RAMJET INLETS TO ABRUPT DOWNSTREAM PERTURBATIONS Final Report, 29 Sep. 1983 - 30 Jun. 1987**

MIKLOS SAJBEN, THOMAS J. BOGAR, and JOSEPH C. KROUTIL Sep. 1988 47 p  
(Contract N60530-83-C-0186)  
(AD-A209788; AD-E900851; MDC-Q1285; NWC-TP-6846) Avail: NTIS HC A03/MF A01 CSCL 21/5

The response of a nominally two-dimensional transonic diffuser flow to abrupt downstream perturbations was examined experimentally. GRA

**N89-27641#** University of Southern California, Los Angeles: Dept. of Aerospace Engineering.

### **STUDIES OF UNSTEADY VORTEX FLAP AERODYNAMICS Final Report, 1 Aug. 1985 - 31 Jan. 1989**

T. MAXWORTHY and H. K. CHENG 20 Jun. 1989 5 p  
(Contract AF-AFOSR-0318-85; AF PROJ. 2307)  
(AD-A209837; AFOSR-89-0933TR) Avail: NTIS HC A02/MF A01 CSCL 01/1

A joint theoretical and experimental program on the unsteady aerodynamics associated with active vortex flaps employed on delta wings was conducted. Flow visualizations were performed along with quantitative flow field measurements via particle tracking techniques for a range of dynamic conditions. Additionally, a theoretical point vortex approach was employed to study the vortex dynamics and resultant unsteady loads. GRA

## 03

### **AIR TRANSPORTATION AND SAFETY**

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

**A89-48744#**

### **PRINCIPAL CHARACTERISTICS OF LIGHTNING ON AIRCRAFT [PRINCIPALES CARACTERISTIQUES DES FOUDDROIEMENTS SUR AVIONS]**

J. L. BOULAY (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Symposium, 73rd, Gol, Norway, May 9-11, 1989) ONERA, TP no. 1989-59, 1989, 11 p. In French. refs  
(ONERA, TP NO. 1989-59)

The modeling and measurement of lightning on aircraft are considered. Experimental studies have been conducted which are based on the launching of small rockets with conducting wires attached to the ground. The study of the lightning-aircraft interaction involves the characterization of the direct effect of lightning on the aircraft, the affect of the electromagnetic field of nearby lightning, the distribution of the electrical and magnetic field components on the aircraft exterior and interior, and the effect of perturbations on on-board equipment. Results are presented for lightning strikes observed on the Transall and CV 580 aircraft. R.R.

**A89-48938**

### **DIAGNOSTICS OF AIRCRAFT COMPONENTS [DIAGNOSTIKA AVIATSIONNYKH DETALEI]**

VLADISLAV N. LOZOVSKII, GENNADII V. BONDAL, ARIS O. KAKSIS, and ALEKSANDR E. KOLTUNOV Moscow, Izdatel'stvo Mashinostroenie, 1988, 280 p. In Russian. refs

The book is concerned with methodological principles of the evaluation of the technical condition of aircraft engine and structural components at the stage of construction, testing, operation, and maintenance. Topics discussed include nondestructive testing of aircraft components, metalophysical analysis of failed components, failure mechanisms, and recommendations concerning the evaluation of the condition of compressor, turbine and combustion chamber components as well as structural components of the airframe and landing gear. V.L.

**A89-49423#**

### **ENVIRONMENTALLY INDUCED SURFACE ROUGHNESS EFFECTS ON LAMINAR FLOW AIRFOILS - IMPLICATIONS FOR FLIGHT SAFETY**

M. B. BRAGG and G. M. GREGOREK (Ohio State University, Columbus) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. refs  
(AIAA PAPER 89-2049)

The effect of insect contamination, ice, frost and rain on airfoils and aircraft are reviewed. Roughness affects airfoils by reducing the lift and increasing the drag. Airfoils with different clean performance (laminar and turbulent) are seen to perform similarly with leading-edge roughness. Ice accretion on airfoils is seen to cause a large drag rise and loss in maximum lift. Several aircraft safety concerns due to airfoil roughness are discussed including the loss of longitudinal control due to tail or canard contamination. Author

**A89-50293**

### **AGEING JET CARE**

J. M. RAMSDEN Flight International (ISSN 0015-3710), vol. 136, July 15, 1989, p. 39-42.

Aging aircraft, unlike humans, can have their 'skins, joints, and organs' indefinitely renewed; a steady course of corrosion-protective maintenance can result in 20-year-old airliners whose condition is superior to that of identical 5-year-old aircraft which have suffered neglect. In response to recent aging-corrosion-related incidents, as well as the prospect of some 277 airliners aged 25 years or more (and fully 3,300 aged 15 years or more), by 1990, aviation industry and airline regulators have formulated mandatory maintenance practices aimed at proceeding beyond scheduled inspections to the termination of cracking and corrosion processes. The FAA is also hiring 900 additional inspectors, bringing its total inspection personnel force to 3000 by 1991. O.C.

**A89-50692**

### **EFFECTS OF LIGHTNING ON MODERN AIRCRAFT [EFFETS DU FOUDDROIEMENT SUR LES AVIONS MODERNES]**

M.-R. REDDAN (Air France, Paris) Navigation (Paris) (ISSN 0028-1530), vol. 37, July 1989, p. 369-376. In French.

The lightning strike phenomenon, involving the dissipation of some 100,000 J/m, is described, and its effects on aircraft are evaluated. The current European civil aircraft strike rate is one per 1000 flight hours. Data show that VHF and UHF radio interference occurs in 52 percent of the lightning strikes, and that lightning produces serious operational consequences in 8 percent of the cases. Modern aircraft are more vulnerable to lightning strikes than previous aircraft due to: (1) the replacement of metallic parts by composite parts which do not provide Faraday-cage electromagnetic protection; (2) the replacement of hydraulic circuits by electromechanical actuators which are more sensitive to lightning strikes; and (3) the larger role played by electronics in current navigation systems, rendering them more vulnerable to power overloads. R.R.

A89-51010

**PRINCIPLES OF THE ORGANIZATION OF FLIGHT OPERATIONS AND FLIGHT SAFETY [OSNOVY ORGANIZATSII LETNOI RABOTY I BEZOPASNOST' POLETOV]**

LARISA V. GORLACH, ANATOLII G. KAL'CHENKO, VLADLEN N. SHILO, and VALERII V. BALIASNIKOV Moscow, Izdatel'stvo Transport, 1988, 272 p. In Russian. refs

The principles of the organization, support, and execution of flight operations and air traffic control are reviewed. In particular, attention is given to the main documents regulating civil aviation, airliners and airliner crews, airports, flight classification, flight regulations, flight support services, flight under special conditions, and flight emergencies. The discussion also covers the planning and control of flight operations, crew training, factors related to flight safety, air accident prevention, and investigation of air accidents. V.L.

A89-51578

**AGING AIRCRAFT AND FATIGUE FAILURE**

P. F. PACKMAN (Southern Methodist University, Dallas, TX) Journal of Air Law and Commerce (ISSN 0021-8642), vol. 54, Summer 1989, p. 965-1009. refs

The technical problems associated with maintaining an adequate level of safety and reliability for aging aircraft are reviewed. The technical factors associated with the safety features inherent in the design of critical load-carrying aircraft are discussed, including fatigue design for airframes, safe life, damage-tolerant design, and crack growth. Nondestructive inspection and maintenance inspection schedules and factors influencing defect detectability are considered. Also, the possibility of increasing the durability of aging aircraft is examined. R.B.

N89-26828# Naval Air Development Center, Warminster, PA. Air Vehicle and Crew Systems Technology Dept.

**AIRCRAFT COLOR DISPLAYS: CHROMATICITY AND LUMINANCE REQUIREMENTS Final Report, Oct. 1987 - Sep. 1988**

WILLIAM A. BREITMAIER 23 Aug. 1988 31 p (AD-A206786; NADC-88105-60) Avail: NTIS HC A03/MF A01 CSCL 01/2

Color coding of aircraft display information, when used properly, can decrease the pilot's workload in performing certain visual tasks. In order to be effective, the luminance levels and chromaticity coordinates (with limits) need to be specified. This report provides human factors design guidelines for developing color display criteria. The issues addressed include luminance contrast, color differences, sunlight ambient illumination, and chromaticity recommendations. GRA

N89-26829# Textron Bell Helicopter, Fort Worth, TX. **OH-58 ENERGY ATTENUATING CREW SEAT FEASIBILITY STUDY Final Report, 28 Sep. 1987 - 27 Sep. 1988**

ROY G. FOX 1 Nov. 1988 74 p (Contract DAMD17-87-C-7032; DA PROJ. 3E1-62777-A-878) (AD-A207506; BHTI-699-099-286) Avail: NTIS HC A04/MF A01 CSCL 01/3

Special energy attenuating seats are used to provide a controlled deceleration over a vertical stroking distance to keep aircraft crash loads within human tolerance. Present energy attenuating crew seats use this approach of translating the entire seat vertically. This requires an area clear of equipment and structure between the seat and the fuselage floor. Installation of an energy attenuating seat in the OH-58 could provide reduced spinal loading in some crashes. However, the OH-58 crew seat is integral with the aircraft structure with no room for an energy attenuating seat which gave rise to the belief that a stroking energy attenuating seat was not technically feasible. An innovative approach was needed to provide such seats with a minimum of OH-58 structural modification. A pivoting seat pan design was conceived and feasibility study was performed for the U.S. Army to provide this preliminary design, fabricate test seats, and modify a dynamic test fuselage and a flyable aircraft. Dynamic testing was performed to prove the feasibility of the pivoting seat pan

energy attenuating crew seat approach. This report discusses the approach which can provide energy attenuating crew seats to be installed in an OH-58, while providing a concept which could potentially provide similar solutions for other aircraft. GRA

N89-26830# Federal Aviation Administration, Washington, DC. Office of Aviation Medicine.

**INJURIES TO SEAT OCCUPANTS OF LIGHT AIRPLANES**

EUGENE J. COLANGELO and JULIE C. RUSSELL Feb. 1989 37 p (AD-A207579; DOT/FAA/AM-89/3) Avail: NTIS HC A03/MF A01 CSCL 01/3

A series of 55 light-airplane accidents was examined in an effort to demonstrate the role of seats in the genesis of injury in seat occupants. Good engineering design of airplane seats is an important related issue which is not treated in this study. Case selection attempted to include only those events in which significant but not extreme accelerations occurred. Ten of the fifty-five cases involved joint failure of seats and restraint systems. The majority of the observations were provided by aviation medical examiners who were typically very highly motivated practitioners of medicine with special interests and accomplishments in aviation. The other cases were reported by FAA accident investigators. No reliable marker of energy level was found in the data collected to control the finding that large accelerations tend to injure people and damage seats as well as most other structures regardless of the other interrelationships that might be involved. GRA

N89-27642# Sandia National Labs., Albuquerque, NM.

**AN ANALYSIS OF SEVERE AIR TRANSPORT ACCIDENTS**

J. D. MCCLURE and R. E. LUNA 1989 9 p Presented at the International Symposium on Packaging and Transporting of Radioactive Materials, Washington, DC, 11 Jun. 1989 (Contract DE-AC04-76DP-00789) (DE89-012642; SAND-89-0922C; CONF-890631-23) Avail: NTIS HC A02/MF A01

The objective of this paper is to analyze the severity of aircraft accidents that may involve the air transport of radioactive materials (RAM). One of the basic aims of this paper is to provide a numerical description of the severity of aircraft transport accidents so that the accident severity can be compared with the accident performance standards that are specified in the International Atomic Energy Authority (IAEA) Safety Series 6, the international packaging standards for the safe movement of RAM. The existing packaging regulations in most countries embrace the packaging standards developed by the IAEA. Historically, the packaging standards for Type B packages have been independent of the transport mode. That is, if the shipment occurs in a certified packaging, then the shipment can take place by any transport mode. In 1975, a legislative action in the U.S. Congress led to the development of a package designed specifically for the air transport of plutonium. Changes were subsequently made to the U.S. packaging regulations to incorporate the plutonium air transport performance standards. These standards were used to certify the air transport package for plutonium which is commonly referred to as PAT-1 (U.S. NRC). The PAT-1 was certified by the U.S. Nuclear Regulatory Commission in September 1978. DOE

N89-27643# Lockheed Aeronautical Systems Co., Burbank, CA. **INVESTIGATION OF TRANSPORT AIRPLANE FUSELAGE FUEL TANK INSTALLATIONS UNDER CRASH CONDITIONS Final Report**

GILL WITTLIN Jul. 1989 92 p (Contract DTFA03-86-C-00005) (DOT/FAA/CT-88/24; LR-31443) Avail: NTIS HC A05/MF A01

Three contemporary fuel tank installation configurations investigated in this study include: (1) a conformable tank containing a bladder and supported within a dedicated structure; (2) a double wall cylindrical strap in an auxiliary tank; and (3) bladder cells fitted in the lower fuselage. Existing crash design criteria are reviewed, as well as current proposals which could affect fuel tank installations. Program KRASH was used to help evaluate the performance of a fuselage mounted tank when subjected to

## 03 AIR TRANSPORTATION AND SAFETY

dynamic loads. A total of 21 cases were analyzed, including 12 vertical impacts and 9 longitudinal pulse conditions and/or configurations. The analytical models included 120-inch sections, 300-inch segments and full airplane representations. Results in the form of floor and fuel tank accelerations, floor and fuel tank attachment loads and fuselage crush were obtained. Two test conditions are proposed to represent conditions that best meet the crash design criteria developed in a previous FAA sponsored parametric study, as well as to recognize realistic structures and tests that can be run. Author

**N89-27644#** Federal Aviation Administration, Washington, DC. Forecast Branch.

### **TERMINAL AREA FORECASTS: FY 1989 - 2005**

THOMAS HENRY Apr. 1989 527 p

(AD-A209805; FAA-APO-89-5) Avail: NTIS HC A23/MF A01 CSDL 01/5

Forecasts are present for aviation activity of 850 airports in the United States for fiscal years 1989 to 2005. These include 398 airports with FAA air traffic control towers and radar approach control service and 17 FAA contract towers. For each, airport, detailed forecasts are made for the four major users of the air traffic system: air carriers, air taxi/commuters, aviation, and military. Summary tables contain national, FAA regional, and State aviation data and other airport specific highlights. The forecasts have been prepared to meet the budget and planning needs of the constituent units of the FAA headquarters and regional offices and to provide airport-specific information that can be used by State and local aviation authorities, the aviation industry, as a whole, and the general public. GRA

## 04

### **AIRCRAFT COMMUNICATIONS AND NAVIGATION**

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

**A89-48895**

#### **AIRBORNE PULSED DOPPLER RADAR**

GUY V. MORRIS (Georgia Institute of Technology, Atlanta) Norwood, MA, Artech House, Inc., 1988, 453 p. refs

Theoretical and applications aspects of pulsed Doppler radars for airborne use are examined in chapters based on lecture notes for a continuing-education course presented at the Georgia Institute of Technology. The fundamental principles are introduced, and particular attention is given to high-, medium-, and low-PRF operating modes; Doppler filtering; pulse compression; synthetic-aperture processing; medium-PRF detectability and range resolution; tracking techniques; target detection; clutter and environmental effects; and automatic detection. Diagrams, flow charts, graphs, and the listings of two FORTRAN demonstration programs are included. T.K.

**A89-48943**

#### **AIR NAVIGATION: HANDBOOK [VOZDUSHNAIA NAVIGATSIIA: SPRAVOCHNIK]**

ALEKSANDR M. BELKIN, NIKOLAI F. MIRONOV, IURII I. RUBLEV, and IURII N. SARAISKII Moscow, Izdatel'stvo Transport, 1988, 304 p. In Russian. refs

Basic information on the theory and practice of air navigation is presented. Methods for increasing the efficiency of air navigation are discussed as well as the solution of navigational problems during the preparation and realization of a flight. Flight safety assurance techniques are presented. K.K.

**A89-49441#**

#### **RADAR COVERAGE ANALYSIS OF LAX TRAFFIC-CONTROL AREAS**

S. A. MONTANO and G. A. THOMPSON (Hughes Aircraft Co.,

Ground Systems Group, Fullerton, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 4 p. (AIAA PAPER 89-2077)

The use of the Special Surveillance System to monitor aircraft entering the terminal control area of an airport is evaluated. The Special Surveillance System is a modification of the Firefinder system, a three-dimensional radar designed to detect projectiles and back plot trajectories to determine points of origin. The system can track 200 targets to an altitude resolution of 180 ft and an azimuth resolution range of 500 ft. The effective coverage of the Special Surveillance System within the terminal control area of the Los Angeles (LAX) airport is determined using a solid model. It is found that the use of solids is a quick, effective, and inexpensive method for determining radar visibility. R.B.

**A89-49776**

#### **A VARIABLE FREQUENCY SELECTION SYSTEM PROPOSED**

PETER W. SEIDEL (EUROCONTROL, Brussels, Belgium) ICAO Bulletin (ISSN 0018-8778), vol. 44, March 1989, p. 15, 16.

The possibility of using a variable frequency selection system (VFSS) as a compliment to Mode S of the planned Secondary Surveillance Radar is considered. The possible organization, implementation, and operation of the VFSS are discussed. It is suggested that the proposed VFSS is needed because the existing VHF air-ground communications system is becoming outdated. R.B.

**A89-49791**

#### **RAIM AND GIC WORKING TOGETHER - THE ULTIMATE SOLUTION TO THE GPS INTEGRITY PROBLEM**

R. GROVER BROWN (Iowa State University of Science and Technology, Ames) Navigation (ISSN 0028-1522), vol. 36, Summer 1989, p. 173-178. Research supported by FAA. refs

An approach combining receiver autonomous integrity monitoring (RAIM) and the GPS integrity channel (GIC) is proposed to solve the GPS integrity problem. The GIC scheme considered provides the user with integrity information via two geostationary satellites. It is suggested that the GIC system should be designed such that the user will be able to both range on the geostationary satellites and receive integrity data from them. The additional ranging capability obtained will make it possible to have RAIM available 100 percent of the time. R.R.

**A89-49792**

#### **CORRECTION ALGORITHMS FOR DIFFERENTIAL GPS REFERENCE STATIONS**

PETER LOOMIS, GREG KREMER, and JAMES REYNOLDS (Trimble Navigation, Sunnyvale, CA) Navigation (ISSN 0028-1522), vol. 36, Summer 1989, p. 179-193. refs

Differential GPS corrections for general navigation purposes are discussed which take into account the effects of selective availability, the ionosphere, data link latency, and processing time. A high-level description of the differential GPS reference station system design is presented. The pseudorange correction generator collects the pseudorange and delta-range data, filters the noisy pseudorange error measurements against the delta-range error measurements, and converts the estimates of pseudorange error and pseudorange rate error into an appropriate pseudorange correction. R.R.

**A89-49843#**

#### **VERIFICATION OF AIRBORNE POSITIONING USING GLOBAL POSITIONING SYSTEM CARRIER PHASE MEASUREMENTS**

GERALD L. MADER and JAMES R. LUCAS (NOAA, Charting and Geodetic Services, Rockville, MD) Journal of Geophysical Research (ISSN 0148-0227), vol. 94, Aug. 10, 1989, p. 10175-10181. refs

Results are presented on two experiments, one conducted in Texas, the other in Washington, designed to determine the accuracy with which an aircraft can be positioned in flight using carrier phase measurements from satellites of the Navstar GPS. In each experiment, a photogrammetric camera was flown over a calibration

area providing ground control, making it possible to perform aerotriangulation on ground targets, or, conversely, for the camera position to be determined independently. The GPS measurements were used to determine the position of an antenna located on the aircraft at the time of each photo. Results showed that GPS carrier phase measurements are suitable for precise kinematic positioning and for remote sensing applications. I.S.

**A89-50301****ION, ANNUAL MEETING, 44TH, U.S. NAVAL ACADEMY, ANNAPOLIS, MD, JUNE 21-23, 1988, PROCEEDINGS**

Meeting sponsored by ION, Ashtech, Inc., Honeywell, Inc., et al. Washington, DC, Institute of Navigation, 1988, 155 p. For individual items see A89-50302 to A89-50309.

Consideration is given to such topics as the benefits of area navigation in regional navigation, GPS operations in Arctic areas, and hybrid mode satellite radio determination. Papers are also presented on aircraft experiences with a hybrid Loran-GPS, an option for mechanizing integrated GPS//INS solutions, and integrating GPS within the USGC HH-65A avionics suite. B.J.

**A89-50304#****RECENT DEVELOPMENTS IN THE 'TERPROM' INTEGRATED NAVIGATION SYSTEM**

ALAN J. ROBINS (British Aerospace, PLC, Dynamics Div., Bristol, England) IN: ION, Annual Meeting, 44th, Annapolis, MD, June 21-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1988, p. 58-66. Research supported by the Ministry of Defence. refs

The British Aerospace TERPROM system is introduced, and the operation of the continuous mode Kalman filter is explained. A number of ways of enhancing the TERPROM technique are introduced, such as the additional use of Doppler, scene matching or GPS data, and the resultant improvement over flat ground is demonstrated. Alternative forms of TERPROM are described, and it is shown that performance with these reversionary modes is equally reliable. Finally, a new navigation system known as BRAINS (the British Aerospace Integrated Navigation System) is introduced. Author

**A89-50307#****PRACTICAL INTEGRATION OF A DIGITAL GPS RECEIVER WITH INS SYSTEMS**

TERRY ELLIS, STEVEN LEASURE, and JAMES THOMAS (Plessey Avionics, Ltd., Havant, England) IN: ION, Annual Meeting, 44th, Annapolis, MD, June 21-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1988, p. 117-123.

Design details of the algorithms used in the PA9051 Digital GPS Receiver to implement the INS integration function are discussed and the results of test flights given. Particularly, the mechanization of the GPS Kalman filter and the simple cascaded INS filter are covered showing how the design was proved in simulation and that the test flights confirmed the correct operation of the system. Details of the lever arm corrections used for the position and velocity are also given. The benefits of aiding the GPS tracking function in terms of improved antijamming margin and reacquisition times are included and simulation results show how an unknown data latency degrades the tracking performance. Author

**A89-50308#****INTEGRATING GPS WITHIN THE USCG HH-65A AVIONICS SUITE**

HARRY SUSZKO (Rockwell International Corp., Collins Government Avionics Div., Cedar Rapids, IA) IN: ION, Annual Meeting, 44th, Annapolis, MD, June 21-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1988, p. 130-136.

An integrated avionic system permits the HH-65A helicopter to operate from prepared and unprepared areas both day and night under visual and instrument flight conditions, providing automatic navigation to a point, search patterns, and guidance into a hover. Integrating GPS within the helicopter will give improved navigation accuracy for search and rescue missions, global operations with

consistent navigation precision, and improved navigation under adverse environmental conditions. Details of GPS integration design, implementation, and system functions are provided. B.J.

**A89-50309#****INTEROPERABILITY OF THE GLOBAL POSITIONING SYSTEM AND LORAN-C**

PER K. ENGE (Worcester Polytechnic Institute, MA) and JAMES R. MCCULLOUGH (Woods Hole Oceanographic Institution, MA) IN: ION, Annual Meeting, 44th, Annapolis, MD, June 21-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1988, p. 137-144. Research supported by Megapulse, Inc. refs

The concept of Loran-aided receiver autonomous integrity monitoring is developed. Specifically, two approaches for describing combining Loran pseudoranges with GPS pseudoranges in the user equipment are described. Both approaches utilize a fixed data base for the estimation of the large portion of the Loran groundwave delay, which is due to propagation over land. However, the approaches differ in how they handle the temporal variations in the additional secondary factor, and the differential front end delay. Specifically, the temporal variation can be ignored, predicted, or computed in real time as part of the navigation solution. B.J.

**A89-51305#****IN FLIGHT EVALUATION OF GPS RECEIVER USING AN AIRCRAFT WITH THE STABILIZED VIDEO CAMERA SYSTEM**

TAKAYUKI NISHI (Fuji Heavy Industries, Ltd., Utsunomiya, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 176-179.

This paper describes the result of the flight test for evaluation of the GPS receiver. A stabilized video camera reference system was installed on an aircraft (FA-300). Stabilized video camera reference system can be the system by which is estimated the accurate position of an aircraft for comparison with the position of the GPS receiver output. The accuracy of this reference system is approximately 20 m at an altitude of 3500 ft; this accuracy is superior to other reference system and provides enough value as reference of the GPS. The flight test of the GPS receiver was performed by using this reference system. As a result, the stabilized video camera reference system can be confirmed as an effective means for reference to the evaluating GPS. Author

**N89-26831#** Federal Aviation Administration, Atlantic City, NJ. Technical Center.

**LORAN C COVERAGE IN ALASKA AFTER DUAL RATING PORT CLARENCE**

ROBERT H. ERIKSON Jun. 1988 40 p

(Contract FAA-T0702-N)

(AD-A196032; DOT/FAA/CT-TN88/22) Avail: NTIS HC A03/MF A01

An analysis by the Federal Aviation Administration predicted Loran C coverage could be expanded throughout the interior of Alaska by modification of an existing Loran C transmitter. The modification would include adding Loran C station Port Clarence as a secondary on the Gulf of Alaska chain (7960) by dual rating the station. A flight test probe conducted in the summer of 1987 into the interior of Alaska to determine the extent of usable signals after dual rating Loran C station Port Clarence is described. Flight measurements indicated a largely increased operational area located in the middle to southern interior of Alaska. Author

**N89-26832\*#** Federal Aviation Administration, Atlantic City, NJ.

**ILS/MLS COLLOCATION TESTS AT MIAMI/TAMIAMI, FLORIDA AIRPORT**

JOHN TOWNSEND Jun. 1989 23 p

(Contract NASA ORDER T-0604-L)

(NASA-CR-185715; NAS 1.26:185715; DOT/FAA/CT-TN89/38)

Avail: NTIS HC A03/MF A01 CSCL 17/7

A series of tests were performed by the Federal Aviation Administration (FAA) Technical Center at the Miami/Tamiami, Florida, Airport to verify the guidance material contained in the proposed amendments to Attachment G to Part 1 of the



## 04 AIRCRAFT COMMUNICATIONS AND NAVIGATION

International Civil Aviation Organization (ICAO) Annex 10. A mock-up of the Technical Center's Test Bed Microwave Landing System (MLS) was collocated with the category 1 instrument landing system (ILS) on runway 9R. Several engineering flight tests were flown with ILS data collected and analyzed. These results were later verified by actually installing the MLS test bed at one of the locations used for the mockup tests. The results indicate that the proposed guidelines are adequate as published, but several items should be considered when implementing these guidelines. These items are presented as recommendations. Author

**N89-26833#** Federal Aviation Administration, Atlantic City, NJ. **AN OPERATIONAL DEMONSTRATION AND FLIGHT TEST OF THE MICROWAVE LANDING SYSTEM (MLS) AT THE MIAMI/TAMIAMI, FLORIDA AIRPORT Technical Report, Apr. 1989**

VINCENT L. BENCIVENGA and ROBERT H. PURSEL Jul. 1989  
37 p  
(DOT/FAA/CT-TN89/37) Avail: NTIS HC A03/MF A01

At the request of the Microwave Landing System (MLS) Program Office, the Federal Aviation Administration (FAA) Technical Center conducted an operational demonstration and flight test of the MLS at Miami/Tamiami, Florida Airport. The demonstration/flight test was conducted in conjunction with an MLS seminar jointly sponsored by U.S. Department of Transportation, FAA, and Transport Canada Aviation Group. The Technical Center's MLS test bed, consisting of a 1.5 deg beamwidth elevation station and a 2 deg beamwidth azimuth station, was transported to, and temporarily installed at the Miami/Tamiami Airport on runway 9R, collocated with the commissioned instrument landing system (ILS). Additionally, an E-Systems preproduction model precision distance measuring equipment (DME/P) transponder was also installed adjacent to the runway 9R localizer equipment shelter. On March 29, 1989, seven 1-hour demonstration and data collection flights were flown for over 60 aviation, industry, and U.S. and international Government attendees. By careful siting of the MLS on runway 9R, proportional MLS signal coverage was also obtained in the approach regions of runways 9L and 13. By utilizing an FAA Technical Center designed and fabricated MLS area navigation (RNAV) computer on board the demonstration aircraft, precision approaches were flown not only to runway 9R, but also to runways 9L and 13. This demonstrated the tremendous flexibility and operational capability of MLS. The MLS signal-in-space on runway 9R met Category 2 ILS tolerances. No degradation of the ILS performance due to the MLS collocation was detected during this demonstration. Author

**N89-27645#** Mitre Corp., McLean, VA. Civil Systems Div. **AUTOMATED PLANNING FUNCTION FOR AERA 3: MANEUVER OPTION MANAGER Final Report**  
WILLIAM P. NIEDRINGHAUS Apr. 1989 45 p  
(Contract DTFA01-89-C-00001)  
(DOT/FAA/DS-89/21; MTR-88W00048) Avail: NTIS HC A03/MF A01

The Maneuver Option Manager (MOM), a methodology to simplify complex air traffic control (ATC) problems is described. A complex problem is identified here as a set of interrelated potential conflicts between pairs of aircraft. It may involve arbitrarily many aircraft. MOM determines which of six simple maneuver options is available (free of such potential conflicts) for each aircraft. These options involve limited displacements left/right ahead/behind above/below nominal. MOM simplifies a complex problem by protecting (for future use) an available maneuver option for one or more of the involved aircraft. Routinely, a single such maneuver option causes complex problems to be broken into independent, smaller, and simpler problems. Author

**N89-27646#** Mitre Corp., McLean, VA. Civil Systems Div. **A MATHEMATICAL FORMULATION FOR PLANNING AUTOMATED AIRCRAFT SEPARATIONS FOR AERA 3 Final Report**  
WILLIAM P. NIEDRINGHAUS Apr. 1989 106 p

(Contract DTFA01-89-C-00001)  
(DOT/FAA/DS-89/20; MTR-88W00049) Avail: NTIS HC A06/MF A01

An algorithm, called Gentle-Strict (GS), is given for automated resolution of crossing conflicts between two aircraft, using parallel lateral offset maneuvers. Though other algorithms have been proposed for this purpose, GS uniquely facilitates quantitative analysis of the conflict resolution process itself, as well as quantitative analysis of the links between pairwise conflict resolution and longer lookahead air traffic control (ATC) strategies. The main result of this document is a closed form mathematical formula which relates parameterizations of: (1) the encounter geometry; (2) the pathkeeping uncertainties; (3) the minimum separation achieved by GS; and (4) the gentleness of parallel lateral offset resolution maneuvers (as parameterized by magnitude of offset and by induced delay upon the aircraft). Author

**N89-28178\*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

**NAVIGATIONAL AND ENVIRONMENTAL MEASUREMENT SYSTEM (NEMS) Abstract Only**

T. D. CLEM *In its* Laboratory for Oceans p 223-225 1988  
Avail: NTIS HC A12/MF A01 CSCL 17/7

The NEMS concept and design were initiated from the need to measure and record positional and environmental information during aircraft flights of developmental science research instrumentation. The unit was designed as a stand-alone system which could serve the needs of instruments whose developmental nature did not justify the cost and complexity of including these measurements within the instrument data system. Initially, the system was comprised of a Loran-C receiver and a portable IBM compatible computer recording position and time. Later, the system was interfaced with the Wallops aircraft inertial navigation system (INS), and various other sensors were supplied and shared by the Goddard science users. Real-time position mapping on video monitors was added for investigator's use and information. In 1987, the use of a Global Positioning System (GPS) receiver was included in some missions. A total configuration of the system and the various sensors which can be incorporated are shown. Author

**N89-28179\*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

**AIRBORNE LIDAR GLOBAL POSITIONING INVESTIGATIONS Abstract Only**

W. B. KRABILL *In its* Laboratory for Oceans p 227-229 1988  
Avail: NTIS HC A12/MF A01 CSCL 17/7

The Global Positioning System (GPS) network of satellites shows high promise of revolutionizing methods for conducting surveying, navigation, and positioning. This is especially true in the case of airborne or satellite positioning. A single GPS receiver (suitably adapted for aircraft deployment) can yield positioning accuracies (world-wide) in the order of 30 to 50 m vertically, as well as horizontally. This accuracy is dramatically improved when a second GPS receiver is positioned at a known horizontal and vertical reference. Absolute horizontal and vertical positioning of 1 to 2 m are easily achieved over areas of separation of tens of km. If four common satellites remain in lock in both receivers, then differential phase pseudo-ranges on the GPS L-band carrier can be utilized to achieve accuracies of + or - 10 cm and perhaps as good as + or - 2 cm. The initial proof of concept investigation for airborne positioning using the phase difference between the airborne and stationary GPS receivers was conducted and is examined. Author



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## AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

**A89-47632#**

### TRANAIR APPLICATIONS TO ENGINE/AIRFRAME INTEGRATION

A. W. CHEN, M. M. CURTIN, R. B. CARLSON, and E. N. TINOCO (Boeing Commercial Airplanes, Seattle, WA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 53-58. refs (AIAA PAPER 89-2165)

Transonic flow analyses of the mutual interference between turbofan exhaust flows and airframe induced flow fields are presented. The method of analysis whereby regions of different total pressures and temperatures are modeled in the newly developed version of a full potential code (TRANAIR) is explained. Comparisons of computed results with test data show good agreement. Author

**A89-47659#**

### METHOD FOR SIMULTANEOUS WING AERODYNAMIC AND STRUCTURAL LOAD PREDICTION

MARK DRELA (MIT, Cambridge, MA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 322-332. Research supported by MIT. refs (AIAA PAPER 89-2200)

A calculation method is presented for the simultaneous solution of aerodynamic and structural loads on arbitrary high aspect ratio wings. Problems together constitute a coupled nonlinear system for the aerodynamic and structural unknowns, which is discretized and solved using a global Newton method. The procedure permits prediction of: aerodynamic and structural loads for a very wide range of operating conditions, induced drag with static wing twist effects, lateral and longitudinal wing static stability derivatives and roll-yaw coupling forces, static divergence and aileron reversal speeds, and buckling loads for externally braced wings. Author

**A89-47660\*#** Douglas Aircraft Co., Inc., Long Beach, CA.

### A NEW AIRFOIL DESIGN CONCEPT

P. A. HENNE and R. D. GREGG (Douglas Aircraft Co., Long Beach, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 333-345. Research supported by the McDonnell Douglas Independent Research and Development Program. refs (Contract NAS1-15327) (AIAA PAPER 89-2201)

The present airfoil design concept is based on utilizing unconventional geometry characteristics near the airfoil trailing edge which include a finite trailing edge thickness, strongly divergent trailing edge upper and lower surfaces, and high surface curvature on the lower surface at or near the lower surface trailing edge. This paper presents computational analyses of airfoils and a wing utilizing the concept, airfoil validation wind tunnel test results of several configurations, and wing-validation wind tunnel test results for a complete wing design. In addition to validating the concept, the airfoil and wing testing provided additional detailed data to better understand the aerodynamic advantage of such an unconventional trailing edge configuration. It is demonstrated that the concept represents a significant step in airfoil technology beyond that achieved with the Supercritical Airfoil. This concept provides the aerodynamicist an additional degree of design freedom and flexibility previously unrecognized. Author

**A89-47662#**

### AN EVALUATION OF THE INFLUENCE OF AIRFOIL SELECTION ON WING-BODY DRAG FOR A GENERAL AVIATION AIRCRAFT

DAVID A. LEDNICER (Analytical Methods, Inc., Redmond, WA) and JOHN G. RONCZ (Gemini Technologies, Inc., Granger, IN) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 354-361. refs (AIAA PAPER 89-2203)

The computational tools available to an aerodynamicist today make it possible to refine an aircraft design to a degree not possible in the past without extensive wind tunnel testing. This paper reports the results of a study intended to define the wing geometry of a high performance, single engine, four seat aircraft, the Melmoth 2. Fundamental questions relating to the computational prediction of aircraft drag had to be confronted and are hopefully answered herein. Once the methodology was developed, parametric studies were conducted on the wing of the subject aircraft. The constraints imposed resulted in the primary variables being wing airfoil type and wing incidence. Wing tip sweep was also investigated. The end result is a more highly optimized low drag aircraft configuration. Author

**A89-47663\*#** Texas A&M Univ., College Station.

### A DIRECT-INVERSE TRANSONIC WING-DESIGN METHOD IN CURVILINEAR COORDINATES INCLUDING VISCOUS-INTERACTION

ROBERT R. RATCLIFF and LELAND A. CARLSON (Texas A & M University, College Station) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 362-379. refs (Contract NAG1-619) (AIAA PAPER 89-2204)

Progress in the direct-inverse wing design method in curvilinear coordinates has been made. A spanwise oscillation problem and proposed remedies are discussed. Test cases are presented which reveal the approximate limits on the wing's aspect ratio and leading edge wing sweep angle for a successful design, and which show the significance of spanwise grid skewness, grid refinement, viscous interaction, the initial airfoil section and Mach number-pressure distribution compatibility on the final design. Furthermore, preliminary results are shown which indicate that it is feasible to successfully design a region of the wing which begins aft of the leading edge and terminates prior to the trailing edge. Author

**A89-47691\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### EXPERIMENTAL INVESTIGATION OF THE HIGH ANGLE OF ATTACK CHARACTERISTICS OF A HIGH PERFORMANCE GENERAL AVIATION AIRCRAFT

H. F. MEYER, L. P. YIP (NASA, Langley Research Center, Hampton, VA), J. N. PERKINS, and R. J. VESS (North Carolina State University, Raleigh) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 733-742. refs (AIAA PAPER 89-2237)

Scale model wind tunnel tests and full scale flight tests have been conducted for the Questair Venture general aviation aircraft configuration in order to investigate its high angle-of-attack aerodynamics. Attention is given to the formulation of a wing leading-edge modification capable of enhancing stall departure characteristics. This modification, which involved both outboard wing leading-edge droop and two chordwise leading-edge slots, is found to produce almost no wing-rock tendency when tested on a wind tunnel free-to-roll apparatus; in the full-scale aircraft, the modification yielded gentle, controllable stall characteristics with little cruise and climb performance penalty. O.C.

**A89-47951**

**ANALYSIS OF METHODS OF RESERVE MASS UTILIZATION IN CARGO AIRCRAFT OPTIMIZATION [ANALIZ PUTEI ISPOL'ZOVANIIA REZERVOV MASSY PRI SOVERSHENSTVOVANII TRANSPORTNOGO SAMOLETA]**

V. P. GOGOLIN *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 3-6. In Russian.

Formulas are obtained for determining fuel savings resulting from a reduction of the airframe mass. Various methods of mass reduction are examined with reference to the constraints imposed by the cargo space requirements, take-off weight, and fuel volume. It is shown that maximum fuel savings are achieved when the reduction in the airframe mass is compensated by an increase in the cargo mass, with the take-off mass and flight range remaining unchanged. V.L.

**A89-47957**

**CONVERGENCE OF THE BLADES OF A COAXIAL MAIN ROTOR DURING ON-DECK STARTUP [SBLIZHENIE LOPASTEI SOOSNOGO NESUSHCHEGO VINTA PRI RASKRUTKE NA PALUBE]**

V. A. PAVLOV, S. A. MIKHAILOV, and E. I. NIKOLAEV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 25-28. In Russian.

A solution is proposed for the problem of the convergence of the blades of the main coaxial rotor of a helicopter during its startup on the deck of a ship. The equations used in the calculations include additional external force factors associated with the rolling motion of the ship and nonuniform air flow over the takeoff and landing pad. V.L.

**A89-47980**

**SELECTION OF COMBINED ACCELERATED TEST REGIMES FOR AIRCRAFT COMPONENTS [VYBOR REZHIMOV SOVMESHCHENNYKH USKORENNYKH ISPYTANII IZDELII AVIATSIONNOI TEKHNIKI]**

A. S. GISHVAROV and O. V. IVANOV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 105-107. In Russian.

The problem of selecting combined accelerated test regimes for aircraft components is formulated as a functional minimization problem. A formula is obtained which provides a way to select accelerated test conditions with allowance for the strength of the discs, blades, rotor bearings, reducer gears, and oil pump components. V.L.

**A89-47985**

**A COMPARISON OF THE THRUST REVERSAL AND OTHER BRAKING CAPABILITIES OF AIRCRAFT USING THE EFFECTIVENESS COEFFICIENT [SRAVNENIE REVERSIROVANIIA I DRUGIKH TORMOZNYKH SREDSTV SAMOLETA S ISPOL'ZOVANIEM KOEFFITSIENTA EFFEKTIVNOSTI]**

A. G. GILERSON *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 2, 1989, p. 3-6. In Russian.

A criterion is proposed which makes it possible to evaluate the effectiveness of thrust reversal under different conditions in comparison with the use of wheel brakes and braking parachutes. The criterion, referred to as the effectiveness coefficient, can be used to evaluate the effectiveness of the thrust reversal system of different aircraft or the same aircraft under different operation conditions. The use of the effectiveness coefficient is illustrated by an example. V.L.

**A89-47999**

**DESIGN OF COMMUNICATION LINES AS PART OF AIRCRAFT EQUIPMENT LAYOUT [PROEKTIROVANIE KOMMUNIKATSII PRI RAZMESHCHENII OBORUDOVANIIA LETATEL'NYKH APPARATOV]**

L. P. BOBRIK, L. V. MARKIN, and V. I. MARKOV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 2, 1989, p. 55-57. In Russian.

An approach to the computer-aided design of communication lines in aircraft, with the length of the lines minimized for a given equipment layout, is presented. The method has been implemented

in computer software written in FORTRAN which can be used as a module of a computer-aided equipment layout system. The mathematical model and formalized description of the initial data proposed here make it possible to base the design on different criteria, including minimization of the effect on the position of the center of mass of the structure. V.L.

**A89-48003**

**A SIMPLIFIED METHOD FOR DETERMINING THE NATURAL FREQUENCY OF HELICOPTER ROTOR BLADES [UPROSHCHENNYI SPOSOB OPREDELENIIA CHASTOT SOBSTVENNYKH KOLEBANII LOPASTI VERTOLETA]**

A. N. CHUIKO, N. I. PAVLIUK, and I. V. SHANIN *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 2, 1989, p. 64-66. In Russian.

A method for determining the natural frequencies of helicopter rotor blades is proposed which uses simplified differential equations of coupled flexural-torsional harmonic vibrations. Calculations for a series of plates with variable mass and stiffness characteristics are compared with experimental data. It is shown that the approach proposed here makes it possible to determine the natural frequencies of variable-stiffness beams to within 5-7 percent using a basic microcomputer. V.L.

**A89-48143**

**AGING AIRCRAFT - TOO OLD TO FLY?**

ERIN E. MURPHY *IEEE Spectrum* (ISSN 0018-9235), vol. 26, June 1989, p. 28-31.

The problem of metal fatigue in aircraft is discussed in the context of risk analysis and assessment. The steps taken by aircraft designers to minimize risk are examined. A major defect of fatigue testing, which is its failure to take into account the effects of corrosion on fatigue cracks, is addressed. The pursuit of more effective methods of nondestructive testing is noted. The role played by fatigue and corrosion in the Aloha Airlines accident of April 28, 1988, in which a flight attendant was lost when a 5.5-m-long portion of the front fuselage of a B-737 ripped off during flight, is cited throughout, and the aircraft manufacturer's approach to the problem is questioned. I.E.

**A89-48191**

**AN ENGINEERING APPROACH FOR NEARLY SHOCK-FREE WING DESIGN**

ZIQIANG ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) and H. SOBIECZKY (DLR, Goettingen, Federal Republic of Germany) *Chinese Journal of Aeronautics* (ISSN 1000-9361), vol. 2, May 1989, p. 81-86. refs

In the present paper, a reliable transonic analysis algorithm with an analytic fictitious gas model is used to develop a simplified version of the design method for finding flows with only weak shocks. In this method, the transpiration velocity boundary condition, rather than the space-marching procedure, is used to simulate the surface deformation. As shown in the numerical example, this procedure yields almost shock-free configurations. Author

**A89-48283**

**LANDING GEAR DESIGN AND DEVELOPMENT**

S. F. N. JENKINS (Seminar on Developments in Aerospace Engineering, Birmingham, England, Oct. 27, 1987) *Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering* (ISSN 0954-4100), vol. 203, no. G1, 1989, p. 67-73.

This paper discusses design requirements and the compatibility of shock absorbers to satisfy the performance required. The effect on landing gear design of trends to use the latest materials, particularly ultra-high-tensile steels, also test methods to confirm stress analysis calculations and flight-by-flight fatigue testing. Author

**A89-48378#**

**DEVELOPMENT AND VALIDATION OF AN F-16C AERODYNAMIC MODEL FROM FLIGHT TEST DATA**

DANIEL P. RINGENBACH (USAF, Edwards AFB, CA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston,

MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 8-13. (AIAA PAPER 89-3261)

A realtime aerodynamic model for the F-16C simulation was developed solely from data acquired from flight test. The model includes major aerodynamic derivatives in pitching, rolling and yawing moments as well as derivatives in normal, chord and side forces. Pilot inputs of lateral and longitudinal stick force, rudder pedal force, power lever angle and speedbrake deflection recorded during flight test were used as input into the simulator and the responses of the aircraft and simulator were compared. The study showed that an aerodynamic model from flight test data showed a substantial improvement over the aerodynamic model developed from wind tunnel data in the high angle-of-attack region but was not extensive enough to develop a simulator for the entire flight envelope. It also showed that the aerodynamic model developed from wind tunnel data was inadequate and should be updated with data acquired during flight test. Author

**A89-48393\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**A COMPARISON OF THE GROUND EFFECTS MEASURED WITH AND WITHOUT RATE-OF-DESCENT MODELING ON THE F-15 S/MTD CONFIGURATION**

GUY T. KEMMERLY (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 130-138. refs (AIAA PAPER 89-3280)

The effect of descent rate (DR) on the approach aerodynamics of the F-15 S/MTD aircraft is investigated experimentally using a moving model in the NASA Langley Vortex Research Facility. A 0.083-scale low-speed rotary-balance model equipped with a thrust-reverser simulator and with grit strips to assure turbulent flow was tested in an approach configuration at forward speed 60 ft/sec, corresponding to  $DR = 4.19$  ft/sec. The results are presented in extensive graphs and compared with wind-tunnel data on the same configuration at  $DR = 0$ . Significant differences are attributed to the DR in the present experiments and the presence of a ground boundary layer in the wind-tunnel tests. It is predicted that safe approaches could be made with the lower thrust reverser vectored up to 80 deg, or even 110 deg if the DR were not arrested near the ground. T.K.

**A89-48395#**  
**REAL-TIME FLIGHT SIMULATION SUPPORT FOR THE X-31 AIRCRAFT PROGRAM**

STEVE ZAMMIT and KOOS ZWAANENBURG (Applied Dynamics International, Inc., Ann Arbor, MI) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 153-167. refs (AIAA PAPER 89-3283)

The real-time simulation of aircraft with many different types of hardware in the loop can be a very challenging task-especially when one has to simulate a high-performance aircraft with fast, nonlinear dynamics, a state-of-the-art flight control system, actuators, and other external hardware simultaneously. This paper discusses in detail the use of the AD 100 simulation computer for the real-time simulation requirements of the X-31 project. Author

**A89-48549**  
**A320 - PAST DEFINITIONS AND FUTURE POSSIBILITIES**

D. H. JAGGER (British Aerospace Commercial Aircraft, Ltd., Airbus Div., Filton, England) Aerospace (UK) (ISSN 0305-0831), vol. 16, Aug. 1989, p. 8-14.

A detailed account is presented of the development history, development status, and configurational and componential development prospects for the A320 family of commercial aircraft. To date, the family encompasses the A320-100 and the A320-200, which has the same passenger capacity as the -100 but incorporates a wing center fuel tank and wingtip flow fences and

may employ either the CFM56-5 or V2500 turbofans. Future variants of the A320 with either lengthened or shortened fuselages are expected to differ from current aircraft with respect to powerplant; both ultrahigh bypass ducted fans and pusher-configuration unducted propfans, in either fuselage-afterbody or 'overwing' nacelles, are under consideration. O.C.

**A89-48654\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**SHAPE SENSITIVITY ANALYSIS OF WING STATIC AEROELASTIC CHARACTERISTICS**

JEAN-FRANCOIS M. BARTHELEMY (NASA, Langley Research Center, Hampton, VA) and FRED D. BERGEN (Virginia Polytechnic Institute and State University, Blacksburg) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 702-709) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 712-717. Previously cited in issue 12, p. 1825, Accession no. A88-32250. refs

**A89-48659#**  
**PRONATED ESCAPE SYSTEM (PRESS)**

ALLEN D. DISSELKOEEN, KEITH HEISE, H. (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH), and CURTIS H. SPENNY (USAF, Institute of Technology, Wright-Patterson AFB, OH) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 744-750. Previously cited in issue 14, p. 2121, Accession no. A89-35205. refs

**A89-48660#**  
**MULTIGRID TRANSONIC COMPUTATIONS ABOUT ARBITRARY AIRCRAFT CONFIGURATIONS**

B. EPSTEIN, A. L. LUNTZ, and A. NACHSHON (Israel Aircraft Industries, Ltd., Lod) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 2, p. 1038-1046) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 751-759. Previously cited in issue 03, p. 265, Accession no. A89-13607. refs

**A89-48667#**  
**COMMENT ON 'DIVERGENCE STUDY OF A HIGH-ASPECT RATIO, FORWARD SWEEP WING'**

WILLIAM P. RODDEN (La Canada Flintridge, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 791. refs

**A89-48734#**  
**A FINITE ELEMENT METHOD TO PREDICT INTERNAL NOISE LEVELS AT DISCRETE FREQUENCIES FOR A PARTIALLY COMPOSITE HELICOPTER FUSELAGE**

M. DUSSAC, P. MARTIN, H. J. MARZE (Aerospatiale, Division Helicopteres, Marignane, France), F. CHABAS, J. M. DAVID (ONERA, Chatillon-sous-Bagneux, France) et al. ONERA, TP no. 1989-49, 1989, 13 p. refs (ONERA, TP NO. 1989-49)

Finite element results for the prediction of the noise levels, at discrete frequencies, inside a partially composite helicopter fuselage are presented and validated by comparison with experimental data obtained aboard the Dauphin helicopter in flight. Special attention is given to the development of a mechanical helicopter model, along with a plate finite element for the medium frequency dynamic analysis of sandwich honeycomb panels. Good agreement is found between experimental acoustic levels obtained at several cabin locations and those predicted by the present numerical method, except for the case of epicyclic stage H3 emergence, particularly for the rear passenger area. R.R.

**A89-48747#**  
**NUMERICAL METHOD FOR THE RESPONSE OF AN AIRCRAFT TO THE ATMOSPHERIC TURBULENCE APPLICATION TO THE NORD 260 AIRPLANE**

J. P. GRISVAL, J. L. MEURZEC, and F. POIRION (ONERA, Chatillon-sous-Bagneux, France) (European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic

of Germany, Apr. 17-19, 1989) ONERA, TP no. 1989-63, 1989, 8 p. refs  
(ONERA, TP NO. 1989-63)

A numerical method of prediction of an airplane response to the cylindrical and isotropic atmospheric turbulence in the subsonic range has been developed at ONERA. The structure is modeled using the modal basis. This basis contains two rigid modes of plunging and pitching and other flexible modes (they are obtained either by calculation either by on-ground vibration measures). The generalized nonstationary aerodynamic forces are calculated using the doublet lattice method on the entire plane, taking into account all the interactions. The responses of the plane to the homogeneous isotropic or cylindrical turbulent field are then obtained. This method is used for the Nord 260 plane. The comparison between the calculated and experimental transfer functions shows that the isotropic model for turbulence is much more realistic than the cylindrical one, especially for large aspect ratio airplanes. The good agreement between the results are shown for the spectral densities, the transfer functions and coherence and thus it validates the numerical method. Author

#### A89-48757#

##### PRELIMINARY COMPARISONS OF TILT ROTOR AND COMPOUND HELICOPTER FOR CIVIL APPLICATIONS

JACQUES ESCULIER (Ministere de la Defense, Departement Helicopteres, Paris, France), BERND GMELIN, ULF SCHMIDT (DLR, Brunswick, Federal Republic of Germany), ALAN JONES (Royal Aerospace Establishment, Farnborough, England), JEAN-JACQUES PHILIPPE (ONERA, Paris, France) et al. ONERA, TP no. 1989-73, 1989, 15 p. Research sponsored by GARTEUR. (ONERA, TP NO. 1989-73)

A collaborative study has been conducted by the GARTEUR (Group for Aeronautical Research and Technology in Europe) to assess the applicability of tilt rotor aircraft and compound helicopters to specific missions (civil transport, offshore transport and long range search and rescue). The two advanced rotorcraft are compared with each other, and the ranges of parameters within these missions to which they are best suited are determined. The study is based upon mathematical models and corresponding data bases at a level appropriate to preliminary design. These together provide the aircraft characteristics in terms of geometrical data, mass breakdown, installed power and performances with respect to the mission under consideration. The results of the computer codes show that, within the assumptions of the study, the economic efficiency is more favorable for the tilt rotor aircraft than for the compound helicopter for the majority of the missions considered. Furthermore, it is shown that the economic potential of the tilt rotor is very substantial and justifies further studies in Europe. Author

#### A89-48766#

##### COMPARISON OF EXPERIMENTAL AND NUMERICAL RESULTS FOR TRANSIENT ELECTROMAGNETIC FIELDS INDUCED ON A SCALE MODEL AIRCRAFT BY CURRENT INJECTION TECHNIQUE

J. GRANDO, G. LABAUNE, J. C. ALLIOT, F. ISSAC, and A. DELANNOY (ONERA, Chatillon-sous-Bagneux, France) (IEEE, International Symposium and URSI, Radio Science Meeting, San Jose, CA, June 26-30, 1989) ONERA, TP no. 1989-86, 1989, 5 p. (ONERA, TP NO. 1989-86)

Transient electromagnetic fields induced on a 1/10-scale model of the Transall C160 aircraft were measured using D-dot and B-dot sensors and compared to numerical simulation results obtained with a time-domain finite-difference method for solving Maxwell's differential curl equations in a bounded three-dimensional space. Measurements are presented for two experimental configurations of current injection: nose to tail and nose to left wing. Experimental results for a typical aircraft configuration agreed well with theoretical predictions with respect to frequency and amplitude. R.R.

#### A89-48833

##### MATHEMATICAL MODEL IDENTIFICATION FOR FLIGHT SIMULATION, BASED ON FLIGHT AND TAXI TESTS

M. BAARSPUL, J. A. MULDER (Delft, Technische Universiteit, Netherlands), A. M. H. NIEUWPOORT, and J. H. BREEMAN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 72-96. refs

The mathematical model of a Cessna Citation 500 aircraft based on a priori models of aerodynamics, engines, mass properties, flight controls and landing gear has been compared with a data base compiled from flight test program results obtained by an instrumented aircraft of this type. Pilot-in-the-loop real-time flight simulations were conducted using a moving-base visual flight simulator for pilot evaluations of both the a priori and composite mathematical models of the Citation 500. A proof-of-match test was created, using separate flight-test maneuvers, on the basis of whose results it has been concluded that aircraft characteristics are satisfactorily simulated. O.C.

#### A89-48838

##### THE TUCANO FLIGHT SIMULATOR

J. TICKLE (Ferranti Computer Systems, Ltd., Bracknell, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 143-154.

The Tucano flight simulator project is currently in the early stages of system definition, subcontracting planning, software design, etc. Cockpit instruments will be facsimiles of the actual ones; the audio system will employ digital techniques to include such effects as the full variety of aircraft noises, as well as navigation system audible tones and flight warning tones. A full simulation of the Tucano navigation system will be provided. Cockpit motion will be furnished by a hydraulically powered, servocontrolled supporting platform. The out-of-cockpit visual system will encompass image-generation and image-display subsystems. Two instructor stations will be provided for simulator control. A distributed computer system will be the basis of all data processing. O.C.

A89-48849\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

##### FLIGHT TESTS CONFIRM X-29 TECHNOLOGIES

JOHN W. HICKS (NASA, Ames Research Center, Moffett Field, CA) and NEIL W. MATHENY Exxon Air World, vol. 41, no. 2, 1989, p. 18-21. refs

Results of test flights of the X-29A which confirmed the viability of the aircraft design and obtained good agreement with preflight predictions are presented. In addition to a forward-swept wing, the features to be evaluated on the X-29 demonstrator were: a digital fly-by-wire flight control, a close-coupled wing-canard configuration, an aeroelastically tailored composite wing skin and a three-surface pitch control configuration. The X-29A advanced technology demonstrator is a single-seat, fighter-type aircraft, best known for its forward-swept wing with a thin supercritical airfoil. The key objectives in developing the technologies incorporated into the X-29A design included establishing new airframe-design freedoms and options, as well as demonstrating that adequate levels of dynamic stability can be achieved by controlling an unstable airframe with a close-coupled canard, symmetric flap, and strake-flap combination. The X-29A aircraft and its related systems performed well and are now in a flight research phase. C.E.

#### A89-48922

##### THE MATHEMATICAL TECHNIQUES IN THE POLET APPLICATIONS-PROGRAM PACKAGE [MATEMATICHESKAIA TEKHNLOGIJA PAKETA PRIKLADNYKH PROGRAMM 'POLET']

ANATOLII N. PANCHENKOV, IURII F. ORLOV, ROMAS IU. SHLAUSTAS, G. I. ANTOSHKINA, and M. N. BORISIUK Novosibirsk, Izdatel'stvo Nauka, 1988, 232 p. In Russian. refs

The mathematical techniques in the POLET package, intended for the optimal design of flight vehicles, are described. The optimal

design algorithms are based on mathematical models and hydrodynamic and aerodynamic methods. The POLET scheme was developed on the basis of the elaboration and algorithmization of asymptotic methods. Results from quadrupole wing theory are presented by way of illustration. K.K.

A89-48946

**AERODYNAMICS AND FLIGHT CHARACTERISTICS OF HELICOPTERS [AERODINAMIKA I LETNYE KHARAKTERISTIKI VERTOLETOV]**

ALEKSANDR I. AKIMOV Moscow, Izdatel'stvo Mashinostroenie, 1988, 144 p. In Russian. refs

The book is concerned with the theoretical principles and practical methods of determining, during the flight, the cruising and takeoff and landing characteristics of helicopters as well as their fuel and transport efficiency and adjusting these characteristics to any specified conditions. The discussion covers the similarity of helicopter flight regimes, determination and adjustment of thrust and velocity characteristics, determination of flight range and duration, and the aerodynamics of helicopters. V.L.

A89-48948#

**THE X-31 - HIGH PERFORMANCE AT LOW COST**

SIDNEY A. POWERS and HARVEY G. SCHELLENGER (Rockwell International Corp., El Segundo, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2122)

The X-31 program is unique in that its purpose is the demonstration of the tactical utility of enhanced fighter maneuverability rather than the generation of in-flight technical data. The genesis of the X-31 vehicle is briefly discussed. The design criteria are presented, portions of the design effort and the impacts of the low cost requirement are described, and the end result is quantified. The aerodynamics of this vehicle are described, as are some of the interesting aerodynamic problems and their solutions. Author

A89-49087#

**OPTIMIZATION OF AIRCRAFT CRUISE PERFORMANCE**

K. D. BILIMORIA (Arizona State University, Tempe) and M. L. SHEPARD IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 338-347. refs (AIAA PAPER 89-3386)

The problem of optimizing aircraft cruise performance is investigated by utilizing a dynamic model with the range and aircraft weight as state variables. The cruise trajectories considered are (1) constant altitude, variable velocity; (2) constant velocity, variable altitude; and (3) variable altitude and velocity. Computations for a medium-haul aircraft revealed the structure of cruise trajectories characterized by a time-fuel trade off parameter. Author

A89-49088#

**AN ALGORITHM FOR IN-FLIGHT SYNTHESIS OF MINIMUM-FUEL CRUISE TRAJECTORIES WITH FIXED ARRIVAL TIME**

H. G. VISSER (Delft, Technische Universiteit, Netherlands) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 348-358. refs (AIAA PAPER 89-3387)

This paper documents the derivation and evaluation of an automatic flight trajectory synthesis algorithm which generates both time-free DOC-optimal and time-fixed fuel-optimal cruise trajectories for flight-management system applications. The algorithm is based on a regularly perturbed optimal control formulation of cruise at constant altitude. A nominal reduced-order model, featuring a U.S. Standard atmosphere and no winds-aloft, is used as a baseline in the present study. Complicating effects such as winds-aloft, off-nominal ambient temperatures, engine losses due to power

extraction and bleedair, etc., are then embedded in the dynamic model using a regular perturbation approach. Author

A89-49103#

**THE FLYING WIND TUNNEL**

R. B. NORRIS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH), S. W. PARIS (Boeing Aerospace and Electronics, Seattle, WA), and E. T. WHITE (GE Aircraft Engines, Cincinnati, OH) AIAA, Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989. 9 p. refs (AIAA PAPER 89-3378)

This paper summarizes the conceptual design of a research vehicle capable of demonstrating hypervelocity airbreathing propulsion and obtaining aerodynamic and aerothermodynamic flight data at hypersonic Mach numbers up to Mach 16. The demonstrator and a modified solid rocket booster system (1 or 2 stages), are air launched from a B-52 aircraft and boosted to speeds ranging from Mach 12 to Mach 16 to test experimental airbreathing engines such as an integrated scramjet. Author

A89-49104#

**A LOCAL CURVE AND SURFACE SCHEME FOR AIRCRAFT GEOMETRIC MODELING**

MINGYAN GAO (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, July 1989, p. 249-256. In Chinese, with abstract in English. refs

The multiknot Hermite splines proposed by Qi and Zhou (1983) are applied to CAD/CAM modeling of aircraft surfaces, extending the Boolean-sum-operator approach of Gao (1986). The basic function of the spline is derived; the cubic formulation of the function is obtained in matrix form; and matrix expressions of the multiknot Hermite curve and surface are established, permitting local modification to form the desired shape in the CAD/CAM process. In sample computations with an interactive design program based on these splines, a savings of 30 percent in CPU time and significant reductions in memory requirements are demonstrated. T.K.

A89-49401#

**UNMANNED HIGH ALTITUDE LONG-ENDURANCE AIRCRAFT**

CHARLES F. PATTERSON (USAF, Wright Research Development Center, Wright-Patterson AFB, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. (AIAA PAPER 89-2011)

A conceptual design study was conducted in-house by the Air Force Wright Research and Development Center to identify promising designs and technologies for efficient high-altitude, long-endurance unmanned aircraft. The designs were driven by the payload (size, weight, and power), payload/aircraft interference considerations, and the desired patrol times. Technology was pushed in the areas of structures, flight controls, payloads, propulsion, airfoil aerodynamics, and aircraft configuration, in order to achieve efficient conceptual designs. Twin-fuselage aircraft, hydrogen-fueled propulsion systems, advanced graphite composite structures, advanced payloads, and advanced airfoils are particularly attractive. Author

A89-49402#

**SPECIAL OPERATIONS FORCE (SOF) TRANSPORT DESIGN STUDIES**

WILLIAM IBINSON and GERALD SWIFT (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2012)

A mission-definition/configurational feature study has been conducted to assess the technology development requirements of a small transport aircraft capable of fulfilling prospective Special Operations Force missions similar to the unsuccessful Iran hostage rescue attempt in 1980. A 10-12 man troop carriage capability, as well as the option to airlift a High Mobility Multipurpose Wheeled

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Vehicle, are sought. The configuration deemed most suitable is that of a 'convertiplane' whose four turbofan engines' low pressure turbine spools can be disengaged from their cruising flight fan drive to power deployable, wingtip nacelle-stowed tilt-rotors during VTOL operations. O.C.

**A89-49403#**

### **HIGH ALTITUDE LONG ENDURANCE (HALE) RPV**

NORMAN C. BAULLINGER and VICTOR R. PAGE (Boeing Co., Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. (AIAA PAPER 89-2014)

This paper addresses development of an unmanned aircraft concept and identifies the necessary technologies to perform a mission consisting of carrying a 2000-lb payload at altitudes greater than 60,000 ft for a period of 100 hr or more. The design, and operational considerations of high-altitude-long-endurance aircraft are considered. Four aircraft were conceptualized, which led to a point-of-departure concept using current technology. Sizing sensitivities and the impact of advanced technology and mission requirements on loiter time and aircraft takeoff gross weight are presented. High leverage technologies identified were propulsion, lightweight structures, and payload. Major reliability drivers were propulsion and avionics. Major configuration drivers included sensor field-of-view, runway widths, and logistic concepts. The aircraft size was very sensitive to mission and design rules. Author

**A89-49410#**

### **MD-90 TRANSPORT AIRCRAFT DESIGN**

P. A. HENNE (Douglas Aircraft Co., Long Beach, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 13 p. refs (AIAA PAPER 89-2023)

The current design status and the technical development of the MD-90 transport aircraft family are discussed, with special consideration given to the ultrahigh-bypass (UHB) Technology Readiness Program for integrating the UHB engine with the current MD-80 airframe. The program provides the basis for launching the detailed design and development of UHB-powered versions of the MD-90 family of aircraft, which can provide remarkable increases in fuel efficiency and relatively low noise levels. Alternative MD-90 configurations, MD-91V and MD-92V, powered by the advanced turbofan (V2500) engine were also developed. If the price of fuel will remain low, the MD-91V and the MD-92V will provide viable choices with lower technical risk for the airline customer. I.S.

**A89-49411#**

### **CREW ESCAPE SYSTEM DESIGN FOR HYPERSONIC VEHICLES**

ARUN K. TRIKHA and THOMAS R. CREIGHTON (Boeing Co., Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p. (AIAA PAPER 89-2025)

The very high speed and possible transatmospheric capability of future hypersonic vehicles impose design requirements on the crew escape systems, which are beyond the capability of the available ejection seats and past capsule designs. This paper discusses the various design issues for hypersonic escape systems. It is shown that design of low-weight heat shields, possibly using ablative materials, will be necessary to keep the weight penalty of a hypersonic escape system at an acceptable level. Author

**A89-49419\*#** National Aeronautics and Space Administration, Washington, DC.

### **US/UK ADVANCED SHORT TAKEOFF AND VERTICAL LANDING PROGRAM (ASTOVL)**

J. LEVINE (NASA, Washington, DC) and MALCOLM INGLIS (Royal Aerospace Establishment, Pyestock, England) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference,

Seattle, WA, July 31-Aug. 2, 1989. 16 p.

(AIAA PAPER 89-2039)

Both the U.S. and the UK have substantial technology bases from past and current R and D programs, a common background of service experience and, potentially, much common interest in the future use of advanced STOVL combat aircraft. Equally interested in the operational advantages of the short takeoff and vertical landing capability of combat aircraft, combined with supersonic and high agility performance, the U.S. and the UK have agreed to collaborate on ASTOVL research underwritten by a Memorandum of Understanding (MOU) (1986) between the two governments. The paper describes the aims and provisions of the MOU, gives the results of studies, illustrates the technology development underway, and outlines the future ASTOVL technology program. Particular attention is given to concept studies on advanced vectored thrust, the ejector augmentor, the hybrid tandem fan, and the remote augmented lift system. C.E.

**A89-49424#**

### **EVALUATION OF ADD-ON DRAG REDUCTION DEVICES FOR LIGHT AIRCRAFT**

HUBERT C. SMITH (Pennsylvania State University, University Park) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p. (AIAA PAPER 89-2050)

A Cherokee Arrow II light aircraft was flight tested after its incorporation of commercially available drag-reduction devices encompassing aileron-gap seals, flap-gap seals, flap-hinge fairings, inboard wheel well fairings, and fuel tank attach-screw fairings. The results obtained indicated that, with all devices installed, the parasite drag coefficient of the aircraft was reduced by about 7 percent, which represented a 2.5-percent increase in maximum speed, a 4.3-percent increase in maximum rate-of-climb, and a 3.7-percent increase in maximum altitude. O.C.

**A89-49430#**

### **SPREADSHEET METHODS FOR AIRCRAFT DESIGN**

ANTHONY P. HAYS (Lockheed Aeronautical Systems Co., Burbank, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs (AIAA PAPER 89-2059)

This paper describes the suggested layout for some spreadsheets to determine the following: takeoff gross weight to perform a required mission, thrust/weight ratio and wing loading to meet performance requirements, characteristics of the atmosphere, drag buildup, weight and balance, and horizontal tail sizing. The spreadsheets are based on methods in textbooks commonly used in teaching aircraft design. Author

**A89-49435\*#** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

### **NASA ROTORCRAFT TECHNOLOGY FOR THE 21ST CENTURY**

JAMES A. ALBERS (NASA, Ames Research Center, Moffett Field, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 23 p. refs (AIAA PAPER 89-2066)

Current and planned rotorcraft technology-related research at NASA's Ames, Lewis, and Langley research centers is discussed with a view to the fruits of these efforts beyond the year 2000. Examples of promising technologies are higher-harmonic and dynamic rotor controls, advanced structural composites, aerodynamics and acoustics simulation models for design predictions, automated flight controls, and high-reliability rotor drivetrains. The overall payoff from an integration of these technologies will allow safe automated flying in all weather conditions, as well as precision-hover and exceptionally low noise and vibration levels. O.C.

A89-49436#

**THE DESIGN CHALLENGE OF APPLYING TILTROTOR TECHNOLOGY TO THE CIVIL MISSION**

JOHN F. WARD (Ward Associates, Easton, MD) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2067)

The paper addresses the challenges the designer must face in developing a viable civil tiltrotor. The issue is one of efficiently applying available technology to create an aircraft capable of safe, reliable, all-weather, scheduled commercial operations at urban vertiports and at high density airports. This challenge to increase air transportation capacity, while minimizing the impact on the surrounding urban community, will require the design of safe tiltrotor aircraft with true VTOL capability. The key design requirements are discussed with emphasis on aircraft propulsion, flight path management, guidance systems, and terminal area procedures.

Author

A89-49438\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**ON THE THRESHOLD - THE OUTLOOK FOR SUPERSONIC AND HYPERSONIC AIRCRAFT**

ROY V. HARRIS, JR. (NASA, Langley Research Center, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2071)

A development history and current development status evaluation is presented with a view to the prospective viability of supersonic, hypersonic, and transatmospheric vehicle R&D efforts. It is stressed that such high-speed vehicles will not supplant the current fleet of subsonic aircraft, but simply address the growing need for very long range commercial and military missions. Mach 2-3 airliners could be developed by the year 2000; Mach 5-6 military reconnaissance aircraft could be operational soon after. Transatmospheric, mixed airbreathing/rocket propulsion single-stage vehicles capable of orbital insertion will require several years of additional development beyond hypersonic ones to become operational. O.C.

A89-49442\*# Planning Research Corp., Hampton, VA.

**AIRCRAFT DESIGN FOR MISSION PERFORMANCE USING NON-LINEAR MULTIOBJECTIVE OPTIMIZATION METHODS**

AUGUSTINE R. DOVI and GREGORY A. WRENN (Planning Research Corp., Aerospace Technologies Div., Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 13 p. refs (Contract NAS1-18000) (AIAA PAPER 89-2078)

A new technique which converts a constrained optimization problem to an unconstrained one where conflicting figures of merit may be simultaneously considered has been combined with a complex mission analysis system. The method is compared with existing single and multiobjective optimization methods. A primary benefit from this new method for multiobjective optimization is the elimination of separate optimizations for each objective, which is required by some optimization methods. A typical wide body transport aircraft is used for the comparative studies. Author

A89-49444#

**THE RAE COMBAT AIRCRAFT MULTI-VARIATE OPTIMISATION METHOD**

J. S. SMITH and C. A. LEE (Royal Aerospace Establishment, Farnborough, England) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p. (AIAA PAPER 89-2080)

The present multivariate optimization method for the synthesis and refinement of combat aircraft configurations encompasses geometric and aerodynamic synthesis and mass-estimation routines that are linked to a constrained optimization program. Tradeoff studies thus conducted can examine the effects of design-

requirement changes; the illustrative applications presented give attention to variations of engine bypass ratio and wing aspect ratio for configurations that have been optimized for a representative intercept mission and typical point performance requirements. Consistent families of optimized configurations are generated by the method. O.C.

A89-49447#

**DIGITAL MOCKUP**

MICHAEL A. RICH (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p. (AIAA PAPER 89-2086)

The basic mock-up functions of the engineering design and verification for a commercial aircraft, the manufacturing support, and the control of mockup data are discussed together with methods for a digital mockup. It is shown that the use of digital mock-ups can eliminate the need of physical mock-ups on sections of the aircraft. Based on results from several small-scale digital mock-up activities, it is shown that significant cost savings can be achieved by reducing the flow time during the integrated design/build process. The inaccuracies of the CATIA CAD/CAM system's modeling capabilities for complex parts are demonstrated and the need for model-construction standards is emphasized. I.S.

A89-49458#

**B747-400 AIRCRAFT CONDITION MONITORING SYSTEM - A CONSISTENT STEP FORWARD BASED ON THE PROVEN A310 CONCEPT**

ROLF SCHOEDDERT (Deutsche Lufthansa AG, Hamburg, Federal Republic of Germany) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. (AIAA PAPER 89-2100)

At the beginning of the 1980s, a new and more comprehensive passenger aircraft engine monitoring concept was introduced. The application and economic aspects of this concept are reviewed based on five years of operational experience with the combined Airbus A310/A300-600 fleet. The lessons learned from the use of integrated condition monitoring systems are summarized, and the application of the concept to the B747-400 ACMS design is addressed. C.D.

A89-49463#

**FATIGUE LIFE DETERMINATION FROM SERVICE EXPERIENCE**

M. A. MORALES (Aerostructures, Inc., Arlington, VA) and T. G. HU (Lockheed Corp., Houston, TX) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. (AIAA PAPER 89-2105)

A methodology for estimating the fatigue life of aircraft in a fleet based on service experience information has been developed. This methodology accounts for the differences in flight hours and usage experienced by individual airplanes in the fleet. The approach is based on probability theory and concentrates on a particular critical location in the airplane. The results yield the probability of failure for each aircraft in the fleet and the most probable number of flight hours for which these aircraft expect a failure to occur. Three different methods for calculating the probability of failure were evaluated. The samples studied consist of several groups of an aging Navy attack aircraft fleet. Comparisons of the results and execution times from the different probability analyses are presented. Author

A89-49465# Notre Dame Univ., IN.

**DESIGN OF UNMANNED FLIGHT VEHICLE SYSTEMS FOR AERODYNAMIC DATA ACQUISITION**

W. HOWARD, D. JENSEN, and S. M. BATILL (Notre Dame, University, IN) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989.



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11 p. Research supported by NASA and Universities Space Research Association. refs  
(AIAA PAPER 89-2110)

Design studies were conducted in order to develop flight vehicle concepts for remotely piloted vehicles intended for aerodynamic data acquisition with particular emphasis on the low Reynolds number flight regime. Five different concepts were developed as part of the senior level Aerospace Systems Design course at the University of Notre Dame. The systems were designed to provide surface pressure and component force measurements on specially instrumented lifting surface test specimens which were to be carried aloft by a base flight vehicle. The project included the fabrication of subscale remotely piloted technology demonstrators to validate the base vehicle flight worthiness. Author

**A89-49466#**  
**PRELIMINARY DESIGN OF A FAMILY OF CLOSE AIR SUPPORT AIRCRAFT**

JEFFREY J. TUSCHHOFF (Kansas, University, Lawrence) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. refs  
(AIAA PAPER 89-2111)

A family of three close air support aircraft is presented. These aircraft are designed with commonality as the main design objective to reduce the life cycle cost. The aircraft are low wing, twin-boom, pusher turboprop configurations. The amount of information displayed to the pilot was reduced to a minimum to greatly simplify the cockpit. The aircraft met the mission specifications and the performance and cost characteristics compared well with other CAS aircraft. The concept of a family of CAS aircraft seems viable after preliminary design. Author

**A89-49467#**  
**SUPERSONIC STOVL CONCEPTUAL DESIGN OF A FIGHTER/ATTACK AIRCRAFT**

DAVID M. BROWN (Northrop Corp., Hawthorne, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p.  
(AIAA PAPER 89-2112)

This paper outlines the development of a conceptual design for a remote augmented lift system (RALS)-powered supersonic short takeoff and vertical landing (STOVL) aircraft. Some of the salient features of the design and the constraints imposed by performance and control considerations are presented in detail. It is concluded that a viable supersonic STOVL aircraft can be developed around the RALS concept. Author

**A89-49469#**  
**ADVANCED V/STOL ATTACK AIRCRAFT DESIGN/OPERATIONS TRADE-OFF**

JOHN J. SCHNEIDER (Boeing Helicopters, Philadelphia, PA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 14 p.  
(AIAA PAPER 89-2116)

This paper discusses a number of candidate high-speed rotorcraft systems and introduces tiltrotor and folding tiltrotor concepts with their technology options that can provide very high-speed VSTOL/STOVL attack aircraft configurations for the future. These aircraft feature canard arrangements, forward swept wings, swept rotor blades, low bypass convertible engines, and the other technologies required to advance the state-of-the-art of VSTOL/STOVL attack aircraft having the desirable 'Soft-Footprint' characteristics. Author

**A89-49470#**  
**TOMCAT-21, EFFECTIVENESS AND AFFORDABILITY**

J. RAHA (Grumman Corp., Bethpage, NY) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p.  
(AIAA PAPER 89-2120)

The Tomcat-21 will be the 21st-century evolution of the F-14 Tomcat, designed to enhance the F-14's anti-air warfare (AAW) mission and to add all weather antisurface warfare (ASUW) missions.

This will be accomplished with effectiveness broadly equaling Next Generation Naval Fighter goals, at lower cost and risk. Tomcat-21 will build on the current F-14 with additional payload/range for both AAW and ASUW; improved sensors and displays; and better aerodynamic high lift systems. Affordability in maintaining force levels is assured by minimizing changes to the airframe, and capitalizing on existing F-14 assets. Author

**A89-49471#**  
**THE EUROPEAN FIGHTER AIRCRAFT DESIGN**

P. WOELK (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p.  
(AIAA PAPER 89-2123)

The European Fighter Aircraft (EFA) will be of twin-turbofan single-seat canard-delta planform configuration, and will have air superiority as its primary role, with air-to-ground missions as a secondary alternative. EFA will be powered by an advanced low-bypass augmented turbofan of 10:1 thrust/weight ratio and an overall compression ratio of 25:1. An account is given of the apportionment of manufacturing responsibilities among the industrial firms of the four countries constituting the EFA consortium, namely Italy, West Germany, the UK, and Spain. Advanced medium-range and short-range AAMs will be carried by EFA, as will a high-performance internal cannon. O.C.

**A89-49475\*#** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**INTEGRATED AERODYNAMIC-STRUCTURAL DESIGN OF A TRANSPORT WING**

B. GROSSMAN, R. T. HAFTKA, P.-J. KAO, D. M. POLEN, M. RAIS-ROHANI (Virginia Polytechnic Institute and State University, Blacksburg), and J. SOBIESZCZANSKI-SOBIESKI (NASA, Langley Research Center, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. refs  
(Contract NSF DMC-86-15336; NAG1-603)  
(AIAA PAPER 89-2129)

The integrated aerodynamic-structural design of a subsonic transport wing for minimum weight subject to required range is formulated and solved. The problem requires large computational resources, and two methods are used to alleviate the computational burden. First, a modular sensitivity method that permits the usage of black-box disciplinary software packages, is used to reduce the cost of sensitivity derivatives. In particular, it is shown that derivatives of the aeroelastic response and divergence speed can be calculated without the costly computation of derivatives of aerodynamic influence coefficient and structural stiffness matrices. A sequential approximate optimization is used to further reduce computational cost. The optimization procedure is shown to require a relatively small number of analysis and sensitivity calculations. Author

**A89-49478\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**INTEGRATED MULTIDISCIPLINARY DESIGN OPTIMIZATION OF ROTORCRAFT**

HOWARD M. ADELMAN (NASA, Langley Research Center, Hampton, VA) and WAYNE R. MANTAY (NASA, Langley Research Center; U.S. Army, Aerostructures Directorate, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs  
(AIAA PAPER 89-2132)

The NASA/Army research plan for developing the logic elements for helicopter rotor design optimization by integrating appropriate disciplines and accounting for important interactions among the disciplines is discussed. The paper describes the optimization formulation in terms of the objective function, design variables, and constraints. The analysis aspects are discussed, and an initial effort at defining the interdisciplinary coupling is summarized. Results are presented on the achievements made in the rotor aerodynamic performance optimization for minimum hover

horsepower, rotor dynamic optimization for vibration reduction, rotor structural optimization for minimum weight, and integrated aerodynamic load/dynamics optimization for minimum vibration and weight. I.S.

**A89-49481#**  
**THE IMPACT OF IHPTET ON THE ENGINE/AIRCRAFT SYSTEM**

PHILIP R. VIARS (GE Aircraft Engines, Cincinnati, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. (AIAA PAPER 89-2137)

The goal of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative is to double propulsion performance. This goal is expected to be achieved through innovative designs and advanced cycles achieving higher cycle temperatures through the use of advanced materials. The newer, more powerful cores are expected to provide the potential for significant engine weight reduction at the same specific thrust (same fan pressure ratio at a higher bypass ratio) or higher specific thrust with a moderate engine weight reduction (higher fan pressure ratio at the same bypass ratio). The aircraft mission requirements will determine the appropriate combination to achieve minimum takeoff gross weight. Author

**A89-49483#**  
**APPLICATION OF SYNTHESIZED TACTICS TO THE DESIGN AND EVALUATION OF VTOL, V/STOL AND STOVL AIRCRAFT**

DAVID L. GREEN and HAROLD ANDREWS (Starmark Corp., Arlington, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 8 p. (AIAA PAPER 89-2143)

Advanced flight simulation capabilities can be used in conjunction with commensurately powerful CAD techniques to conduct aircrew evaluations of conceptual aircraft configurations in simulated combat. Attention is presently given to the cases of prospective VTOL, V/STOL, and STOVL aircraft, using these simulation/design techniques to evaluate their tactically significant and often radically different functional capabilities, as well as allowing the pilots of the simulated threat aircraft to react to the novel designs through adjustment of their own tactical repertoire. The operational requirements and design features of a tilt-rotor VTOL aircraft have been defined in this fashion. O.C.

**A89-49488#**  
**PRELIMINARY DESIGN OF CIVIL TRANSPORT AIRCRAFT**

CHRISTIANE MICHAUT, DANIEL CAVALLI, HUU-THANH HUYNH, and HUNG LE THUY (ONERA, Chatillon-sous-Bagneux, France) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. refs (AIAA PAPER 89-2152; ONERA, TP NO. 1989-98)

An iterative optimization technique which is based on the generalized projected gradient method has been used to quantify the impact of new technologies on civil transport aircraft. The present numerical code determines the aircraft parameters (including wing planform, weights, flight profile) which minimize a selected criteria (such as direct operating cost), while fulfilling such mission requirements as range, take-off field length, and approach speed. Results have been obtained using the code for the case of the design of a current medium range aircraft. R.R.

**A89-49678#**  
**VALIDATION OF COMPUTATIONAL AERODYNAMICS APPLIED TO GENERAL AVIATION CONFIGURATIONS**

NEAL J. PFEIFFER and TOM D. ZICKUHR (Beech Aircraft Corp., Wichita, KS) AIAA, Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989. 11 p. (AIAA PAPER 89-2169)

The application of the VSAERO panel method aerodynamics analysis technique to the Beech Starship and the Beech 1900D general aviation aircraft is examined. Comparisons are made between results computed by the method and experimental findings

made in wind tunnels. It is concluded that, with the panel method, spanload distributions can be well represented using the panel method for complex configurations such as those found with canards and T-tails. The force and moment results are useful for checking modifications to baseline configurations. Control deflections as well as aircraft orientation can be modeled, and when these are combined, the aircraft can be trimmed for a specific flight condition. C.D.

**A89-50068\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**WING-FLUTTER CALCULATIONS WITH THE CAP-TSD UNSTEADY TRANSONIC SMALL-DISTURBANCE PROGRAM**

ROBERT M. BENNETT, JOHN T. BATINA, and HERBERT J. CUNNINGHAM (NASA, Langley Research Center, Hampton, VA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 1085-1095) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 876-882. Previously cited in issue 12, p. 1826, Accession no. A88-32288. refs

**A89-50170**  
**OPERATIONAL ADVANTAGES AND POWER EFFICIENCY OF THE FENESTRON AS COMPARED TO A CONVENTIONAL TAIL ROTOR**

A. VUILLET (Aerospatiale, Division Helicopteres, Marignane, France) Vertiflite (ISSN 0042-4455), vol. 35, July-Aug. 1989, p. 24-29.

This paper discusses the design and the operational advantages of the fenestron tail rotor for vertical flight aircraft. Compared to conventional tail rotors, the fenestron design offers advantages of safety in flight and on the ground; improved rotor protection from sand, rain, snow, and ice; excellent yaw maneuverability; and higher noise attenuation and lower acoustic detectability. The fenestron can be designed for the same power efficiency as a conventional tail rotor in hover; in forward flight, at least 2 to 3 percent of total power can be saved. I.S.

**A89-50273**  
**FOKKER 100 FLIGHT DECK - DESIGNED FOR HIGH FREQUENCY OPERATIONS IN HIGH DENSITY ENVIRONMENTS**

RUDI DEN HERTOOG (Fokker Aircraft, Amsterdam, Netherlands) ICAO Bulletin (ISSN 0018-8778), vol. 44, Feb. 1989, p. 11-14.

The improvements that have resulted from the introduction of an advanced two-man flight deck on the Fokker 100 are discussed. It is shown how computerization, along with a fully integrated autopilot and autothrottle, should reduce cockpit workload and enhance flight safety. The use of early flight test results in the development of the flight deck is addressed, and the redundant flight management system is described. The incorporation of map presentation as an option is addressed, and future prospects for the system are considered. C.D.

**A89-50274**  
**EUROFAR - AN ADVANCED ROTORCRAFT PROGRAMME IS UNDER WAY**

J. ANDRES and J. RENAUD (Aerospatiale, Division Helicopteres, Paris, France) ICAO Bulletin (ISSN 0018-8778), vol. 44, Feb. 1989, p. 15-18.

The EUROFAR program, which involves the development by seven industrial partners of a European future advanced rotorcraft, is discussed. The limitations of the helicopter that are to be remedied by such a rotorcraft are described, and today's design trend is reviewed. The advantages of tilt-rotor aircraft are addressed, and the specific objectives for a preliminary 10-ton rotorcraft are presented. The EUROFAR program timetable is summarized. C.D.

**A89-50275**  
**AGV - A HYPERSONIC TRANSPORT AIRCRAFT**

JEAN CLAUDE PILON (Aerospatiale, Toulouse, France) ICAO Bulletin (ISSN 0018-8778), vol. 44, Feb. 1989, p. 23-27.

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

The concept of an Avion a Grande Vitesse (AGV), a 150-passenger hypersonic transport aircraft targeted for the year 2015, is discussed. The planned performance of the aircraft and preliminary parameters are examined. The uniqueness of the AGV approach and the AGV's aerodynamics and powerplant are addressed. The different types of fuel that the AGV might use and the tradeoffs involved are examined, and the AGV's structural needs are discussed. Market considerations are examined. C.D.

**A89-50361**

### **IMPROVED HELICOPTER ACCIDENT SAFETY USING FIBER COMPOSITE CONSTRUCTION [VERBESSERTE UNFALLSCHUTZ BEI HUBSCHRAUBERN DURCH FASERVERBUNDBAUWEISE]**

CHRISTOF KINDERVATER and HERBERT GEORGI (DLR, Institut fuer Bauweisen- und Konstruktionsforschung, Stuttgart, Federal Republic of Germany) DLR-Nachrichten (ISSN 0011-4901), June 1989, p. 14-18. In German.

The concept of helicopter crash safety is reviewed, and construction methods using fiber composite materials to enhance safety are examined. Different types of underbody structures to promote safety are described, and a comparison of Al construction and FVW construction is given. Analytic crash simulation is discussed. C.D.

**A89-50372**

### **PARAMETER STUDY OF FIGHTER AIRCRAFT CONFIGURATIONS USING A SIMPLE PERFORMANCE SYNTHESIS MODEL FOR THE OVERALL AIRFRAME-ENGINE SYSTEM [PARAMETERSTUDIEN AN KAMPFFLUGZEUGKONFIGURATIONEN MIT HILFE EINES EINFACHEN LEISTUNGSSYNTHESEMODELLS FUER DAS GESAMTSYSTEM FLUGWERK-TRIEBWERK]**

L. VON BONIN (DLR, Institut fuer Strukturmechanik, Brunswick, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, May-June 1989, p. 166-177. In German. refs

The paper describes a system model which permits technical assessment of the overall airframe/engine system for fast high-performance aircraft at the requirement documentation state. It also permits unit cost investigations by providing preliminary estimates of the weight of such aircraft. Typical flight performance data for combat aircraft and performance data for modern turbine engines are used to provide a direct analytical/numerical relationship between the drag characteristics and the thrust and fuel consumption behavior, the component weights, and the performance specifications of the requirement document. The aircraft flight performance synthesis and the performance of the engine installation are finally obtained from a mass balance which leads to the aircraft take-off weight. The computational results are derived by varying main design parameters of the wing unit and engine for, preferably, one of two basic aerodynamic configurations specified. Author

**A89-50801#**

### **V-22 OSPREY DEVELOPMENTAL STATUS**

STANLEY MARTIN (Bell Helicopter Textron, Fort Worth, TX) and RICHARD OSTLUND (Boeing Helicopters, Philadelphia, PA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. (AIAA PAPER 89-2113)

The development history and current status of the V-22 Osprey tilt-wing aircraft are presented, with emphasis on those advanced-technology elements of the configuration toward which the preliminary design program directed intensive risk-minimization efforts. Attention is given to the all-composite V-22 primary structure, whose flight-qualified assembly was arrived at through a step-by-step component buildup in structural testing. Features of the V-22 rotor drive system unique to a tilt-rotor configuration were also subjected to exceptionally rigorous qualification. O.C.

**A89-50802\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **A SUPERSONIC THROUGH-FLOW FAN ENGINE AIRFRAME INTEGRATION STUDY**

PAUL J. BARNHART (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs (Contract NAS3-25266) (AIAA PAPER 89-2140)

A study is undertaken to investigate the engine airframe integration effects for supersonic through-flow fan engines installed on a Mach 3.20 supersonic cruise vehicle. Six different supersonic through-flow fan engine installations covering the effects of engine size, nacelle contour, nacelle placement, and approximate bypass plume effects are presented. The different supersonic through-flow fan installations are compared with a conventional turbine bypass engine configuration on the same basic airframe. The supersonic through-flow fan engine integrations are shown to be comparable to the turbine bypass engine configuration on the basis of installed nacelle wave drag. The supersonic through-flow fan engine airframe integrated vehicles have superior aerodynamic performance on the basis of maximum lift-to-drag ratio than the turbine bypass engine installation over the entire operating Mach number range from 1.10 to 3.20. When approximate bypass plume modeling is included, the supersonic through-flow fan engine configuration shows even larger improvements over the turbine bypass engine configuration. Author

**A89-50816\*#** Boeing Helicopter Co., Philadelphia, PA.

### **A LOOK AT TOMORROW'S CIVIL TILTROTOR**

JOSEPH B. WILKERSON (Boeing Helicopters, Philadelphia, PA) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 26 p. Research sponsored by NASA, FAA, and DOD. refs (SAWE PAPER 1820)

The present evaluation of the development status of the tilt-rotor VTOL aircraft concept proceeds to identify a large civilian market potential for vehicles of this type, especially along high commuter traffic density urban corridors. A variant of the V-22 tilt-rotor is judged to be of sufficient size for this high-density passenger market in the near term, provided that the rotor-drive system undergoes suitable modifications for more reliable one-engine-inoperative emergency operation. New, larger-than-V-22 and least-cost-optimized civil tilt-rotors carrying as many as 75 passengers are under study, but will require the construction of 'vertiports' at strategically advantageous urban locations. O.C.

**A89-50818**

### **VTOL FLIGHT PERFORMANCE/WEIGHT AND BALANCE COMPUTER DEVELOPMENT**

A. BILLING (Horizons Technology, Inc., San Diego, CA) and JOHN G. SUTTON (United Technologies Corp., Sikorsky Aircraft Div., Stratford, CT) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 37 p. (SAWE PAPER 1824)

The development of VTOL performance/weight and balance computations devices is considered. The MH-53E helicopter missions, the development of the Electronic Flight Performance (EFP) computer, and the flight performance computer capability are described. The potential capabilities of next generation VTOL performance computer systems are discussed. Diagrams of various early load control devices, the MH-53E helicopter, the EFP computer, and mission profiles are provided. I.F.

**A89-50825**

### **FLIGHT CONTROL SYSTEM WEIGHT PREDICTION FOR MODERN FIGHTER/ATTACK AIRCRAFT**

STEPHEN L. ELMORE (LTV Corp., LTV Aircraft Products Group, Dallas, TX) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 25 p. (SAWE PAPER 1839)

The development of updated flight controls weight prediction methods to account for new flight control technologies is discussed.

Recently developed flight control technologies such as the control augmentation system, the stability augmentation system, fly by wire, servo actuators, fly by light, high pressure hydraulic systems, and all-electric aircraft are reviewed. The lack of consistent AN coding (MIL-STD-1374A) and the advent of multifunctional coding are examined in relation to weight estimation equations. The process of deriving revised flight control systems weight estimation equations for fighter/attack aircraft is outlined. R.B.

**A89-50826****LOADABILITY CONSIDERATIONS IN PRELIMINARY DESIGN**

PAUL W. SCOTT (Douglas Aircraft Co., Long Beach, CA) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 20 p. refs  
(SAWE PAPER 1840)

The present analysis of the 'loadability' factor in military airlift aircraft, which is defined as flexibility in the accommodation of payloads without exceeding volume or center-of-gravity (CG) limitations, gives attention to the relationship of payload volume to average payload density, the payload CG range, and the location of the payload CG range, for currently operational and prospective airlifter designs. The greatest significance of the loadability parameter lies in its effect on the sizing of aircraft empennage; this effect is especially important in the case of VTOL aircraft, with their intrinsically more critical balance considerations. O.C.

**A89-50827****EXTENDING DERIVATIVE AIRPLANE CAPABILITIES - WEIGHT AND BALANCE CONSIDERATIONS**

BILL WILLIAMS (Boeing Commercial Airplanes, Seattle, WA) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 13 p.  
(SAWE PAPER 1845)

The loadability limits associated with defining a center of gravity range for a typical wing-engine aircraft are examined. A constant moment diagram is utilized to evaluate the loadability of the aircraft. The methods employed to determine the available center of gravity range for the aircraft configuration and to create a derivative are described. The effects of common configuration changes, such as gross weight increase, body stretches, and engine modifications, on the center of gravity range, and the effect of loadability on the aircraft are analyzed. I.F.

**A89-50831****IMPACT OF ADVANCED MATERIALS/STRUCTURAL CONCEPTS ON FUTURE WEIGHT ESTIMATION**

STEVEN J. ZAIDEL (McDonnell Aircraft Co., Saint Louis, MO) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 21 p. refs  
(SAWE PAPER 1849)

The goals of the USAF Project Forecast II encompass materials and structural system advancements which could lead to a 50-percent airframe structural weight reduction, in military aircraft capable of Mach 2.5, by the year 2000. Efforts must accordingly be made to develop suitable methods for the evaluation of weight-related factors in novel aircraft configurations incorporating these technologies. Attention is presently given to a methodology based on factors which reflect subcomponent weight distribution, failure modes, material properties, and structural concepts. Superplastically formed/diffusion bonded metallic structures are typical of the advanced airframe concepts whose weight-estimation procedures are addressed. O.C.

**A89-50832****THE USE OF FIBER REINFORCED THERMOPLASTICS AS A PRIMARY STRUCTURE ON THE MCDONNELL DOUGLAS AH-64 APACHE HELICOPTER**

GRETCHEN S. THIERSTEIN and STEVE P. CHEN (McDonnell Douglas Helicopter Co., Mesa, AZ) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 15 p.  
(SAWE PAPER 1850)

By contrast with thermosetting polymer resins, thermoplastic polymers for advanced composite matrix applications exhibit high

toughness, possess unlimited shelf life, and can be reprocessed and spliced/combined to reduce scrap. Thermoplastics also require significantly shorter curing times than thermosets, leading to more efficient manufacturing of structures. Attention is presently given to the results of a study in which an AH-64 helicopter's metallic vertical stabilizer skin was replaced with one of AS-4 carbon fiber-reinforced PEEK semicrystalline thermoplastic. Press-consolidation proved to be a suitable processing method for laminates of this composite system. O.C.

**A89-51215#****STRUCTURAL PERFORMANCE OF RADOMES AT HIGH MACH NUMBERS**

C. R. LAMAR, D. W. PLONK, and S. C. NEEL (Georgia Institute of Technology, Atlanta) IN: Symposium on Electromagnetic Windows, 19th, Atlanta, GA, Sept. 7-9, 1988, Proceedings. Volume 1. Atlanta, GA, Georgia Institute of Technology, 1988, p. 65-73. refs

The thermal and pressure loads on axially symmetric shapes at high Mach numbers are determined from aerodynamic considerations. The effect of these loads on ceramic radomes is computed. A one-dimensional analytical solution for thermal stress is developed and compared to a two-dimensional finite element analysis. A comparison is also made between experimental results and theory. Problems with the analysis are discussed, and a suggested experimental method using laser heating is presented. Author

**A89-51221\*#** National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

**FLUTTER TESTING OF MODERN AIRCRAFT**

JEFF JOHNSON (NASA, Flight Research Center, Edwards, CA) AIAA Student Journal (ISSN 0001-1460), vol. 27, Spring 1989, p. 6-11.

Structural dynamicists avoid aircraft structural flutter through the use of flutter analyses, wind tunnel tests, ground-vibration tests, and flight flutter testing. FEM and unsteady aerodynamics models are often employed in analyses whose results' accuracies are verified by wind tunnel test results. Ground-vibration testing is used to ascertain an airframe's resonant modes of vibration and their associated frequencies and damping rates; these data are then compared to the FEM analysis results. Flutter wind tunnel testing serves the same purpose for unsteady aerodynamic analysis as ground vibration testing does for the vibration analysis. Finally, flight flutter testing ensures that no flutter is present at any point in the envelope. O.C.

**A89-51303\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**FLIGHT MEASURED DOWNWASH OF QSRA**

JOSEPH C. EPEL, DENNIS W. RIDDLE, and VICTOR C. STEVENS (NASA, Ames Research Center, Moffett Field, CA) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 164-167. Previously announced in STAR as N89-17593.

Several reports have been written on the performance of the Quiet Short-Haul Research Aircraft, which shows the advantages of upper-surface blowing or the propulsive-lift wing as it applies to lift, maneuverability, and short takeoff and landing. This high lift generation at low speeds results in substantial downwash, especially in the low-aft fuselage tail position. The high T-tail of the Quiet Short-Haul Research Aircraft minimizes the undesirable downwash effects from the propulsive-lift wing. Queries from Department of Defense agencies and industry for quantitative values prompted a series of flight-measured downwash tests at the high T-tail and the low aft fuselage position. The results are presented in a summarized format, showing downwash, Delta epsilon/Delta a, for both locations. As would be expected, downwash increases for increased power and USB flap settings. The downwash is greater in the low aft-fuselage position as compared to the high T-tail area. Author

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

**A89-51304#**

### **FEASIBILITY STUDY ON A LONG DURATION AIRPLANE AT HIGH ALTITUDE FOR THE COMMUNICATION RELAY PURPOSE**

KINGO TAKASAWA (National Aerospace Laboratory, Chofu, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 172-175. Research supported by the Science and Technology Agency. refs

A simple CAD program to treat the integrated effect of the aerodynamic performance, the propulsive power requirement and the structural weight penalty was composed to serve for the preliminary design of a microwave-powered aircraft. Contributions of selected parameters to the payload capability were investigated. A resultant aircraft computed by throwing a set of preferable parameters into it was compared with a baseline aircraft. Author

**A89-51352**

### **WHAT DRIVES UNIQUE CONFIGURATIONS**

JAN ROSKAM (Kansas, University, Lawrence) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 1-17. refs  
(SAE PAPER 881353)

The lines of conceptual development in aircraft design efforts which lead in the direction of eccentric and unique configurations in response to exceptionally severe and specialized performance requirements are presently illustrated. Attention is given to the historically noteworthy cases of 'flying wing' aircraft, such as the YB-49 bomber and Horten IX fighter, as well as the XP-55 and Kyushu Shinden canard configuration fighters that are the historical antecedents of such contemporary business aircraft as the Starship I and P-180 Avanti. Not only a single, extreme design requirement, but an unprecedented integration of a variety of disparate design requirements, can lead aerodynamicists to radical configurations.

O.C.

### **A89-51353\* Douglas Aircraft Co., Inc., Long Beach, CA. AERODYNAMIC TECHNOLOGY OPPORTUNITIES FOR A HIGH-SPEED CIVIL TRANSPORT**

H. ROBERT WELGE (Douglas Aircraft Co., Long Beach, CA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 19-25. Research sponsored by McDonnell Douglas Corp. refs (Contract NAS1-18378)  
(SAE PAPER 881354)

A NASA-sponsored study has undertaken the definition of SST and HST configurations resulting in substantial reductions relative to current technology in takeoff gross weight, sonic boom overpressures, and airport-vicinity propulsion and aerodynamic noise. CFD methods have been applied to vehicle-shaping and laminar boundary layer flow area-maximizing configurational studies. Various planforms and active boundary-layer control methods are considered. Computer-managed wing control surface deflections are identified as substantial contributors to wing aerodynamic load and structural weight reduction, while correcting undesirable aerodynamic-pitching characteristics.

O.C.

**A89-51355\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **FIFTY YEARS OF LAMINAR FLOW FLIGHT TESTING**

R. D. WAGNER, D. V. MADDALON, D. W. BARTLETT (NASA, Langley Research Center, Hampton, VA), and F. S. COLLIER, JR. (High Technology Corp., Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 45-69. refs  
(SAE PAPER 881393)

Laminar flow flight experiments conducted over the past 50 years are reviewed. The emphasis is on flight testing conducted

under the NASA Laminar Flow Control Program, which has been directed towards the most challenging technology application, the high-subsonic-speed transport. The F111/TACT NLF Glove Flight Test, the F-14 Variable-Sweep Transition Flight Experiment, the 757 Wing-Noise Survey and NLF Glove Flight Test, the NASA Jetstar Leading-Edge Flight Test Program, and the recently initiated Hybrid Laminar-Flow-Control Flight Experiment are discussed.

Author

**A89-51361**

### **APPLICATION OF KTRAN TRANSONIC SMALL-DISTURBANCE CODE TO THE CHALLENGER BUSINESS JET CONFIGURATION WITH WINGLETS**

F. KAFYEKE, P. PIPERNI, and S. ROBIN IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 159-176. Research supported by DND of Canada. refs  
(SAE PAPER 881483)

A transonic small-disturbance code for the analysis of three-dimensional wing/body/pylon/store configurations (AGARD CP-412-8) has been extended to calculate flows around complete aircraft such as the Challenger executive jet. The program uses a modified transonic small-disturbance equation discretized in Cartesian and cylindrical coordinates and a grid embedding technique to capture flow details around specific components. The program is capable of representing Challenger-type wide-body fuselages, large-aspect-ratio supercritical wings, high-bypass turbofan engines, and canted winglets. Correlations with wind-tunnel and flight-test data demonstrate the capability of the method.

Author

**A89-51362**

### **A VSAERO ANALYSIS OF SEVERAL CANARD CONFIGURED AIRCRAFT**

DAVID LEDNICER IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988, Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 203-213. refs  
(SAE PAPER 881485)

This paper reports the results of an analysis of several canard configured aircraft using the VSAERO low-order panel method. Aircraft analyzed within include the Rutan Long EZ, Solitaire, VariViggen, VariViggen SP and Quickie homebuilt aircraft. The use of VSAERO in the development of the Rutan Voyager is also discussed. In all cases VSAERO models of the complete aircraft have been used to calculate the aerodynamic performance of the aircraft. Comparisons of these results with flight test data are included where data are available. Aerodynamic panelling programs such as VSAERO allow the determination of an aircraft's induced drag. To substantiate this methodology comparisons of results with the classical Prandtl-Munk theory and wind tunnel test results are also included. These comparisons validate the use of VSAERO in the prediction of induced drag. Further comparisons with flight test results for several aircraft are included.

Author

**N89-26835#** National Aerospace Lab., Tokyo (Japan). STOL Aircraft Project Group.

### **THE CONCEPTUAL DESIGN STUDY OF USB POWERED LIFT AIRCRAFTS IN FY 1986**

Jan. 1988 57 p In JAPANESE; ENGLISH summary (NAL-TR-958; ISSN-0389-4010) Avail: NTIS HC A04/MF A01

The possibility of applications to various types of transports of the overwhelming high lift capability inherent in the USB powered lift concept was investigated with the use of a computer aided design (CAD) program. Emphasis is placed on the application of USB technology to regional transports of both land based and amphibian types, because of their relatively high probability of realization relating to the 4th national comprehensive development plan. In addition to the CAD study, some relevant subjects such as examination of the predicted demand for regional air transportation, an evaluation of the engine cross shafting concept, an estimation of aerodynamic derivatives due to side-slip motion,

consideration of common aircraft structure for both land based and amphibian type aircraft, and a survey of advanced navigation systems were also studied. Author

**N89-26836** Department of the Air Force, Washington, DC.  
**HOSE REEL MONITOR FOR INFLIGHT REFUELING SYSTEM Patent**  
 TSUTOMU YAMAMOTO, inventor (to AF) 10 Jan. 1989 6 p  
 Filed 14 Jan. 1988  
 (AD-D014054; US-PATENT-4,796,838;  
 US-PATENT-APPL-SN-144885; US-PATENT-CLASS-244-135)  
 Avail: US Patent and Trademark Office CSCL 13/7

A bank of comparators is used to control a logic circuit which indicates proper system operation when measured hydraulic reel motor control pressures are within normal limits for the current airspeed after hose deployment. Also, before such deployment, simulated test signals are applied to the comparators to ensure proper operation of the comparators and logic circuitry. GRA

**N89-26837** Department of the Air Force, Washington, DC.  
**COMBINATION BOUNDARY LAYER CONTROL SYSTEM FOR HIGH ALTITUDE AIRCRAFT Patent**  
 GEORGE D. BREWER, inventor (to AF) and DAVID P. MARSHALL, inventor (to AF) 28 Feb. 1989 5 p Filed 12 Aug. 1987  
 (AD-D014075; US-PATENT-4,807,831;  
 US-PATENT-APPL-SN-084341; US-PATENT-CLASS-244-117)  
 Avail: US Patent and Trademark Office CSCL 13/7

This patent comprises a combination boundary layer control system that uses both suction and cryogenic wall cooling to reduce aircraft drag. The invention is particularly useful in circumstances where liquid hydrogen or other cryogenic fuels are used to operate the aircraft. In the preferred embodiment, a network of D-tube ducts are provided that are fluidly connected to a cryogenic fluid source. These cryogenic fluid ducts are selectively fed cryogenic fluid to reduce aircraft surface temperature and promote adhesion of boundary layer air to the aircraft. An air duct system is also provided to apply suction to the aircraft surface in order to remove the boundary layer at low altitude. The suction is applied by means of a multitude of minute holes in the aircraft skin which are fluidly connected to the air duct system. GRA

**N89-26836#** General Dynamics Corp., Fort Worth, TX.  
**ADVANCED DURABILITY ANALYSIS. VOLUME 2: ANALYTICAL PREDICTIONS, TEST RESULTS AND ANALYTICAL CORRELATIONS Final Report, Oct. 1984 - Feb. 1989**  
 S. D. MANNING and J. N. YANG (United Analysis, Inc., Vienna, VA.) 27 Feb. 1989 286 p  
 (Contract F33615-84-C-3208)  
 (AD-A207215; AFWAL-TR-86-3017-VOL-2) Avail: NTIS HC A13/MF A01 CSCL 01/3

Advanced durability analysis design tools have been developed for metallic aircraft structures. These tools can be used to evaluate durability design requirements for functional impairments due to: (1) excessive cracking, and (2) fuel leakage ligament breakage. The methodology accounts for the initial fatigue quality variation of structural details, the crack growth accumulation for a population of structural details under specified design conditions and structural properties. Step by step procedures are provided. This volume is limited to the analytical methods, technical aspects, concepts and philosophy for the durability analysis of metallic aircraft structures. The methodology reflects a probabilistic approach, a fracture mechanics philosophy and both deterministic and stochastic crack growth methods. It can be used to predict the probability of crack exceedance at any service time and/or the cumulative distribution of the time to reach any crack size. The methodology applies to the small crack size range associated with excessive cracking (e.g., less than 0.05') and to large through-the-thickness cracks (e.g., 0.5' to 0.75') associated with fuel leakage/ligament breakage. GRA

**N89-26839#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.

**AIRWORTHINESS AND FLIGHT CHARACTERISTICS EVALUATION OF THE EH-60A (QUICK FIX) HELICOPTER Final Report, 25 Nov. 1987 - 18 May 1988**

DAVID B. CRIPPS, DONALD L. UNDERWOOD, DAVID A. DOWNEY, GEORGE M. YAMAKAWA, CHARLES Q. CROWELL, and JOSEPH A. LYLE Oct. 1988 98 p  
 (AD-A207417; USAAEFA-87-07) Avail: NTIS HC A05/MF A01 CSCL 01/3

The U.S. Army Aviation Engineering Flight Activity conducted a limited Airworthiness and Flight Characteristics test of the EH-60A (Quick Fix) helicopter. During the test program, 49 flights were conducted for a total of 63.5 hours, of which 47.1 were productive. Initially the EH-60A was modified to the utility configuration where 22.3 productive hours were flown airspeed calibration, level flight performance, and vibration characteristics. All tests were performed at a Quick Fix mission center of gravity of approximately 361.9 fuselage station for both the utility and Quick Fix configuration. The Quick Fix configuration resulted in a 5.2 square feet increase in equivalent flat plate area which results in a 5 percent degradation in specific range at the recommended cruise airspeed, a 2 percent increase in fuel flow at the maximum endurance airspeed, and a 4 knot degradation in maximum level flight airspeed at sea level standard day conditions and mission gross weight (17,200 pound). The handling qualities of the Quick Fix configured EH-60A were essentially unchanged from the standard UH-60A helicopter. The clearance between the main rotor blades and direction finding dipole antennas during nose down slope landings was adequate. The absence of lower console lighting for the communication and navigation equipment was identified as a deficiency. GRA

**N89-26840#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.

**PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60A EXTERNAL FUEL SYSTEM Final Report, 21 May - 20 May 1988**

MICHAEL K. HERBST, MICHAEL A. GLEASON, PAUL LOSIER, and REGINALD C. MURRELL Dec. 1988 114 p  
 (AD-A207570; USAAEFA-87-04) Avail: NTIS HC A06/MF A01 CSCL 01/3

Testing was conducted to determine the effects of the installation of the External Fuel System (EFS) on the performance and handling qualities of the UH-60A helicopter. A total of 27 productive flight hours were flown at Edwards Air Force Base, California between 21 March and 20 May 1988. The evaluation did not reveal any problems that should preclude airworthiness qualification. The installation of the EFS with two 230-gallon tanks caused an increase in power required to hover in ground effect (10-foot wheel height) and out of ground effect of approximately 5 percent and 6 percent, respectively. The change in equivalent flat plate area in the EFS configuration with two 230-gallon tanks varied from 6.2 to 12.4 square feet when compared to the UH-60A in the normal utility configuration. The drag of the UH-60A in the EFS configuration with two 230-gallon tanks is significantly increased when the cargo doors and gunner windows are open. Three shortcomings and two Prime Item Development Specification noncompliances were identified during the handling qualities evaluation of the UH-60A in the EFS configuration. Two of the shortcomings have been noted during previous evaluations of the UH-60A in the normal utility configuration. Handling qualities were not significantly different than those of the UH-60A in the normal utility configuration. GRA

**N89-26841\*#** McDonnell-Douglas Corp., Long Beach, CA.  
**FEASIBILITY AND BENEFITS OF LAMINAR FLOW CONTROL ON SUPERSONIC CRUISE AIRPLANES**

A. G. POWELL, S. AGRAWAL, and T. R. LACEY Jul. 1989 121 p Prepared in cooperation with McDonnell Aircraft Co., Saint Louis, MO  
 (Contract NAS1-18037)  
 (NASA-CR-181817; NAS 1.26:181817) Avail: NTIS HC A06/MF A01 CSCL 01/3



## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

An evaluation was made of the applicability and benefits of laminar flow control (LFC) technology to supersonic cruise airplanes. Ancillary objectives were to identify the technical issues critical to supersonic LFC application, and to determine how those issues can be addressed through flight and wind-tunnel testing. Vehicle types studied include a Mach 2.2 supersonic transport configuration, a Mach 4.0 transport, and two Mach 2-class fighter concepts. Laminar flow control methodologies developed for subsonic and transonic wing laminarization were extended and applied. No intractable aerodynamic problems were found in applying LFC to airplanes of the Mach 2 class, even ones of large size. Improvements of 12 to 17 percent in lift-drag ratios were found. Several key technical issues, such as contamination avoidance and excrescence criteria were identified. Recommendations are made for their resolution. A need for an inverse supersonic wing design methodology is indicated. Author

**N89-26842\*#** Douglas Aircraft Co., Inc., Long Beach, CA.  
**COMPOSITE TRANSPORT WING TECHNOLOGY DEVELOPMENT**

RAM C. MADAN Feb. 1988 92 p  
(Contract NAS1-17970)  
(NASA-CR-178409; NAS 1.26:178409) Avail: NTIS HC A05/MF A01 CSCL 01/3

The design, fabrication, testing, and analysis of stiffened wing cover panels to assess damage tolerance criteria are discussed. The damage tolerance improvements were demonstrated in a test program using full-sized cover panel subcomponents. The panels utilized a hard skin concept with identical laminates of 44-percent 0-degree, 44-percent plus or minus 45-degree, and 12-percent 90-degree plies in the skins and stiffeners. The panel skins were impacted at midbay between the stiffeners, directly over the stiffener, and over the stiffener flange edge. The stiffener blades were impacted laterally. Impact energy levels of 100 ft-lb and 200 ft-lb were used. NASTRAN finite-element analyses were performed to simulate the nonvisible damage that was detected in the panels by nondestructive inspection. A closed-form solution for generalized loading was developed to evaluate the peel stresses in the bonded structure. Two-dimensional delamination growth analysis was developed using the principle of minimum potential energy in terms of closed-form solution for critical strain. An analysis was conducted to determine the residual compressive stress in the panels after impact damage, and the analytical predictions were verified by compression testing of the damaged panels. Author

**N89-26843\*#** Army Aerostructures Directorate, Hampton, VA.  
**SCALING EFFECTS IN THE STATIC LARGE DEFLECTION RESPONSE OF GRAPHITE-EPOXY COMPOSITE BEAMS**

KAREN E. JACKSON and EDWIN L. FASANELLA (Planning Research Corp., Hampton, VA.) Jun. 1989 15 p Presented at the AHS National Technical Specialists' Meeting on Advanced Rotorcraft Structures, Williamsburg, VA, 25-27 Oct. 1988 Previously announced in IAA as A89-29466  
(NASA-TM-101619; NAS 1.15:101619; AVSCOM-TM-89-B-006)  
Avail: NTIS HC A03/MF A01 CSCL 01/3

Scaling effects in the large deflection response of graphite-epoxy composite beams was investigated. Eight different scale model beams ranging from 1/6 to full-scale were subjected to an eccentric axial compressive load to promote large bending deformations and failures. Beams having laminate stacking sequences including unidirectional, angle ply, cross ply, and quasi-isotropic were tested to examine a wide variety of composite response and failure modes. The model beams were loaded under scaled test conditions until catastrophic failure. Data acquired included load, end displacement, and strain measurements, and qualitative failure measurements. The experimental data is compared to a large rotation beam analysis and a finite element model analysis. Results from the tests indicate that the beam response becomes nonlinear. Failure modes are consistent between scale models within a laminate family, however, a significant scale effect is observed in strength of the scaled beams. Author

**N89-26844\*#** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

**METHOD FOR EXPERIMENTAL DETERMINATION OF FLUTTER SPEED BY PARAMETER IDENTIFICATION**

E. NISSIM (Technion - Israel Inst. of Tech., Haifa.) and GLENN B. GILYARD Washington Jun. 1989 44 p Previously announced in IAA as A89-30801  
(NASA-TP-2923; H-1510; NAS 1.60:2923) Avail: NTIS HC A03/MF A01 CSCL 01/3

A method for flight flutter testing is proposed which enables one to determine the flutter dynamic pressure from flights flown far below the flutter dynamic pressure. The method is based on the identification of the coefficients of the equations of motion at low dynamic pressures, followed by the solution of these equations to compute the flutter dynamic pressure. The initial results of simulated data reported in the present work indicate that the method can accurately predict the flutter dynamic pressure, as described. If no insurmountable difficulties arise in the implementation of this method, it may significantly improve the procedures for flight flutter testing. Author

**N89-27647\*#** Boeing Commercial Airplane Co., Seattle, WA. New Airplane Development.

**HIGH-SPEED CIVIL TRANSPORT STUDY. SUMMARY Final Report**

Washington Sep. 1989 41 p  
(Contract NAS1-18377)  
(NASA-CR-4234; NAS 1.26:4234) Avail: NTIS HC A03/MF A01

A system of study of the potential for a high speed commercial transport aircraft addressed technology, economic, and environmental constraints. Market projections indicated a need for fleets of transport with supersonic or greater cruise speeds by the years 2000 to 2005. The associated design requirements called for a vehicle to carry 250 to 300 passengers over a range of 5000 to 6000 nautical miles. The study was initially unconstrained in terms of vehicle characteristics, such as cruise speed, propulsion systems, fuels, or structural materials. Analyses led to a focus on the most promising vehicle concepts. These were concepts that used a kerosene type fuel and cruised at Mach numbers between 2.0 to 3.2. Further systems study identified the impact of environmental constraints (for community noise, sonic boom, and engine emissions) on economic attractiveness and technological needs. Results showed that current technology cannot produce a viable high speed civil transport. Significant advances are needed to take off gross weight and allow for both economic attractiveness and environment acceptability. Specific technological requirements were identified to meet these needs. Author

**N89-27648\*#** Boeing Commercial Airplane Co., Seattle, WA. New Airplane Development.

**HIGH-SPEED CIVIL TRANSPORT STUDY Final Report**

Washington Sep. 1989 126 p  
(Contract NAS1-18377)  
(NASA-CR-4233; NAS 1.26:4233) Avail: NTIS HC A07/MF A01 CSCL 01/3

A system study of the potential for a high-speed commercial transport has addressed technological, economic, and environmental constraints. Market projections indicate a need for fleets of transports with supersonic or greater cruise speeds by the year 2000 to 2005. The associated design requirements called for a vehicle to carry 250 to 300 passengers over a range of 5,000 to 6,000 nautical miles. The study was initially unconstrained in terms of vehicle characteristic, such as cruise speed, propulsion systems, fuels, or structural materials. Analyses led to a focus on the most promising vehicle concepts. These were concepts that used a kerosene-type fuel and cruised at Mach numbers between 2.0 to 3.2. Further systems study identified the impact of environmental constraints (for community noise, sonic boom, and engine emissions) on economic attractiveness and technological needs. Results showed that current technology cannot produce a viable high-speed civil transport; significant advances are required to reduce takeoff gross weight and allow for both economic



attractiveness and environmental acceptability. Specific technological requirements were identified to meet these needs.

Author

**N89-27649#** Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.

**ANALYSIS OF A SYSTEM TO PREVENT HELICOPTER ROTOR BLADE-AIRFRAME STRIKES Final Report, 1 Nov. 1986 - 31 Dec. 1988**

B. W. MCCORMICK and R. G. MELTON 1 May 1989 111 p (Contract DAAL03-87-K-0002) (AD-A209804; ARO-23726.1-EG) Avail: NTIS HC A06/MF A01 CSDL 01/3

Rotor blade-airframe strikes are rare but they do occur. Three areas of the airframe are particularly vulnerable: the tail boom, canopy and, in the case of the underslung, teetering rotor, the rotor shaft. This latter case is known as mast bumping. This report studies a system to prevent a helicopter rotor blade from striking any part of the airframe. Essentially, the system continuously predicts ahead the rotor blade flapping in response to an input such as pilot control or an atmospheric disturbance. If a blade strike is predicted to occur then an appropriate feedback control is applied to alter the future flapping. The prediction is then begun again with the altered control. In the actual system, an enunciator might warn the pilot at the time that an attempt is made to control input which could be hazardous. Two somewhat independent approaches to the design of the controller are taken. One of the programs is entirely numerical in its approach. The other uses modern control theory and considers the preliminary aspects of implementing the controller in digital hardware. Both methods indicate the feasibility of preventing excessive flapping, although the question of implementation in a dedicated microprocessor is not fully resolved. GRA

## 06

## AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

**A89-47607**

**AN AIRBORNE U-BAND SOLID STATE PULSE-COMPRESSION RADAR**

M. BISCHOFF, J. DREIER, H. DREHER, and M. PATZWahl (AEG AG, Ulm, Federal Republic of Germany) IN: Military microwaves '88; Proceedings of the Sixth Conference, London, England, July 5-7, 1988. Tunbridge Wells, England, Microwave Exhibitions and Publishers, Ltd., 1988, p. 455-459. refs

A radar for the measurement of targets and clutter from a moveable airborne platform has been developed which uses a SAW-based pulse-compression system to achieve the required range resolution. The present mm-wave airborne radar consists of a solid-state transmitter and a coherent receiver, and it includes such features as a roll and pitch compensated antenna, pulse-to-pulse frequency agility, PRF agility, two waveforms, and an optical transmission link with high data rates. Test results are presented for a U-band pulse-compression radar in a mast-mounted configuration on top of a helicopter. R.R.

**A89-48303#**

**A LIGHTWEIGHT MPRF AIRBORNE RADAR - A SYSTEM POINT OF VIEW**

GENNARO FEDELE (Fabbrica Italiana Apparecchiature Radioelettriche S.p.A., Rome, Italy) Alta Frequenza (English Edition) (ISSN 0002-6557), vol. 58, Mar.-Apr. 1989, p. 87-96. refs

The advent of multirole aircraft in recent decades demands multimode functions from airborne radars. Modern reconfigurable or programmable signal processors, featuring high throughput, provide flexible hardware to satisfy many of these demands. This

paper discusses the guidelines of the system design approach for the lightweight 'Grifo' radar. Particular emphasis is given to the medium pulse repetition frequency waveform design and to the main hardware solutions to fulfill the system requirements and constraints and to enhance the reconfigurability for multimode operation with minimum pilot workload. Author

**A89-48402#**

**HELMET MOUNTED DISPLAY APPLICATIONS FOR ENHANCED PILOT AWARENESS**

GREGORY M. HARDYMAN and MICHAEL H. SMITH (Lockheed Aeronautical Systems Co., Burbank, CA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 221-225. (AIAA PAPER 89-3292)

The possible use of helmet-mounted displays (HMDs) to facilitate target designation and tracking by fighter-aircraft pilots is discussed, reviewing the results of recent studies at the Lockheed Weapon Systems Simulation Center. The main components of the HMDs include a helmet-mounted sight, a magnetic head-movement tracking system, and a graphics display system. In the simulations, particular attention was given to the dome and cockpit geometry, the graphics display geometry, the update rates and data synchronization, and tracking accuracy. It was found that accurate tracking and adequate simulation of tracking problems require a 20-deg-FOV helmet sight and a 28-foot simulator dome. The HMD demonstrated target queuing and designation capabilities in a beyond-visual-range (BVR) combat scenario; efforts are underway to extend HMD application to within-visual-range (WVR) scenarios and the important BVR-WVR transition. T.K.

**A89-49065#**

**WINDSHEAR DETECTION AND GUIDANCE SYSTEM FOR THE FOKKER 100 AIRCRAFT - REVIEW OF A DEVELOPMENT PROCESS**

J. VAN HENGST, G. A. J. VAN DE MOESDIJK, and P. J. VAN DER GEEST (Fokker Aircraft, Schiphol, Netherlands) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 121-128. (AIAA PAPER 89-3361)

The Fokker 100 will be equipped with a fully-integrated windshear detection, warning, and avoidance system, which should permit this aircraft to perform the windshear-event recovery maneuver with coupled throttle and autopilot controls. The recovery guidance control laws have been implemented in the existing automatic flight-control augmentation system, as an add-on to existing takeoff/go-around control laws. The encounter of a hazard-posing windshear event during takeoff will institute a maximum-available-thrust acceleration. O.C.

**A89-49428#**

**MONITORING FLIGHT OPERATIONS USING FLIGHT RECORDED DATA**

LARRY WILLIAMSON (British Airways, PLC, London, England) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. (AIAA PAPER 89-2056)

The use of flight data recording within British Airways is described. Analog recorders were initially used, followed by digital recording systems, with the acquisition and analysis of data on a larger and more automated scale becoming a reality. SESMA Program Management meetings carried out on a day-by-day basis and semiannual meetings between Airlines, RAE, Meteorological Office, Air Traffic Control and others are considered necessary to discuss topical subjects, exchange views and perhaps initiate research projects. SESMA, part of CAADRP (Civil Aircraft Airworthiness Data Recording Programme), has as its primary objective the maintenance and improvement of safety. Some examples of information obtained from CAADRP/SESMA are presented, including turbulence analysis, vortex wake encounters, and runway roughness monitoring. C.E.

## 06 AIRCRAFT INSTRUMENTATION

**A89-49452#**

### **BUTTON BOARDS - A CONNECTORLESS HIGH-SPEED INTERCONNECT FOR AVIONICS**

R. SMOLLEY (TRW, Inc., Redondo Beach, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p.  
(AIAA PAPER 89-2093)

The button board interconnect system has been developed to resolve issues of high life-cycle cost and unreliability posed by third level interconnect technologies in avionics. Although the primary application of the button board technology is directed at VHSIC Phase 2 processor level 3 interconnect, it has direct applicability for level 2 and level 1 connection issues. It can also be used for various interconnect configurations such as conventional packaging, solderless packaging, coaxial connection and bulk head connectors, and three-dimensional packaging. The mechanical design and button board contact features are described, and the configuration and interconnect performance are outlined.

C.D.

**A89-49454#**

### **AVIONICS MAINTAINABILITY - MORE IMPORTANT THAN RELIABILITY**

JEAN GEBMAN (Rand Corp., Santa Monica, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs  
(AIAA PAPER 89-2096)

The paper proposes a new approach to viewing R&M that emphasizes the two most fundamental R&M characteristics: (1) fault initiation and (2) fault removal. Managers need a minimum set of indicators that provide a comprehensive characterization of how a system or subsystem is doing in terms of these fundamental characteristics. Two parameters are suggested for such purposes: (1) mean flight time between flights with shop confirmed failures (MTBF); and (2) fault removal efficiency. Using such parameters to analyze contemporary field experience, it is found that progress in MTBF is not being matched by progress in fault removal efficiency. Because fault removal efficiency has fallen so far behind progress in reliability, the paper examines the proposition that progress in maintainability is now more important than progress in reliability.

Author

**A89-49455#**

### **PILOT'S ASSOCIATE - THE GENERATION OF REAL-TIME PERFORMANCE**

DAVID M. SMITH and MARTIN BROADWELL, JR. (Lockheed Aeronautical Systems Co., Marietta, GA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p.  
(AIAA PAPER 89-2097)

The challenge of implementing the functions of the Pilot's Associate (PA) on the avionics architectures of the next generation of aircraft is discussed. The current view of the architecture developed by the Joint Integrated Avionics Working Group as it relates to PA implementation is addressed. A generic description is given of the future PA architecture, together with estimates of its memory and processing requirements in its full-scale development configuration.

C.D.

**A89-49456#**

### **COCKPIT INFORMATION MANAGEMENT THROUGH AN INTELLIGENT PILOT/VEHICLE INTERFACE**

RALPH E. LAMBERT (McDonnell Aircraft Co., Saint Louis, MO) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p.  
(AIAA PAPER 89-2098)

The development of a cockpit information management system that can integrate data into useable information for the pilot is discussed, focusing on the pilot/vehicle interface (PVI). The ways in which a PVI would transmit information to the pilot of a fighter and attack aircraft are examined for various events, including encounter with enemy aircraft, alternate target decision, fuel problems, and recovery.

R.B.

**A89-49457#**

### **MODERN AVIONICS CONNECTOR UNRELIABILITY**

R. AL MORRISON and JONATHON Y. SIMMONS (Lockheed Aeronautical Systems Co., Burbank, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p.  
(AIAA PAPER 89-2099)

Connectors have always been a major source of avionics failure, and in the last 20 years very little has been done to improve their reliability. The parameters involved in connector failure and the various modes of failure are reviewed. A new connector failure mode analysis and testing program is examined, including the failure mode testing involved and the results obtained so far which have validated the various failure modes.

C.D.

**A89-49777**

### **WHAT ARE THE NEW TECHNOLOGY OPTIONS FOR AVIONICS?**

T. G. ANODINA (International Scientific Experimental Centre of ATC, USSR) and G. N. GROMOV (All-Union Scientific Research Institute of Radio Equipment, Leningrad, USSR) ICAO Bulletin (ISSN 0018-8778), vol. 44, March 1989, p. 23-25.

Trends towards future developments in avionics technology are outlined. The introduction of advanced microelectronics and computer technologies to increase the capabilities of airborne and ground-based equipment is discussed. Possible improvements in weather, navigation, air traffic control, and flight systems are listed. In addition, the need for better communications-navigation-surveillance integration is considered.

R.B.

**A89-50302#**

### **A CRITICAL EXAMINATION OF SENSOR FUSION**

JAMES L. FARRELL (Westinghouse Defense and Electronics Systems Center, Baltimore, MD) IN: ION, Annual Meeting, 44th, Annapolis, MD, June 21-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1988, p. 38-45. refs

The paper examines the operation of a generic dual-mode subsystem (FLIR and SAR) under conditions of measurement availability that facilitate some of the requisite mapping operations. Specifically, an advanced version of the system described by Holm (1987) is analyzed, with emphasis on placement of range/Doppler and azimuth/elevation cell contents.

B.J.

**A89-50375**

### **GENERAL IDEAS CONCERNING CAS SYSTEMS [IDEAS GENERALES SOBRE LOS SISTEMAS C.A.S.]**

EUGENIO LALLEMAND ABELLA *Ingenieria Aeronautica y Astronautica* (ISSN 0020-1006), June-July 1989, p. 11-16. In Spanish.

In the Fall of 1987, the U.S. Congress passed legislation making the installation of the TCAS-2 anticollision system mandatory on all U.S. commercial aircraft of more than 30-seat passenger capacity, over the course of four years. The FAA had previously published a Notice of Proposed Rulemaking detailing its intentions on the development, certification, and installation of this collision-avoidance system (CAS). An account is presently given of the basic functions of a CAS, the characteristics of various CAS-implementation technologies, considerations concerning risk evaluation, the basic kinematic model embodied by a CAS, and the communications techniques employed in prospective CASs.

O.C.

**A89-50820**

### **AIRPLANE CENTER OF GRAVITY AND FUEL LEVEL ADVISORY SYSTEM**

RICHARD L. ADELSON (Boeing Military Airplanes, Wichita, KS) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 13 p.  
(SAWE PAPER 1828)

The development of an airplane center of gravity/fuel level advisory system to assist in aircraft balance control during flight is discussed. The system is intended for aircraft that are sensitive

to balance due to the addition of fuselage fuel tanks, weapons bays, and wing mounted stores. The systems features, equipment, and operation are described. Results are presented from tests in which the system was installed on in a USAF B-52 simulator.

R.B.

#### 89-51232

##### **AIRPLANE INSTRUMENT TO DETECT ICE PARTICLES**

J. J. JONES, C. GROTEBECK (New Mexico Institute of Mining and Technology, Socorro), and B. VONNEGUT (New York, State University, Albany) *Journal of Atmospheric and Oceanic Technology* (ISSN 0739-0572), vol. 6, Aug. 1989, p. 545-551. refs

(Contract N00014-80-C-0258; N00014-80-C-0312; NSF ATM-84-19112; NSF ATM-82-05468; NSF ATM-82-18621; NSF ATM-86-00526)

A simple instrument that detects ice particles has been developed for use in airplane studies of thunderstorms. Although sophisticated instruments are available for imaging atmospheric ice particles, the spatial resolution of the particle concentration determined from their data is limited by the small size of the sample area. The ice detector described here provides a real-time indication of the presence of ice crystals within and in the vicinity of clouds, and provides an approximate measure of their concentrations with excellent spatial resolution. This device, which is simple and inexpensive, has been flown for five summers in New Mexico thunderstorms.

Author

**89-26845** Department of the Navy, Washington, DC.

##### **COST-OPTIMAL STATE FEEDBACK CONTROLLER FOR ALL-ATTITUDE GIMBAL SYSTEM Patent**

GEORGE L. LAURO, inventor (to Navy) 7 Mar. 1989 11 p Filed 2 Apr. 1987

(AD-D013972; US-PATENT-4,811,233;

US-PATENT-APPL-SN-036225) Avail: US Patent and Trademark Office CSCL 17/7

An improved cost-optimal state feedback control system is disclosed for stabilizing the inertial reference platform in all-attitude inertial guidance systems which uses the region control concept. It reduces the computational requirements of cost-minimizing state feedback to within the capacity of aerospace vehicle on board control processors. The control system iterates the feedback compensation process so as to reduce the R-gyro error to essentially a zero value and to prevent the gimbal assembly from entering a gimbal lock orientation.

GRA

**89-26846#** Aeronautical Systems Div., Wright-Patterson AFB, OH.

##### **F-15E EADI (ELECTRONIC ATTITUDE DIRECTOR INDICATOR) EVALUATION: A COMPARISON OF THREE FORMATS Final Report, Apr. - May 1988**

R. K. BURNS and P. B. LOVERING (Midwest Research Inst., Dayton, OH.) Jun. 1988 74 p

(AD-A206809; ASD-TR-88-5030) Avail: NTIS HC A04/MF A01 CSCL 01/3

The primary task for any pilot is to maintain attitude awareness and spatial orientation throughout all phases of flight. Even the slightest hesitation or attitude interpretation error during the all intensive low altitude, high speed night mission could rapidly become a catastrophic error. The attitude display must provide an unambiguous presentation of aircraft attitude in a manner which allows the pilot to respond immediately without thinking which way is the shortest path to wings level flight. The present study compared the baseline F-15E electronic attitude display to two other displays: the F-15E display with sky pointer arrows and a 180-degree field-of-view-dimensional display with sky pointer arrows. The results indicated significantly faster decision times for the baseline F-15E display (1.03 seconds) and F-15E display with arrows (1.00 seconds) relative to the three-dimensional display (1.18 seconds). This difference was present only for the 55-degree nose high attitude conditions. Nose low attitudes were significantly different in decision time. Correct responses using the F-15E display

with arrows (90 percent) were significantly higher than the baseline F-15E display (76 percent) for nose low attitudes. GRA

**89-27651#** Rome Air Development Center, Griffiss AFB, NY.

##### **AVIONICS SYSTEM ENGINEERING: AN INTRODUCTION**

FRED I. DIAMOND *In* AGARD, Systems Engineering 6 p May 1989

Avail: NTIS HC A07/MF A01

System engineering is the process used in the evolution of systems from identification of a need through construction and/or production and deployment in an operational environment. It is a process that involves the application of appropriate scientific and technical knowledge to transform an operational need into a system configuration with defined parameters, through an iterative process of analysis, design, test, and evaluation; to integrate all performance requirements, including reliability, maintainability, and supportability into the total engineering effort; and to integrate related components to insure interoperability and optimum system performance. It is a process that also considers economic factors such as development and life cycle costs. The life cycle process involves several key steps, many iterative, but in an orderly and controlled manner. These steps include requirements, architecture specification, design, development/construction, test and evaluation, and operational use. With the growing complexity of avionics systems, effective systems engineering is critical. Therefore, greater emphasis is placed on architectures, subsystem design, and interfaces and system integration. Only through a total systems engineering approach from the very initial phases of the system life cycle can a well-engineered system be achieved. The payoff will be reduced cost of ownership and greater mission effectiveness.

Author

**89-27652#** Westinghouse Electric Corp., Baltimore, MD.

##### **AVIONIC SYSTEM REQUIREMENTS**

HARVEY M. PASKIN *In* AGARD, Systems Engineering 6 p May 1989

Avail: NTIS HC A07/MF A01

Avionics system requirements are addressed at the conceptual level in light of changing threats, acquisition strategies, technology, and business environments. The objective is to provide a perspective of total integrated avionics system performance which illuminates broad requirement issues rather than specific subsystem specifications. The fundamental tenet is that although parametric and functional avionics system requirements can be related intuitively to mission related activities, a more global view is necessary to ensure that system requirements aptly address the gamut of factors which relentlessly bear on the ultimate system design, development, production, and support. The premise is that avionics requirements are driven by four factors: information and data sources, control opportunities and information needs; concepts and algorithmic techniques; and realization technologies. These four factors are set in a generic systems structure which shows their interrelationships and provides the framework for conceptualizing avionics system solutions to meet particular mission needs. The structure focuses on the role of avionics in providing situation assessment, response selection, response implementation, and communications. With this structures in place, avionics system requirements are then examined within the context of architecture, techniques, technology, producibility, and supportability. Author

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##### **INTEGRATED AVIONICS: CONCEPTUAL DESIGN**

MICHAEL J. BREZA *In* AGARD, Systems Engineering 3 p May 1989

Avail: NTIS HC A07/MF A01

Avionics of modern military aircraft is essential for maximizing performance realization of the total aeronautical system. In the early conceptual phase, aeronautical systems designers give scant attention to the interaction of avionics components. The aircraft design team generally provides weight, volume, and power considerations for the desired avionics functions and assumes that an avionics suite can eventually be assembled. Even less

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attention is given to the potential synergistic effect avionics can have with the aircraft design process. In contrast, the designers expend a large effort on finding the best balanced combination of airframe and propulsion components which satisfy the design objectives. An attempt is made to show why avionics must be a co-equal member of the aeronautical system along with airframe, propulsion, and armament. In becoming a co-equal partner, avionics must be an element of the system design analysis, commencing with the early conceptual design phase of a new aeronautical system. Author

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### **THE EVOLUTION OF DIGITAL AVIONICS ARCHITECTURES/SYSTEMS**

JOHN C. OSTGAARD and D. REED MORGAN /n AGARD, Systems Engineering 22 p May 1989  
Avail: NTIS HC A07/MF A01

The evolutionary design/development of modern-day digital information systems is examined. Included are the initial attempts at using digital technology in the early 1970s, the system integration thrusts of the 1980s, and the continued system technology revolution of the 1990s. Author

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### **AVIONIC SYSTEM DESIGN METHODOLOGY**

M. J. TOOZE /n AGARD, Systems Engineering 9 p May 1989  
Avail: NTIS HC A07/MF A01

An approach is described for an avionic system design and its application to modular avionic architecture. The approach is to test various candidate architectures using a common functional requirement. The method commences with a requirement analysis carried out in a top-down fashion to arrive at a full functional description. A parallel phase determines the technological base and defines a number of candidate architectures and corresponding component sets (module sets in the case of modular architecture). Thus technological performance and in-place equipment limitations are included at an early stage independent of the requirement. Hence top-down means bottom-up, by taking various architecture candidates and corresponding modular sets and applying the functional description of the requirement, so each architecture may be investigated for its capability to cope with the trial or application system. Assessment of reliability and performance objectives is discussed. Also included is reference to the areas of operating systems and BITE which may form part of the system but are not necessarily directly represented at the boundaries of the system. The philosophy of the approach is evaluated and does not extend to application of the various CASE design tools which exist (or may be specified) in order to carry out such a project in practice. Author

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### **RAPID PROTOTYPING OF COMPLEX AVIONICS SYSTEMS**

L. BERARDI /n AGARD, Systems Engineering 18 p May 1989  
Avail: NTIS HC A07/MF A01

The use of a rapid prototyping approach in the initial stages of complex avionics system design can complement some traditional computer design methods. In fact most of the computer aids in engineering and design are aimed to a better, coherent and, as far as possible, complete description of the project, but not too much is done on the verification of the proposed concept implementation. The advantage of having in the early design a software prototype of the system to highlight undesirable characteristics or possible improvements when the system has a high degree of complexity is discussed. Then a design tool called Expert Consultant for Avionics System Transformation Exploitation (ECATE) is described. ECATE is an expert system that prototypes the information handling architecture of an avionics system. The use of knowledge engineering and, in general, artificial intelligence approach for the rapid prototyping has proven very effective, because of the high flexibility, complex domain mastering capability, and heuristic methods typical of these techniques. Finally a

description of a complete, integrated environment for the rapid development of prototypes of avionics systems, by using artificial intelligence and computer tools, is given. Author

**N89-27658#** Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).

### **MODELING FUNCTIONAL SPECIFICATIONS FOR ONBOARD SOFTWARE [MAQUETTAGE DES SPECIFICATIONS FONCTIONNELLES DU LOGICIEL EMBARQUE]**

PATRICK SCHIRLE /n AGARD, Systems Engineering 19 p May 1989 In FRENCH

Avail: NTIS HC A07/MF A01

Software development for military avionics requires extensive documentation of functional and contractual specifications. The modeling of specifications permits: (1) improvement of the formal quality of specifications; (2) functional validation throughout the entire software life cycle; (3) generation of acceptance criteria; and (4) establishment of a functional reference for system integration. The role of specifications modeling in the software development process is discussed and experiences with the Rafale A and Mirage 2000 NC avionics systems are described. Transl. by M.G.

**N89-27659#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.

### **VERIFICATION OF THE PRODUCTION SAFE FLIGHT INSTRUMENT CORPORATION OV/RV-1D STALL WARNING SYSTEM Final Report, 17 - 25 Aug. 1988**

JOSEPH C. MIESS, CHARLES Q. CROWELL, and PATRICK SULLIVAN Nov. 1988 44 p  
(AD-A207392) Avail: NTIS HC A03/MF A01 CSCL 01/4

A Safe Flight Instrument Corporation (SFIC) stall warning system and prototype normal acceleration (g) limit aural warning device were evaluated on an OV-1D(C). Fifteen productive test flight hours were completed. Interchangeability of the SFIC stall warning system between aircraft was demonstrated by the good correlation of data between Grumman's test on aircraft and U.S. Army Aviation Engineering Flight Activity's (AEFA's) test on aircraft. Grumman's data shows adequate warning margin for LSSS on. There were, inadequate stall margins with LSSS not installed for dual-engine unaccelerated stalls, drop tanks only, and no-stores configurations. Single engine warning margins were inadequate, especially with the right engine operating near maximum power. Accelerated stall warning margins were satisfactory for all wing stores configurations. If the SFIC system is installed on operational aircraft without LSSS, the SFIC system should be adjusted to provide approximately 3 knots more warning margin for low power stalls. GRA

**N89-27660#** Naval Postgraduate School, Monterey, CA.  
**EVALUATION OF HEAD-UP DISPLAY FORMATS FOR THE F/A-18 HORNET M.S. Thesis**

LEAH M. ROUST Mar. 1989 105 p  
(AD-A208651) Avail: NTIS HC A06/MF A01 CSCL 25/3

This study evaluates symbols and formats for the F/A-18 Hornet head-up display (HUD) and Attitude Directional Indicator (ADI) for use by pilots in recovering from unusual aircraft attitudes. Two surveys were conducted to collect pilot opinions on various symbols and formats, based on past experimental research and current recommendations. For the HUD symbols according to the amount of information these symbols provide for the pilot while he is in an unusual attitude. In some cases, the pilots also were asked to choose their preferred symbols. The second survey was based on the results of the first and was administered to 56 F/A-18 pilots. These pilots selected their preferred HUD or ADI display formats, choosing one from two to five possibilities in each case. The specific symbols and formats that were evaluated are described in detail. Survey results are provided, and recommendations are made for display implementation and for further research and testing of symbols and formats. GRA

## 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.

**A89-47670#****ON THE USE OF PROPLETS AS A MEANS FOR REDUCING BLADE COMPRESSIBILITY LOSSES**

WALTER O. VALAREZO (Douglas Aircraft Co., Long Beach, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 452-457. refs (AIAA PAPER 89-2213)

Advanced propeller designs can operate efficiently at high subsonic forward speeds (Mach 0.8). However, at these high speeds propeller blades experience locally supersonic flow over a significant fraction of their radius due to high rotational speeds. The supersonic onset flow to the blades virtually guarantees the appearance of shocks on the blades with the associated aerodynamic performance losses. These losses directly impact the highest forward speed the propeller can efficiently attain as well as the integration of the propulsor with the airframe. This paper introduces the application of a winglet-like device (proplet) to advanced propeller designs to decrease tip speeds and to render the onset flow to the propeller essentially subsonic, therefore minimizing compressibility losses. The device is numerically demonstrated to offer significantly improved propeller efficiency if properly integrated with the remainder of the blade. Details of the verification work and associated design procedure are shown.

Author

**A89-47673#****ANALYSIS AND DESIGN OF DUAL-ROTATION PROPELLERS**

G. S. PAGE and R. H. LIEBECK (Douglas Aircraft Co., Long Beach, CA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 473-480. refs (AIAA PAPER 89-2216)

The vortex-blade element propeller design and analysis procedure defined by Adkins and Liebeck has been extended to the design and analysis of counterrotating propellers. The extensions are consistent with the analyses used in the prior work, with conditions added to account for the effects of a close-coupled pair of counterrotating propellers. An analytic verification of the optimum blade loading is made for counterrotating propellers with an arbitrary number of blades. A means of determining the optimum loading for counterrotating propellers is developed independent of the measured results of Theodorson. Sample calculations and a comparison with experimental results are presented.

Author

**A89-47963****INFLUENCE OF NONEQUILIBRIUM EFFECTS ON ELECTRICAL CONDUCTIVITY IN FLOWS OF HETEROGENEOUS COMBUSTION PRODUCTS IN NOZZLES [VLIANIE NERAVNOVESNYKH EFFEKTOV NA ELEKTROPROVODNOST' PRI TECHENII GETEROGENNYKH PRODUKTOV SGORANIIA V SOPLAKH]**

M. M. LAMPASOV, G. B. ODINOKOVA, and A. S. CHERENKOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 49-52. In Russian. refs

The paper is concerned with the effect of rate and temperature nonequilibrium on the electrophysical properties during the chemically nonequilibrium expansion of a heterogeneous mixture. The analysis uses a mathematical model of the nonequilibrium flow of a two-phase ionized mixture which makes it possible to allow for such phenomena as electron and ion emission and capture

by condensed particles and phase exchange processes in the presence of temperature and rate nonequilibrium between the phases. V.L.

**A89-47967****DETERMINATION OF THE FREQUENCY CHARACTERISTICS OF THE COMBUSTION CHAMBER CYCLE [OPREDELENIE CHASTOTNYKH KHARAKTERISTIK RABOCHEGO PROTSESSA KAMERY SGORANIIA]**

A. V. ANDREEV, V. G. BAZAROV, E. I. MARCHUKOV, B. G. MINGAZOV, and A. V. TALANTOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 63-66. In Russian.

A simplified method is proposed for calculating the transfer function for the operating cycle of the combustion chamber of an aircraft gas turbine engine. Experimental data are also presented on the conversion of fuel flow rate fluctuations to gas pressure fluctuations within the combustion chamber of a gas turbine engine. V.L.

**A89-47974****SYSTEM DESIGN OF THE FLOW PATH CONFIGURATION OF AN ENGINE USING A CAD SYSTEM [SISTEMNOE PROEKTIROVANIE OBLIKA PROTOCHNOI CHASTI DVIGATELIA S POMOSHCH'IU SAPR]**

S. B. GRIGOR'EV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 90-92. In Russian.

An approach to the computer-aided design of gas turbine engines at the technical proposal stage is examined. The mathematical models included in a subsystem for the analysis of the geometric and kinematic parameters of the engine are reviewed, and a design algorithm is presented. V.L.

**A89-47979****RELATION OF TURBOFAN STRUCTURAL PARAMETERS TO THE CONFIGURATION AND DRAG OF THE NACELLE OF A BYPASS ENGINE [SVIAZ' KONSTRUKTIVNYKH PARAMETROV TURBOVENTILIATORA S KONFIGURATSIEI GONDOLY TRDD I EE SOPROTIVLENIEM]**

S. P. ANDREEV, L. N. DRUZHININ, and M. M. TSKHOVREBOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 104, 105. In Russian.

The relationship between the number of turbofan stages and the configuration and drag characteristics of the bypass engine nacelle is analyzed using a complex powerplant model which includes engine design, nacelle configuration selection algorithm, and calculation of the external flow field and jet parameters. It is shown, in particular, that the total drag of the powerplant practically does not change as a result of changes in the nacelle configuration with the number of turbine stages for turbofans with 3-6 stages. V.L.

**A89-47981****CHARACTERISTICS OF THE COMBINED SUPPORT OF A GAS TURBINE ENGINE IN THE ABSENCE OF OIL SUPPLY TO THE BALL BEARING [KHARAKTERISTIKI KOMBINIROVANNOI OPORY GTD PRI OTSUTSTVII PODACHI MASLA NA SHARIKOPODSHIPNIK]**

V. M. DEMIDOVICH, L. V. GORIUNOV, and N. A. IAKIMOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 108, 109. In Russian.

Experiments were carried out to investigate the behavior of the combined support of a gas turbine engine consisting of a ball bearing and a hydrostatic bearing under conditions simulating the failure of the oil system to supply coolant oil to the ball bearing. It is shown that the use of a ball bearing in the support of a gas turbine engine not only significantly (by a factor of 2.5) reduces the rotational speed of the inner race but also makes it possible to maintain normal operation in the case of oil supply interruption. V.L.

A89-47982

**A STUDY OF RESIDUAL STRESS DISTRIBUTION IN THE LOCK SECTION OF THE BLADE OF A GAS TURBINE ENGINE ON THE BASIS OF INITIAL DEFORMATIONS [ISSLEDOVANIE RASPREDELENIYA OSTATOCHNYKH NAPRIAZHENII V ZAMKOVOI CHASTI LOPATKI TURBINY GTD PO PERVONACHAL'NYM DEFORMATSIIAM]**

V. F. PAVLOV, A. K. STOLIAROV, and V. N. UKHOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 109-111. In Russian.

Residual stresses in the lock section of a gas turbine blade were calculated by the finite element method based on isotropic initial deformations for the case of plane deformation. The calculations were carried out for the case of the uniform hardening of the entire surface of the blade and for the case where the curved part of the depressions was left unhardened. It is shown that residual stress distribution on the surface of a depression depends on the hardened layer thickness and also on the position of the depression relative to the specimen edge. V.L.

A89-47993

**LIMITING THE SERVICE PERIOD OF GAS TURBINE ENGINE COMPONENTS ON THE BASIS OF TECHNICAL/ECONOMICAL EFFICIENCY [OGRANICHENIE NARABOTKI UZLOV GTD IZ USLOVIA TEKHNIKO-EKONOMICHESKOI EFEKTIVNOSTI EGO ISPOL'ZOVANIYA V EKSPLUATATSII]**

M. A. KABESHOV, M. E. SHAIKIN, and V. T. SHEPEL' Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 34-36. In Russian.

A technical/economical approach is proposed for determining the optimal service period of gas turbine engine components before repairs. A criterion based on the cost effectiveness of engine operation is used which takes account of the profit resulting from engine operation and losses due to parametric failures. The approach proposed here is illustrated by a specific example. V.L.

A89-47995

**EVALUATION OF THE ACOUSTIC CHARACTERISTICS OF GAS TURBINE ENGINES USING EXPERIMENTAL NOISE DATA FOR A PROTOTYPE ENGINE [OTSENKA AKUSTICHESKIKH KHARAKTERISTIK GTD S ISPOL'ZOVANIEM EKSPERIMENTAL'NYKH DANNYKH PO SHUMU DVIGATELIA-PROTOTIPA]**

I. S. ZAGUZOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 40-43. In Russian.

An approach to the evaluation of the noise level of gas turbine engines is proposed which is based on an analysis of the results of stationary acoustic tests on a prototype engine. It is shown that such an approach makes it possible to improve the accuracy of determining the acoustic characteristics of the gas turbine engine being developed. An algorithm for determining engine noise levels at standard control points in the field is presented. V.L.

A89-48007

**EFFECT OF A BEND IN THE CONTOUR OF THE LAVAL NOZZLE OF A GAS TURBINE ENGINE ON FLOW IN THE SUPERSONIC SECTION [VLIANIE IZLOMA KONTURA SOPLA LAVALIA GTD NA TECHENIE V SVERZVUKOVOI CHASTI]**

IU. I. TSYBIZOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 73-75. In Russian.

Results of experimental studies of a series of plane and axisymmetric Laval nozzles (subsonic convergence angle, 0-40 deg; supersonic convergence angle 30-10 deg) are generalized and discussed with particular reference to the adjustable nozzles of aircraft gas turbine engines. Three characteristic regions are identified on the curve describing wall pressure distribution in the supersonic section; flow characteristics in each of these regions are briefly examined. V.L.

A89-48009

**A METHOD FOR CALCULATING THE THERMAL STATE OF A COOLED GAS TURBINE BLADE WITH A HEAT-INSULATION COATING [METOD RASCHETA TEPLOVOGO SOSTOIANIYA OKHLAZHDAEMOI LOPATKI GAZOVOI TURBINY S TEPLOZASHCHITNYM POKRYTIEM]**

V. M. IL'IN, S. A. LEBEDEV, and K. G. ZAROV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 78-80. In Russian.

A method for calculating the thermal state of a turbine blade with a heat-insulation coating is proposed for the case where the gas and cooling air temperatures change linearly with time. The method is based on the reduction of the problem of heat conduction in the blade section to a one-dimensional problem. The results obtained by using this method are found to be practically identical with results based on the elementary balance method. V.L.

A89-48277

**TRENDS IN MILITARY AIRCRAFT PROPULSION**

R. M. DENNING and N. A. MITCHELL (Rolls-Royce, PLC, Filton, England) (Seminar on the Future in Aircraft Powerplants, Birmingham, England, Oct. 29, 1987) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G1, 1989, p. 11-23. Research supported by the Ministry of Defence Procurement Executive.

The major factors determining the choice of engine cycle for a combat aircraft are the requirements of the design mission and those of aircraft speed and agility. The requirement for jet-borne flight in STOVL aircraft imposes further demands on cycle and configuration. The changing nature of combat aircraft requirements is the reason for changes in engine design. Specific thrust is shown to be the major parameter defining engine suitability for a particular role. An examination of mixed turbofan characteristics shows that specific thrust is also the key to understanding the relationships between engine characteristics. The implications of stoichiometric limits on cycle temperatures and the benefits of variable cycle engines are examined. Recent work on advanced STOVL aircraft is reviewed and aircraft/engine concepts designed to meet the requirements of the role are assessed. Author

A89-48282

**SPLIT TORQUE HELICOPTER TRANSMISSIONS WITH WIDELY SEPARATED ENGINES**

G. WHITE (Western Gear Corp., City of Industry, CA) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G1, 1989, p. 53-65. refs

A three-stage helicopter transmission of split torque type is shown to offer advances in a configuration that allows the engine axes to be widely separated and parallel. Three variants of the configuration are examined; one design with separated drive paths and four final-drive pinions is discussed in detail. This design offers 26 percent less weight and 9 percent lower losses than current production transmissions. Comparison is made with spycyclic type transmissions of similar rating that have been developed in the past decade. Author

A89-48466

**VIBRATION OF BLADED FLEXIBLE ROTOR DUE TO GYROSCOPIC MOMENT**

M. SAKATA, K. KIMURA, S. K. PARK (Tokyo Institute of Technology, Japan), and H. OHNABE (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) Journal of Sound and Vibration (ISSN 0022-460X), vol. 131, June 22, 1989, p. 417-430. refs

Rotating disks of jet engines are subjected to gyroscopic moment due to angular velocity when the aircraft turns or responds to disturbances. The vibration of a lightweight rotor system, which comprises a flexible disk with flexible blades and a flexible shaft with rigid bearings, is analyzed in the case of a steady turn by a finite element method (FEM) in order to cope with the complicated rotor configurations. In the FEM computations, the shaft is represented by beam elements, the disk by annular elements, and blades by beam elements in order to reduce the dimension of matrices. The computed results are compared with the

experimental data obtained by a test conducted on a model rotor. Good agreement was obtained between the computed and experimental results. Author

**A89-48521**  
**TURBOFAN FORCED MIXER/NOZZLE TEMPERATURE AND FLOW FIELD MODELLING**

P. KOUTMOS and J. J. MCGUIRK (Imperial College of Science and Technology, London, England) International Journal of Heat and Mass Transfer (ISSN 0017-9310), vol. 32, June 1989, p. 1141-1153. Research supported by Rolls-Royce, PLC. refs

A finite-volume solution procedure for the steady three-dimensional elliptic equations of fluid flow is used to calculate the flow and temperature fields in a multilobed turbofan mixer/nozzle combination. In the present study, turbulence is modeled using the two-equation k-epsilon eddy viscosity model. Forced mixer performance is found to be dominated by a periodic array of axial vorticity cells created by the lobe geometry. The method is shown to reproduce the observed downstream development of the large-scale secondary motions and their strong influence on the temperature signature at the nozzle exit, and to provide accurate predictions for such parameters as mixer total pressure loss and mixer efficiency. R.R.

**A89-48522**  
**STUDY OF THREE-DIMENSIONAL GAS-TURBINE COMBUSTOR FLOWS**

W. SHYY (Florida, University, Gainesville), M. E. BRAATEN (GE Research and Development Center, Schenectady, NY), and D. L. BURRUS (GE Aircraft Engines, Cincinnati, OH) International Journal of Heat and Mass Transfer (ISSN 0017-9310), vol. 32, June 1989, p. 1155-1164. refs

Computational and experimental results were obtained for the three-dimensional flow in an annular gas turbine combustor. The algorithm employed uses nonorthogonal curvilinear coordinates, second-order accurate discretizations, a multigrid iterative solution procedure, the standard k-epsilon turbulence model, and a combustion model containing an assumed probability density function and the conserved scalar variable formulation. Experimental results for the characteristic temperature pattern in the exit plane and for the effect of changing the dilution hole arrangements on the combustor performance are found to be well predicted by the theory. R.R.

**A89-48759#**  
**EXPERIMENTAL STUDY OF A REVERSE FLOW COMBUSTOR - INFLUENCE OF PRIMARY HOLES ON COMBUSTOR EFFICIENCY**

ANNE CADIOU (ONERA, Chatillon-sous-Bagneux, France) and GUY GRIENCHE (Turbomeca, Bizanos, France) ONERA, TP no. 1989-77, 1989, 8 p. Research sponsored by Turbomeca. (ONERA, TP NO. 1989-77)

The primary zone of the reverse flow combustors for helicopters tested at ONERA is fed with air from primary holes, multiples holes for the wall cooling and prevaporizer tubes. The effect of the primary holes on the combustor performances has been studied. Gas sampling inside the combustor has been achieved in order to understand the flow mechanisms with and without primary holes. The differences observed on the 2 configurations are not significant. Air from the prevaporizer tubes and from the wall cooling is sufficient for the air feeding of the primary zone. Author

**A89-48760#**  
**REEVALUATION OF RESEARCHES ON THE FREE ROTATING VANELESS DIFFUSER**

YVES RIBAUD and CHRISTIAN FRADIN (ONERA, Chatillon-sous-Bagneux, France) ONERA, TP no. 1989-78, 1989, 15 p. refs (ONERA, TP NO. 1989-78)

An attempt is made to reevaluate the studies performed by Rodgers and Mnew (1974) and Fradin and Ribaud (1972) on the rotating vaneless diffuser (RVD). These two studies are complementary. The first deals with a high-speed RVD fed by a

swirl-generating nozzle and giving high Mach numbers. The second concerns a real compressor comprising a low-speed rotor followed by an RVD. The free rotation of the RVD reduces the friction losses by about 70 percent. The high-speed mechanical design of the RVD is a success. The structure of the flow at the rotor outlet seems to have an important effect on the efficiency of the RVD. New types of RVDs should be experimented on, and new comparative experiments attempted. The application of the RVD concept to low-specific-speed compressors is also proposed. Author

**A89-49020**  
**APPLICATION OF MODERN MEASUREMENT METHODS TO TURBOMACHINES [METHODES MODERNES DE MESURES APPLIQUEES AUX TURBOMACHINES]**

J. PAULON (ONERA, Chatillon-sous-Bagneux, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 1, 1989, p. 9-15. In French. refs

Recent techniques for monitoring the behavior of turbomachines are reviewed which are applicable to the validation of aerodynamic models. Special attention is given to the use of piezoelectric and film transducers for measuring pressure, the use of unsteady pressure recorders and laser anemometers for the direct and indirect measurement of velocity, the use of capacitive gages for tip clearance measurements, and the use of CARS for concentration measurements. Temperature measurements are obtained by such devices as film transducers, CARS, IR cameras (using either optomechanical or electronic scanning), and optical fibers (for high-temperature measurements). R.R.

**A89-49021**  
**THEORETICAL STUDIES OF AEROELASTICITY IN AERONAUTICAL COMPRESSORS [ETUDES THEORIQUES D'AEROELASTICITE DANS LES COMPRESSEURS AERONAUTIQUES]**

H. QUINIOU (SNECMA, Moissy Cramayel, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 1, 1989, p. 61-71. In French. refs

The physical phenomena contributing to compressor blade flutter have been modeled, with application to gas turbine engine design. Six types of blade flutter have been identified: (1) subsonic stall flutter; (2) supersonic deenergized flutter; (3) blockage flutter; (4) energized supersonic flutter at high compression rates; and (5) energized supersonic flutter at low compression rates. Analysis techniques employed include finite element calculations (for determining the structural characteristics of blade profiles) and aerodynamic methods based on solution of the unsteady Euler equations (such as two-dimensional and three-dimensional blade-to-blade calculations). Interblade studies are performed in order to investigate the effect of wakes from upstream blade rows on the behavior of the rotor blades. R.R.

**A89-49022**  
**COMPRESSOR BLADE FLUTTER - AN UNDERSTANDING BASED ON WIND TUNNEL TESTS [LE FLOTTEMENT DES AUBES DE COMPRESSEUR - UNE CERTAINE COMPREHENSION GRACE A DES ESSAIS EN SOUFFLERIE]**

E. SZECHENYI and I. CAFARELLI (ONERA, Chatillon-sous-Bagneux, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 1, 1989, p. 73-87. In French. refs

The development of modern turbojet engines is tending increasingly toward the use of inlet fans having blades with sharp leading edges and relatively low natural frequencies of vibration. These characteristics increase the propensity of blade flutter. Tests on actual compressors have shown that a variety of blade instabilities can exist. For instance, flutter can occur on one or more blades independent of the neighboring blades of each, or else flutter vibrations can affect all the blades of a rotor which then vibrate according to rotor modes. This paper attempts to give some understanding of the physical causes of these different forms of flutter. The discussion is based on experimental results obtained in a straight cascade wind tunnel. Author



## 07 AIRCRAFT PROPULSION AND POWER

**A89-49407#**

### **PROPULSION OPTIMIZATION FOR CONCEPTUAL STOVL AIRCRAFT**

C. TODD HAVEY and MARGARET M. KLINE (Boeing Military Airplanes, Wichita, KS) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p.  
(AIAA PAPER 89-2020)

In STOVL aircraft, the most critical optimization parameters are propulsion weight fraction and the fuel weight fraction, or the combination of these two. Using existing propulsion system techniques, sensitivity studies can be made using assumptions along with computer codes generated for that purpose. Then these sensitivities can be examined to indicate an optimum combination. In this way it is possible to optimize the propulsion system configurations without extensive aerodynamic performance involvement. Author

**A89-49408#**

### **VSCF ELECTRICAL POWER GENERATION UNIT FOR THE CFM56 ENGINED BOEING 737**

MARCIA B. STRAHL, DONALD L. BACKSTROM, and ROBERT G. SUNDERHAUS (Westinghouse Electric Corp., Electrical Systems Div., Lima, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p.  
(AIAA PAPER 89-2021)

A variable speed constant frequency electrical power generation unit has been developed for the CFM56 powered 737 (-300, -400, and -500) aircraft. The VSCF unit replaces the mechanical constant speed drive (CSD) and air-cooled generator with a lighter weight electrical assembly of better maintainability and higher efficiency. The VSCF unit is designed as a one-for-one replacement for the constant speed drive/generator assembly and does not require any changes to the aircraft wiring or plumbing. Its utilization will be transparent to the flight crew and the assemblies can be mixed or matched on an aircraft. Author

**A89-49412#**

### **ONE-DIMENSIONAL MODELING OF HYPERSONIC FLIGHT PROPULSION ENGINES**

F. ARMENGAUD, R. DECHER, B. LAFOSSE (Washington, University, Seattle), and A. KOOPMAN (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 16 p. refs  
(AIAA PAPER 89-2026)

The propulsion system for a hypersonic vehicle is examined for the purpose of obtaining simple and insightful performance relationships. The specific thrust and impulse are calculated using simple, one-dimensional aerothermodynamic equations which approximate the behavior of the components. The validity of a number of assumptions, such as the working fluid description and the effect of combustion chemistry are investigated. The analysis is restricted to the hydrogen combustion regime with equivalence ratio less than or equal to unity. The modeling described shows the overall behavior of the propulsion system and identifies the need for substantial geometric variability if the system is to be used over a wide range of flight Mach number. Author

**A89-49418#**

### **THE CFM56 VENTURE**

JEAN BILLEN and RAM MATTA (CFM International, Inc., Cincinnati, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p.  
(AIAA PAPER 89-2038)

This paper is intended to describe how two companies, GE in the U.S.A. and SNECMA in France, initiated the CFM56 engine program and nurtured it to the point where it is widely recognized as a model of successful international cooperation. The paper summarizes the history of the program, which started 18 years ago in 1971, explains how the program is organized, and provides a technical review of the various engine models which make up

the CFM56 family. The paper also addresses the key factors which, in the opinion of the authors, have made the GE/SNECMA cooperation so successful. Author

**A89-49482#**

### **INSTALLATION FEATURES OF ADVANCED, VERY HIGH BYPASS TURBOFAN PROPULSION SYSTEMS**

JON A. MARX (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p.  
(AIAA PAPER 89-2141)

Advanced ducted turbopropfan installation configurations with bypass ratios of the order of 16:1 are presently discussed with a view to the minimization of drag increases due to the exceptionally large fan rotor diameters involved, as well as to the preclusion of aerodynamic and mechanical losses that may be incurred through the need to mount accessories on such engines' cores. Additional concerns arise from the ground clearance and wing-interaction consequences of the large-diameter nacelles. Attention is given to the packaging of accessory components, as well as to the fundamental need for a reduction of their sizes and even their innovative relocation. O.C.

**A89-49684#**

### **THE INFLUENCE OF FAN RADIAL ENTROPY MIGRATION ON ENGINE PERFORMANCE**

J. L. KERREBROCK, A. H. EPSTEIN, and P. A. KOTIDIS (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.  
(AIAA PAPER 89-2468)

There is a growing body of information supporting the conjecture of Kerrebrock (1981) that the low efficiencies measured in transonic fans near the tips are at least in part due to transport toward the tip of fluid which has suffered entropy increase at small radii in the rotor. Recently, Kotidis (1988) has presented experimental evidence for such transport in a high-performance transonic rotor. This paper deals with the impact of such transport, in the fan of turbofan engines, on the overall engine performance, by comparing the performance when the high-entropy fluid is transported and discharged with the fan airstream, to that when it is carried through the engine core. It is concluded that the performance of high-bypass engines can be significantly better in the presence of radial transport than in its absence, partly as a result of the higher core efficiency which results from inlet air to the core of lower entropy, partly due to the higher bypass ratio which maintains equality between the core and fan exhausts. Author

**A89-49688\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **TRANSIENT FLOW THRUST PREDICTION FOR AN EJECTOR PROPULSION CONCEPT**

C. DRUMMOND (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. Previously announced in STAR as N89-24318. refs  
(AIAA PAPER 89-2906)

A method for predicting transient thrust augmenting ejector characteristics is introduced. The analysis blends classic self-similar turbulent jet descriptions with a mixing region control volume analysis to predict transient effects in a new way. Details of the theoretical foundation, the solution algorithm, and sample calculations are given. Author

**A89-50363**

**STEADY AND UNSTEADY PRESSURES AND FORCES IN A VIBRATING EJECTOR ENGINE IN THE SUBSONIC AND TRANSONIC SPEED REGIMES [STATIONÄRE UND INSTATIONÄRE DRUCKE UND KRAFTEN AN EINEM SCHWINGENDEN EJEKTORTRIEBWERK IM SUBSONISCHEN UND TRANSONISCHEN GESCHWINDIGKEITSBEREICH]**  
HERMANN TRIEBSTEIN and GUENTHER SCHEWE (DLR, Institut

fuer Aeroelastik, Goettingen, Federal Republic of Germany) DLR-Nachrichten (ISSN 0011-4901), June 1989, p. 23-26. In German.

Experimental studies of the steady and unsteady aerodynamic forces using an ejector engine model with subsonic and transonic flows were used to investigate the influence of angle of attack, Mach number, mass flow coefficients, and reduced frequency on the pressure distribution and the coefficients of force and moment. The results showed that pressure distribution for transonic flow changed significantly in comparison to that for subsonic flow, but that the total forces changed little. The steady and unsteady aerodynamic forces increase with increasing input mass flow coefficient, while the direct jet propulsive effect is small. The unsteady aerodynamic forces increase gradually with reduced frequency. C.D.

**A89-50373**

**ASPECTS OF THE NUMERICAL SIMULATION OF TURBULENT FLOW IN COMBUSTOR TYPE CONFIGURATIONS  
[GESICHTSPUNKTE DER NUMERISCHEN SIMULATION  
TURBULENTER STROMUNGEN IN  
BRENNKAMMERTYPISCHEN KONFIGURATIONEN]**

B. NOLL, H.-J. BAUER, and S. WITTIG (Karlsruhe, Universitaet, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, May-June 1989, p. 178-187. In German. refs  
(Contract DFG-SFB-167)

Specific aspects of the numerical simulation of jet engine combustor flow using finite volume methods are discussed. The computation of two-dimensional flows in complex combustor geometries based on boundary-fitted computational grids is one of the major topics considered. The paper illustrates the potential and the restrictions of nonorthogonal curvilinear grids with results derived from a number of practical flow problems. In considering the computation of three-dimensional flows, the discretization scheme is one of the main problems. However, the efficiency of the numerical code presented was greatly improved by applying advanced methods for the velocity-pressure coupling and by advanced solution algorithms. The application of array processors further increased the computational speed. Author

**A89-51025**

**A STUDY OF HEAT TRANSFER DURING THE DESIGN OF A COOLING SYSTEM FOR GAS TURBINE BLADES  
[ISSLEDOVANIIE TEPLOOBMENA PRI RAZRABOTKE SISTEMY OKHLAZHDENIIA LOPATOK GAZOVYKH TURBIN]**

S. Z. KOPELEV, M. N. GALKIN, A. N. BOIKO, and I. V. SHEVCHENKO Akademiia Nauk SSSR, Izvestiia, Energetika i Transport (ISSN 0002-3310), May-June 1989, p. 98-105. In Russian. refs

Theoretical principles and methods are presented for the thermal diagnostics of turbine blades using modeling stands with a liquid-metal coolant where blades are blasted with cooling air in a solidifying zinc melt and the intensity of internal heat transfer is determined from the local thickness and the phase transition heat of the metal crust solidified at the external surface of the blade. It is shown that, in liquid-zinc blade tests, flow distribution in the internal channels closely simulates that observed in gasdynamic stands. The regimes of model testing making it possible to apply the results to full-scale turbines are determined. V.L.

**A89-51337#**

**SCRAMJET PROPULSION**

F. DONALD STULL (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 10 p.  
(AIAA PAPER 89-5012)

The objectives and requirements of the NASP program are discussed. The following areas of scramjet propulsion technology are of particular importance: inlets, combustors, nozzles, component integration, and test facilities. In the case of the inlets, combustors, and nozzles, emphasis is placed on the development of a high Mach number design methodology, and the establishment

of a high Mach number performance data base that will meet the goals of high performance and minimum weight engine required for NASP. It is noted that test facilities are required to provide Mach 508 test capabilities which are sufficiently large and to provide very high Mach number simulations for smaller-scale component tests. K.K.

**A89-51574**

**HSCT PROPULSION STUDIES FOCUS ON REDUCING EMISSIONS, NOISE**

STANLEY W. KANDEBO Aviation Week and Space Technology (ISSN 0005-2175), vol. 130, July 10, 1989, p. 34-36.

NASA-Lewis, in collaboration with two leading U.S. aircraft engine manufacturers, has initiated a decade-long research effort exploring future high-speed civil transport (HSCT) propulsion system configurations and component technologies. These HSCT propulsion studies will be organized into two overlapping phases: that of 1990-1995 will attempt to identify technological barriers to development of environmentally acceptable and economically attractive powerplants; that of 1992-1997 will then focus on the validation of the technologies conveyed as means to the goal of HSCT propulsion. The HSCT envisioned would be an atmospheric pollution-minimizing and airport vicinity-quiet 250-300 passenger SST cruising at Mach 2-3 over 5500-6500 n mi ranges. O.C.

**N89-26847** Department of the Air Force, Washington, DC.

**NOZZLE FLAP HINGE JOINT Patent**

WILLIAM M. MADDEN, inventor (to AF), CLAUDE R. STOGNER, inventor (to AF), and CHARLES E. SPAETH, inventor (to AF) 12 Jul. 1988 4 p Filed 24 Feb. 1987  
(AD-D014002; US-PATENT-4,756,053;  
US-PATENT-APPL-SN-018118; US-PATENT-CLASS-162-23)  
Avail: US Patent and Trademark Office CSDL 13/5

This patent relates to a hinge joint for a nozzle flap for a gas turbine engine exhaust nozzle. First and second flaps are joined at a hinge joint formed by a hollow hinge pin passing through alternating lug extensions of the first and second flaps. A plurality of flow openings in the hollow hinge pin are provided for establishing fluid communication between the interior of the first flap and the interior of the second flap. GRA

**N89-26848** Department of the Air Force, Washington, DC.

**BACK-UP CONTROL SYSTEM FOR F101 ENGINE AND ITS DERIVATIVES Patent**

WALTER D. HUTTO, JR., inventor (to AF) and WILLIAM W. STOCKTON, inventor (to AF) 3 Jan. 1989 13 p Filed 14 May 1987  
(AD-D014051; US-PATENT-4,794,755;  
US-PATENT-APPL-SN-049351; US-PATENT-CLASS-60-39-281)  
Avail: US Patent and Trademark Office CSDL 01/4

A back-up control system is implemented in a single engine aircraft to provide inactivation of a faulty primary system and engagement of secondary system, and thereby provide a means of maintaining controllable flight sustaining thrust. The aircraft's hydromechanical main engine control and its companion pressure and temperature sensors can develop faults which can result in the inability of the engine to deliver flight sustaining thrust. The electronic control contains logic functions which indicate failure of the main engine control when all of the following exists for a minimum of three seconds: (1) the power lever is at a position requesting a level of dry thrust which exceeds a predetermined threshold; (2) core engine speed is below that required to deliver the predetermined level of dry thrust; (3) core engine speed is not increasing; and (4) turbine temperature is beneath the maximum allowable limit. The backup system is used in conjunction with a three position cockpit switch having normal, on and standby position. In the normal position the back-up system is off and must be manually activated by switching to the on position. In the standby position, the backup system is automatically activated when the necessary conditions occur. GRA

**N89-26849** Department of the Air Force, Washington, DC.

**VARIABLE NOZZLE AREA TURBINE VANE COOLING Patent**

## 07 AIRCRAFT PROPULSION AND POWER

EDWARD S. HSIA, inventor (to AF), JOHN H. STARKWEATHER, inventor (to AF), and WILLIAM K. KOFFEL, inventor (to AF) 17 Jan. 1989 13 p Filed 19 May 1986 (AD-D014071; US-PATENT-4,798,515; US-PATENT-APPL-SN-895016; US-PATENT-CLASS-415-115) Avail: US Patent and Trademark Office CSCL 21/5

The cooling insert for a movable vane in a jet engine is divided into plural overlapping forward and aft segregated members, each member being coolant fed through separate vane trunnion areas and each insert is of successively decreasing cross-sectional area. Problems of locally inadequate vane cooling, coolant match point movement, and unequal coolant supply pressures are addressed by the disclosed apparatus. Reuse of the trunnion supplied impingement cooling air for additional cooling functions is also disclosed. GRA

**N89-26850** Department of the Air Force, Washington, DC.  
**COMPRESSOR BLADE CLEARANCE MEASUREMENT SYSTEM Patent**

ROSARIO N. DEMERS, inventor (to AF) 21 Feb. 1989 19 p Filed 11 Mar. 1987 Supersedes AD-D012777 (AD-D014073; US-PATENT-4,806,848; US-PATENT-APPL-SN-024490; US-PATENT-CLASS-324-61) Avail: US Patent and Trademark Office CSCL 14/2

The system is used to measure the gap between the turbine engine compressor blade tip and the compressor case. The measurement is accomplished while the engine is running. This system has several features which minimize problems plaguing earlier systems. These include tuning stability and sensitivity drift. Both these problems are intensified by the environmental factors present on compressors, i.e., wide temperature fluctuations, vibrations, conductive contamination of probe tips and others. The circuitry in this new system provides phase lock feedback to control tuning and shunt calibration to measure sensitivity. The use of high frequency excitation lowers the probe tip impedance, thus minimizing the effects of contamination. The ability to control tuning and to calibrate has been demonstrated. GRA

**N89-26851#** Naval Air Propulsion Test Center, Trenton, NJ. Propulsion Engineering Dept.  
**STATISTICS ON AIRCRAFT GAS TURBINE ENGINE ROTOR FAILURES THAT OCCURRED IN US COMMERCIAL AVIATION DURING 1983 Final Report**

R. A. DELUCIA and J. T. SALVINO Mar. 1989 23 p (Contract DOT-FA71NAA-P98) (AD-A207592; NAPC-PE-184; DOT/FAA/CT-89/5) Avail: NTIS HC A03/MF A01 CSCL 21/5

This report presents statistics relating to gas turbine engine rotor failures which occurred during 1983 in commercial aviation service use. One-hundred and seventy-two failures occurred in 1983. Rotor fragments were generated in 96 of the failures and, of these, 9 were uncontained. The predominant failures involved blade fragments, 95.4 percent of which were contained. Five disk failures occurred and four were uncontained. Fifty-nine percent of the 172 failures occurred during the takeoff and climb stages of flight. This service data analysis is prepared on a calendar year basis and published yearly. The data support flight safety analyses, proposed regulatory actions, certification standards, and cost benefit analyses. GRA

**N89-26852** Department of the Air Force, Washington, DC.  
**AFTERBURNER FLAMEHOLDER CONSTRUCTION Patent**  
DONALD W. ELDREDGE, inventor (to AF) and BILLY R. MILAM, inventor (to AF) 28 Mar. 1989 4 p Filed 25 Jun. 1987 (AD-D014116; US-PATENT-4,815,283; US-PATENT-APPL-SN-066154; US-PATENT-CLASS-602-610) Avail: US Patent and Trademark Office CSCL 21/5

A flameholder for a gas turbine engine includes a retainer plate on the igniter holder boss which protrudes from the flameholder gutter and extends through a clearance hole in the outer shroud. The retainer plate permits thermally induced growth of the parts but does not allow the fuel spray and air flow gap

near the igniter to increase significantly, thus assuredly maintaining a sufficiently rich fuel/air mixture to promote ignition. GRA

**N89-26853** Department of the Air Force, Washington, DC.  
**NOZZLE FLANGE ATTACHMENT AND SEALING ARRANGEMENT Patent**

HAROLD R. HANSEL, inventor (to AF) and VINCENT M. DRERUP, inventor (to AF) 28 Mar. 1989 5 p Filed 13 Nov. 1987 (AD-D014123; US-PATENT-4,815,933; US-PATENT-APPL-SN-122153; US-PATENT-CLASS-415-189) Avail: US Patent and Trademark Office CSCL 21/5

The invention comprises a boltless turbine nozzle and nozzle support assembly that includes a turbine nozzle mounting flange seated in a nozzle seat forming a part of the nozzle support. Pins are used for affixing the nozzle support seat and baffles are providing for maintaining the pins in their desired locations. A retaining ring is preferably used to retain the baffles adjacent to the pins. A pressure actuated pliable seal is affixed to the turbine nozzle adjacent to the nozzle seat in order to provide an air seal across the completed assembly. GRA

**N89-26854#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

**MEASUREMENT UNCERTAINTY WITHIN THE UNIFORM ENGINE TEST PROGRAMME**

J. P. K. VLEGHERT, ed. (National Aerospace Lab., Amsterdam, Netherlands) May 1989 77 p (AGARD-AG-307; ISBN-92-835-0508-5; AD-A211105) Avail: NTIS HC A05/MF A01

This AGARDograph is an outcome of the Propulsion and Energetics Panel Working Group 15 on, Uniform Engine Testing Programme (AGARD AR 248). During the performance of this Group it appeared that the results of some test runs were somewhat scattered, without an obvious explanation. The Group, therefore, formed a sub-Group with the task of carefully assessing the uncertainties of the measured data in order to find out whether the scattering was within the expected uncertainty or whether an explanation must be found. Since the results of the efforts of the sub-Group have some importance beyond the Working Group 15 tests, it was decided to report them in the form of an AGARDograph. In Chapter 5 the different uncertainties are estimated. The discussion on the uncertainties appears in Chapter 6 and in the following Chapter 7, ten conclusions are drawn from the efforts. This AGARDograph was prepared at the request of the Propulsion and Energetics Panel of AGARD. Author

**N89-26856#** Astron Research and Engineering, Sunnyvale, CA.  
**DEMONSTRATION OF OBLIQUE DETONATION WAVE FOR HYPERSONIC PROPULSION Final Technical Report, 1 Aug. 1988 - 31 Jan. 1989**

TAKASHI NAKAMURA, MICHAEL J. SCHUH, DONALD S. RANDALL, THOMAS J. DAHM, and DAVID T. PRATT 30 Mar. 1989 118 p (Contract F49620-88-C-0130) (AD-A208268; ASTRON-7151-001; AFOSR-89-0659TR) Avail: NTIS HC A06/MF A01 CSCL 21/5

The Oblique Detonation Wave Engine (ODWE) offers a number of advantages over the Supersonic Combustor Ramjet (SCRAMJET) for hypersonic aeropropulsion. The objective of this program is to obtain data on the stability of the Oblique Detonation Wave (ODW) and to assess the applicability of the ODW to hypersonic propulsion. The program consists of the basic study of the ODW phenomenon and the design study of the test facility (Phase 1), and an in-depth experimental study of the ODW in a ram cannon-type combustion tube with a hypervelocity projectile launched into the tube by a two-stage light-gas gun (Phase 2). This Phase 1 report summarizes the results pertaining to the stability of the ODW and the experimental facility designs. It is concluded that ODW will be initiated and sustained in the test facility configuration and that the tests will generate data concerning key issues for the application of the ODW to hypersonic propulsion. GRA

**N89-27661#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

**BLADING DESIGN FOR AXIAL TURBOMACHINES**

May 1989 212 p Lecture series held in Toronto, Ontario, 1-2 Jun. 1989, in Cologne, Fed. Republic of Germany, 15-16 Jun. 1989, and in Ecully, France, 19-20 Jun. 1989 (AGARD-LS-167; ISBN-92-835-0512-3) Avail: NTIS HC A10/MF A01

The efficiency and performance of the turbomachinery components of future aero engines can considerably be improved by applying recent advances in understanding the flow behavior of axial compressor and turbine bladings. Thus, the optimal profile pressure distribution as input for new blading design methods has an important effect on losses and flow deflection. The boundary-layer behavior has to be carefully taken into account with respect to laminar/turbulent transition, shock/boundary-layer interaction and separation effects. In addition to these aerodynamical questions, unsteady effects and the limitations from structural and vibrational conditions also have to be taken into account. Two main topics are discussed: design methods and their principles and limitations, and application to axial compressors and turbines.

**N89-27662#** Hochschule der Bundeswehr, Munich (Germany, F.R.). Inst. fuer Strahlantriebe.

**REVIEW ON TURBOMACHINERY BLADING DESIGN PROBLEMS**

L. FOTTNER *In* AGARD, Blading Design for Axial Turbomachines 13 p May 1989

Avail: NTIS HC A10/MF A01

Based on the design objectives for the bladings of highly-loaded, high Mach number turbocomponents the main problem areas to be taken into account during the design process are derived. These refer to the flow field conditions with respect to the effect of the Mach number on the profile contour shape, the aerodynamic loading, especially compressor bladings, and the boundary-layer behavior. In addition, blading design has to account for the secondary flow effects and unsteady flow conditions. Author

**N89-27663#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

**DESIGN CRITERIA FOR OPTIMAL BLADING DESIGN**

HANS STARKEN *In* AGARD, Blading Design for Axial Turbomachines 17 p May 1989

Avail: NTIS HC A10/MF A01

Since about 1975 numerical methods are available to compute cascade blade shapes from prescribed surface velocity distributions in compressible flow range. Two-dimensional or quasi three-dimensional inverse or design methods enabled thereby the improvement of compressor and turbine cascades via an optimized blade pressure distribution. The theoretical and experimental development of such pressure distributions is described for the subsonic, supersonic, transonic, and supersonic velocity range of the compressor cascades. The equivalent problems in turbine cascades are indicated. Author

**N89-27664#** Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

**OVERVIEW ON BLADING DESIGN METHODS**

G. MEAUZE *In* AGARD, Blading Design for Axial Turbomachines 20 p May 1989

Avail: NTIS HC A10/MF A01

Rather than presenting an exhaustive catalog on the design method calculations, the possible ways to use the calculation methods are discussed, as well as the problems of their practical applications. The complexity of the flow behavior is recalled through a turbomachine and the simplifications which must be adopted, i.e., a mean axisymmetric steady through flow hypothesis. The particular case of an isolated blade row with the possible use of a full 3-D design approach is presented. The well-known quasi 3-D approach combining the mean through flow and the

blade-to-blade calculations is discussed where some details are given on direct and inverse methods for both through flow and cascade flow. Author

**N89-27665#** Iowa State Univ. of Science and Technology, Ames. Dept. of Mechanical Engineering.

**PERFORMANCE PREDICTION FOR AXIAL-FLOW COMPRESSOR AND TURBINE BLADING**

GEORGE K. SEROVY *In* AGARD, Blading Design for Axial Turbomachines 19 p May 1989

Avail: NTIS HC A10/MF A01

The performance of compressor and turbine blading must be predicted in all levels of a conventional design system, beginning in the preliminary design phase before blade row geometry is defined. Because of this requirement, many levels of complexity exist in both input and output of prediction methods, and alternative methods exist within each phase of design. A brief review of performance prediction problems and current solutions is presented. Because details of equations and methods cannot and should not be included, reference to original documents in readily available sources are classified according to their place in configuration design and analysis. It is concluded that both quasi-three-dimensional and three-dimensional computation methods have a potential for future development in terms of configuration optimization. Additionally, it is concluded that experimental data correlation is not dead, and that improvement potential exists in every area of the performance estimation problem. Author

**N89-27666#** Rolls-Royce Ltd., Derby (England).

**BLADING DESIGN FOR MULTI-STAGE HP COMPRESSORS**

P. STOW *In* AGARD, Blading Design for Axial Turbomachines 29 p May 1989

Avail: NTIS HC A10/MF A01

Computer aided turbomachinery blade design is discussed with the emphasis on the mathematical models that are needed in order to account for the important physical phenomena. The various aspects of a typical blade design system are presented covering through-flow and blade-to-blade analysis. The through-flow discussion covers linked through-flow-blade-to-blade analysis, blade loss models, end-wall boundary layers, secondary flow analysis, and spanwise mixing models. Blade section design using mixed design and analysis methods is covered together with loss prediction using coupled inviscid boundary layer approaches. Limitations of the coupled approach are discussed together with the emerging role of Reynolds averaged Navier-Stokes methods aimed at removing these limitations. The need for fully three-dimensional methods is covered together with their incorporation into the design system. Finally areas for future development and application are discussed. Author

**N89-27667#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.

**TRANSONIC AND SUPERSONIC COMPRESSOR BLADING DESIGN**

A. J. WENNERSTROM *In* AGARD, Blading Design for Axial Turbomachines 22 p May 1989

Avail: NTIS HC A10/MF A01

A design is presented for axial compressor stages for which the achievement of high performance is both critical from the standpoint of a thermodynamic cycle and also difficult because of high aerodynamic loading, Mach number, or both. The type of method of interest is often termed a through-blade design procedure. The general methodology employed is covered including the computational framework. The kinds of information derived from empiricism is discussed, followed by those areas where design guidance is lacking and logical assumptions are used. The foregoing can theoretically result in an infinite range of solutions. An optimization criteria is presented through striving to obtain the one best solution. Three examples are shown covering the Mach number range of about 0.7 to 1.6 to illustrate the success of the approach. Several other factors which must be taken into account in a design are mentioned. Also, several glaring weaknesses in

the present design methods are identified. The lecture concludes with some comments on current design trends and computational goals. Author

**N89-27668#** Centre de Villaroche, Moissy (France).  
**BLADING DESIGN FOR COOLED HIGH-PRESSURE TURBINES**  
 P. F. BRY *In* AGARD, Blading Design for Axial-Turbomachines  
 42 p May 1989  
 Avail: NTIS HC A10/MF A01

The past fifty years have seen the tremendous development of jet engine propulsion. Testing has become very complex and has paralleled the increasing complexity observed in the domain of computational methods. The best compromise must be found for the inner and outer shapes of the nozzles and blades. This can only be achieved if internal and external designs are performed by an integrated team of specialists. Tools are described that are available for helping design engineers to reach this objective. Examples of what can be achieved are presented. Both theoretical and experimental aspects are addressed since they are an integral part of the design process. Author

**N89-27669#** Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).  
**AERODYNAMIC DESIGN OF LOW PRESSURE TURBINES**  
 J. HOURMOUZADIS *In* AGARD, Blading Design for Axial Turbomachines 40 p May 1989  
 Avail: NTIS HC A10/MF A01

The aerodynamic requirements for low pressure (LP) turbines covering a wide range of Mach and Reynolds numbers are derived from the applications for turbofan, shaft, and propfan engines. Designing turbines for high performance levels is based on extensive experience and modern prediction techniques. Methodology, experimental background, measurement techniques, and design systems are reviewed. The merits and limitations of present computation procedures are discussed. The close interaction between research and industrial development is discussed and the differences are pointed out. Two-dimensional pressure distributions can be predicted by a variety of very efficient inviscid methods. Boundary layer prediction is handicapped by complexity including separation and transition. The characteristic of the Prandtl boundary layer is developed and the physical model leading to the concept of Controlled Boundary Layer (CBL) design is presented. The effects of unsteadiness and turbulence in turbomachinery as well as the extension to transonic flow are considered. The understanding of the inviscid 3-D aerodynamics and their introduction in the design systems is presented. Secondary flows and their direct and indirect effects on losses are discussed. The problems to be addressed in the intermediate and long term research and development work are listed and their significance commented upon. Author

**N89-27670\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.  
**MACH 5 INLET CFD AND EXPERIMENTAL RESULTS**  
 LOIS J. WEIR, D. R. REDDY, and GEORGE D. RUPP (Sverdrup Technology, Inc., Cleveland, OH.) Jul. 1989 16 p Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; sponsored in part by AIAA, ASME, SAE, and ASEE (NASA-TM-102317; E-5011; NAS 1.15:102317; AIAA-89-2355)  
 Avail: NTIS HC A03/MF A01 CSCL 21/5

An experimental research program was conducted in the NASA Lewis Research Center 10 x 10 ft supersonic wind tunnel. The 2-D inlet model was designed to study the Mach 3.0 to 5.0 speed range for an over-under turbojet plus ramjet propulsion system. The model was extensively instrumented to provide both analytical code validation data as well as inlet performance information. Support studies for the program include flow field predictions with both 3-D parabolized Navier-Stokes (PNS) and 3-D full Navier-Stokes (FNS) analytical codes. Analytical predictions and experimental results are compared. Author

## AIRCRAFT STABILITY AND CONTROL

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

**A89-47523**  
**VERIFICATION OF THE FLIGHT CHARACTERISTICS OF TRAINING AIRCRAFT WITH A RELAXED STATIC STABILITY ON THE TL-39 FLIGHT SIMULATOR [OVERENI LETOVYCH VLASTNOSTI CVICNEHO LETOUNU SE SNIZENOU STATICKOU STABILITOU NA LETOVEM SIMULATORU TL-39]**  
 ISMAIL MAHMOUD KAMIL and VLADIMIR TICHOPAD Zpravodaj VZLU (ISSN 0044-5355), no. 3, 1989, p. 131-134. In Czech.

The process of measuring flight characteristics of training aircraft with a relaxed static stability using the TL-39 flight simulator is discussed. The aircraft static stability was decreased by moving the center of gravity to a point behind the aerodynamic center of the aircraft. The flight characteristics were assessed using recorded deviations of various characteristics from their specified values and qualitative pilot evaluations. R.B.

**A89-47653\*#** Eidetics International, Inc., Torrance, CA.  
**DEVELOPMENT OF NON-CONVENTIONAL CONTROL METHODS FOR HIGH ANGLE OF ATTACK FLIGHT USING VORTEX MANIPULATION**  
 GERALD N. MALCOLM, T. TERRY NG, LIANE C. LEWIS (Eidetics International, Inc., Torrance, CA), and DANIEL G. MURRI (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 249-267. refs (Contract F33615-86-C-3623) (AIAA PAPER 89-2192)

Low-speed wind tunnel experiments have been conducted to define methods for the manipulation of a generic fighter forebody's vortices in order to generate controlled yawing moments at high alpha. Attention is given to two vortex-control schemes: one involving independently controlled forebody tip strakes, and the other individually controlled blowing ports on the forebody. The most effective methods for forebody yawing-moment control were found to be the minimization of natural asymmetry with a pair of symmetrically mounted tip strakes, and the perturbation of the vortex system away from the symmetric condition with asymmetric blowing. O.C.

**A89-47680#**  
**TWO-DIMENSIONAL FLIGHT MECHANICS MODEL INCORPORATING A RAPIDLY ROTATING AIRFOIL**  
 WILLIAM D. SIURU, JR., CHARLES E. FOSHA, and CRAIG BARBER (Colorado, University, Colorado Springs) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 610-621. Research supported by USAF. (AIAA PAPER 89-2224)

The flight mechanics of an aircraft configuration incorporating an oscillating airfoil for the enhancement of dynamic lift have been investigated using a two-dimensional simulation model with aircraft-features and flight parameter inputs and outputs encompassing aircraft trajectory, velocities and accelerations, pitch angle, and angles-of-attack for both the aircraft and its oscillating airfoil. In many cases, it is found that averaged coefficients may be substituted for detailed coefficient histories with good results and far more efficient computation. O.C.

A89-47939

**AIRCRAFT DEFLECTIONS DUE TO OSCILLATIONS DURING UNCONTROLLED FLIGHT IN THE ATMOSPHERE [RASSEIVANIE LETATEL'NYKH APPARATOV ZA SCHET KOLEBANII PRI NEUPRAVLIYAEMOM DVIZHENII V ATMOSFERE]**

O. A. PRIVARNIKOV *Samoletostroenie - Tekhnika Vozdushnogo Flota* (ISSN 0581-4634), no. 55, 1988, p. 61-64. In Russian.

Analytical relationships are derived for calculating the distance deviations due to the swaying of the aircraft from the ascending and descending trajectory legs of the passive-flight phase. Using these equations, the effect of the starting angular-motion characteristics on the aircraft deflection was investigated. I.S.

A89-47960

**CONTROL OF THE DESCENT OF A FLIGHT VEHICLE ALONG A GLIDE PATH IN THE GRAZING REGIME [UPRAVLENIE SNIZHENIEM LETATEL'NOGO APPARATA PO GLISSADE V SKOL'ZASHCHEM REZHIME]**

A. I. ZOTEEV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 35-39. In Russian. refs

A nonlinear law is proposed for controlling the motion of a flight vehicle during its descent along a stiff glide path. The law is based on the principle of force control in a class of piecewise continuous functions with discontinuities of the first kind and implements motion along a glide path in the grazing regime. V.L.

A89-47978

**DEGENERATE CLIMB PATH OPTIMIZATION PROBLEM FOR SUPERSONIC AIRCRAFT [VYROZHDENNAIA ZADACHA OPTIMIZATSII TRAEKTORII NABORA VYSOTY SVERKHZVUKOVOGO SAMOLETA]**

V. P. SURIN *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 101-103. In Russian. refs

A general method for solving the degenerate climb path optimization problem for supersonic aircraft is proposed which is based on finding the necessary and sufficient optimality conditions. Analytical expressions are obtained for the extremum in altitude-velocity coordinates. Conditions for the transfer from the subsonic to the supersonic branch of the extremum are determined for an arbitrary transfer path. V.L.

A89-48192

**THE STUDY OF THE GLOBAL STABILITY OF HIGH PERFORMANCE AIRCRAFT AT HIGH ANGLES-OF-ATTACK**

HAO GAO and ZHIQIANG ZHOU (Northwestern Polytechnical University, Xian, People's Republic of China) *Chinese Journal of Aeronautics* (ISSN 1000-9361), vol. 2, May 1989, p. 87-101. refs

To study the global stability of the high performance aircraft at high angles-of-attack, a new approach based on the qualitative theory of ODE bifurcation analysis, and catastrophe theory was developed. First, a series of algorithms is given, by which equilibrium, bifurcation surfaces, and periodic attractors are calculated, and the global stability of the aircraft is discussed. Secondly, the relations between the stability criteria commonly used in aircraft designs and the eigenvalues of linearized matrices at the equilibrium points are studied. Finally, by means of a calculation for a concrete aircraft, some important high angles-of-attack flight phenomena, such as jump, hysteresis, wing rock, and spin are analyzed using this approach. Author

**A89-48433\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**RECOVERY STRATEGIES FOR MICROBURST ENCOUNTERS USING REACTIVE AND FORWARD-LOOK WIND SHEAR DETECTION**

DAVID A. HINTON (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 429-440. refs (AIAA PAPER 89-3325)

The threat of convective microburst wind shear phenomena to

aircraft is studied. An attempt was made to quantify the benefits of forward-look sensing and to develop and test a candidate set of strategies for recovery from inadvertent microburst encounters during the landing approach. A batch simulation of various wind shear encounters was carried out; the simulation consisted of a point-mass aircraft model, an analytical microburst, and a simple wind shear detection scheme. It was found that forward-look alerts given 10 sec prior to microburst entry permitted recoveries to be made with little altitude loss. K.K.

A89-48655#

**DEVELOPMENT OF A VERSATILE ROTATION TRANSFORMATION ALGORITHM FOR AUTOMATIC MODEL ATTITUDE POSITIONING**

E. R. HEIM and R. W. HOBBS (Calspan Corp., Arnold AFB, TN) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Aug. 1989, p. 718-722. Previously cited in issue 07, p. 952, Accession no. A88-22039.

A89-49056#

**RELATIONSHIPS AMONG NONLINEAR AERODYNAMIC INDICIAL RESPONSE MODELS, OSCILLATORY MOTION DATA, AND STABILITY DERIVATIVES**

JERRY E. JENKINS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 43-51. Research supported by USAF. refs (AIAA PAPER 89-3351)

Simplifications to the functional form for the nonlinear indicial response model and its application to the aerodynamic response due to arbitrary motion inputs are discussed. Useful relationships between indicial response parameters and steady-state oscillatory force and moment data can be obtained by representing the indicial response with a Taylor series (in terms of onset motion parameters) and approximating the superposition integral with an asymptotic expansion. In particular, the appearance of certain harmonics and their variation with frequency, amplitude, and mean angle of attack can be traced to specific onset parameters. Restrictions imposed by using the asymptotic expansion are also examined. Nonlinear stability derivatives are shown to be related to specific indicial response characteristics. Author

A89-49060#

**ON PARAMETER ESTIMATION OF HIGHLY AUGMENTED AIRCRAFT**

VLADISLAV KLEIN (George Washington University, Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 83-91. refs (AIAA PAPER 89-3356)

An approach to parameter estimation of a highly augmented aircraft from flight data is given which includes a procedure for detection and assessment of data collinearity, and two ways of dealing with collinearity: biased estimation techniques and the redesign experiment. Computer-generated inputs were used in the excitation of aircraft responses. The suggested approach to parameter estimation is demonstrated in two examples. The results indicate that the biased estimators have far better accuracy than the results from the ordinary least-squares technique. Furthermore, the use of computer-generated inputs substantially decreased data collinearity. Author

A89-49061#

**A STANDARD EVALUATION MANEUVER SET FOR AGILITY AND THE EXTENDED FLIGHT ENVELOPE - AN EXTENSION TO HQDT**

T. J. CORD (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 92-95. refs (AIAA PAPER 89-3357)

Possible evaluation tasks are formulated with a view to

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improving the overall combat aircraft design process with respect to agility and flight-envelope extension. The maneuver segments discussed are (1) a 180-deg heading change; (2) high-alpha target-acquisition and tracking; (3) a 'scissors' transition between high wing loading conditions by means of a rapid roll; (4) the transition from beyond-to-within visual range; (5) a roll to target-acquisition with near-gross takeoff weight loading; (6) a missile end-game evasive maneuver; (7) a high-speed/maximum load-factor turn; and (8) a tactical final approach. These maneuvers will extend the 'Handling Qualities During Transition' process.

O.C.

### A89-49062#

#### COOPER-HARPER PILOT RATING VARIABILITY

DAVID J. WILSON and DAVID R. RILEY (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 96-105. refs (AIAA PAPER 89-3358)

Flying qualities experiments rely on Cooper-Harper Ratings as well as pilot comments to determine desirable aircraft dynamics. Such flying qualities experiments are vital for the continuing development of flying qualities specifications for future aircraft designs. Unfortunately, several sources of experimental variation affect Cooper-Harper Rating data. The lack of pilot repeatability, pilot preference, interpretation of the Cooper-Harper Rating scale, or poor experimental setup can reduce confidence in the results. Experimental methods were developed to reduce or minimize the effects of such variations, thereby increasing confidence in experimental findings.

Author

### A89-49064#

#### FLYING A WIND SHEAR IN THE C-5

R. T. MEYER, E. S. BARLAND, and B. J. DVORCAK (Lockheed Aeronautical Systems Co., Marietta, GA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 113-120. (AIAA PAPER 89-3360)

A flight simulation experiment has investigated the flight characteristics of the C-5 in a wind shear environment. This was part of a three-phase study, with the end result being recommended procedures for incorporation into the C-5 flight manual. The present C-5 has a wind shear warning system installed and procedures for wind shear encounters are discussed. Findings of the investigation show that the C-5 has no undesirable flying qualities in a typical turbulent wind shear environment and has the capability to fly through an encounter with a combined 40-knot horizontal and 20-knot vertical shear if sufficient altitude exists and proper recognition is followed by prudent pilot action.

Author

### A89-49066#

#### COUPLED STATIC AND DYNAMIC STABILITY PARAMETERS

JURI KALVISTE and BOB ELLER (Northrop Corp., Aircraft Div., Hawthorne, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 129-143. (AIAA PAPER 89-3362)

A set of new stability parameters have been developed for analysis of aircraft stability throughout the flight envelope. These parameters define aircraft stability based on the aircraft's aerodynamic and inertial properties and include both static and dynamic effects, inertial coupling, and kinematic coupling effects. A method of relating these parameters to the conventional stability modes of the aircraft has been developed and can be used to isolate the formation of new dynamic modes due to coupling.

Author

### A89-49067#

#### PREDICTION OF AIRCRAFT SPIN RECOVERY

C. A. MARTIN and S. D. HILL (Department of Defence, Aeronautical

Research Laboratories, Melbourne, Australia) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 144-153. refs (AIAA PAPER 89-3363)

Rotary balance measurements obtained with a 1/7-scale wind tunnel model of a basic training aircraft during its design development have been employed in conjunction with a six-degree-of-freedom flight dynamics model of aircraft spin in the prediction of equilibrium spin conditions and spin recovery characteristics. Comparisons are made with results from dynamic scale-model wind tunnel tests in order to validate the flight-dynamic model. This analysis indicates that the neglect of the side-force equation in the approximate trim equations is justified in most cases.

O.C.

### A89-49070#

#### EVALUATION OF DYNAMIC BEHAVIOUR OF AN AIRCRAFT WITH DELTA-WING CONFIGURATION AT HIGH ALPHA

SHANGXIANG ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) and ROLF STAUFENBIEL (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 174-182. Research supported by DFG. refs (AIAA PAPER 89-3366)

An analysis of vortex breakdown on flight dynamics behavior of an aircraft with delta-wing configuration operating at high angle of attack is presented. The experimental data of the unsteady aerodynamic forces and moments in water/wind tunnel are fit by using rational approximation functions in the entire Laplace space that yields a set of canonical state equations. With the augmented aircraft dynamic system, the simulations of aircraft motion under a typical (1-cos) form of elevator deflection and the atmospheric turbulence inputs are conducted. The dynamic responses show a strong impact of aerodynamic time lag due to leading edge vortex breakdown on the short period motion, in particular, the system damping is remarkably reduced.

Author

### A89-49084#

#### EXPERIMENTAL MEASUREMENTS OF THE AERODYNAMIC HINGE MOMENT ON A PLAIN TRAILING-EDGE FLAP AT $M = 10$

ROBERT DUFFY (Rensselaer Polytechnic Institute, Troy, NY), HILLARY DONDES, and PRICE TERZIS IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 314-319. refs (AIAA PAPER 89-3383)

This paper presents the results of an experimental investigation to measure the hinge moment of a plain 28-percent chord trailing-edge flap at angles varying from 0 to 20 deg and flap deflections from 0 to 30 deg. The tests were carried out in the RPI shock tunnel. The average Mach number over the model was 10.5, the average free stream static pressure was 0.512 psfa and the average stagnation temperature was 1489 R. The Reynolds number/ft averaged 450,000. At zero angle-of-attack, the data was compared to a single- and a double-shock theory; the double-shock theory could predict within 15 percent of the measured hinge moment. The data is presented in coefficient form and was found to vary nonlinearly with both angle of attack and flap deflection.

Author

### A89-49090#

#### QUALITATIVE AND QUANTITATIVE COMPARISON OF GOVERNMENT AND INDUSTRY AGILITY METRICS

R. BITTEN (Rockwell International Corp., Los Angeles, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 368-376. refs (AIAA PAPER 89-3389)



A qualitative comparison is made of the similarities and differences between the aircraft agility metrics proposed to date by government and industry; an effort is also made to quantitatively compare their sensitivity to variations in agility-related design parameters. Each of the four agility metrics is found to measure an aspect of aircraft performance in an unprecedented way. The dynamic speed turn plot measures conventional maneuverability in a way uniquely ties to a relevant combat task; 'time-to' metrics measure functional agility in a way that can easily be interpreted by pilots in the form of pointing spheres; etc. A comprehensive systems approach to aircraft design would employ each of these metrics, in addition to classical energy maneuverability measures. O.C.

**A89-49091#**  
**FLYING QUALITIES CRITERIA FOR PRECISE LANDING OF A STOL FIGHTER**

DAVID J. MOORHOUSE, DAVID B. LEGGETT, and KENNETH A. FEESER (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 377-384. refs (AIAA PAPER 89-3390)

The STOL/Maneuver Technology Demonstrator (S/MTD) program has as its goal the definition of technologies enabling a modified F-15B to land on a 50 x 1500-ft runway, using thrust-reversing nozzles in conjunction with control laws developed to minimize touchdown dispersion. The S/MTD control laws feature augmented airspeed stability, or 'speed-hold', and decoupled airspeed and pitch-rate responses. A piloted simulation has been conducted to define the required pitch attitude bandwidth with and without speed-hold. Preliminary results indicate that higher values of pitch bandwidth are required if there is coupling between the axes, or if airspeed stability is low. O.C.

**A89-49092#**  
**ROLL RESPONSE CRITERIA FOR HIGH MANEUVERABLE AIRCRAFT USING GIBSON'S METHOD**

MARIO INNOCENTI (Auburn University, AL) and AJAY THUKRAL IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 385-393. refs (AIAA PAPER 89-3391)

The paper deals with a preliminary investigation of critical parameters for roll response handling qualities using time-response and frequency-response techniques referred to as Gibson's method. The techniques are now extended to the evaluation of roll performance. The response of the aircraft to block-type roll-rate command is analyzed to determine the effects of parameters such as time constant, time delay, and bank acceleration. Nichols charts are used to identify potential dynamic instabilities such as roll-ratcheting. The validation of the procedure is performed by analyzing the LATHOS data-base and with the use of personal computer software. Author

**A89-49093#**  
**DEFICIENCIES OF LONG-TERM DYNAMICS REQUIREMENTS AND NEW PERSPECTIVES**

GOTTFRIED SACHS (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 394-403. refs (AIAA PAPER 89-3392)

The present consideration of the long-term dynamics of aircraft cruising at Mach greater than 2 indicates how their characteristics compare with existing flying qualities requirements and flight standards. Attention is given to the correlation between airspeed and pitch-attitude for commanded pitch-attitude changes; it is shown that this correlation in supersonic flight is not unequivocal, that it differs substantially from the relationship in subsonic and transonic flight, and that the additional, underlying flight-mechanics

'height' mode in supersonic flight is present and responsible for exerting a significant influence. It is shown with respect to aperiodic airspeed divergence that there are deficiencies in the assumed connection between this divergence and related control gradients. O.C.

**A89-49109#**  
**ON SELF-TUNING CONTROLLER FOR AIRCRAFT TERRAIN FOLLOWING/GUST ALLEVIATION CONTROL SYSTEM**

XIJUN LIU, LIANGFU LEI, and SHUNDA XIAO (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, July 1989, p. 337-345. In Chinese, with abstract in English. refs

A technique for incorporating gust alleviation into fighter-aircraft terrain-following automatic control systems is described. An explicit multidimensional self-tuning control algorithm is derived to permit real-time reduction of both normal overload and course deviation due to gusts. This algorithm is then modified by reducing the number of parameters to be identified, and the results of performance simulations are presented in tables and graphs. The controller is shown to meet the flying-quality requirements of MIL-F-8785C. T.K.

**A89-49404#**  
**AIRCRAFT AGILITY - THE SCIENCE AND THE OPPORTUNITIES**

M. D. DORN (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p. refs (AIAA PAPER 89-2015)

Trends in fighter aircraft technology, along with evolving mission requirements, are shifting the focus of close-in-combat analysis toward smaller time-scales. As a result, metrics are needed which focus with better resolution on these reduced time-scales. A general definition of agility is suggested, and analytical techniques for identifying agility metrics are explored. These methods are shown to yield the proposed metrics and are then extended to suggest generalized forms for agility. Author

**A89-49405#**  
**ASSESSMENT OF THE EFFECTS OF RECONFIGURATION ON AEROSERVOELASTIC STABILITY MARGINS**

RICHARD MERCADANTE and EDWARD J. LAURIE (Grumman Corp., Aircraft Systems Div., Bethpage, NY) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs (AIAA PAPER 89-2016)

Current Reconfigurable Control Law (RCL) technology addresses the effects of control surface impairments (ballistic damage or actuator failures) by attempting to maintain pre-impairment rigid body dynamics. Expanded RCL technology attempts to provide similar dynamics, as well as reducing uncommanded cross-coupling between axes. This is referred to as a Control Distributor Concept (CDC). An investigation was undertaken to assess the effects of a CDC on ASE (aeroservoelastic) stability margins of a modern fighter aircraft. Author

**A89-49406#**  
**WORST-CASE ANALYSIS OF FLIGHT CONTROL SYSTEMS USING THE STRUCTURED SINGULAR VALUE**

R. LANE DAILEY and DAGFINN GANGSAAS (Boeing Co., Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. refs (AIAA PAPER 89-2018)

An algorithm for the calculation of Doyle's (1982) structured singular value  $\mu$  and Safonov's (1982) multivariable stability margin  $k(m)$  has been applied to the case of real scalar parameter uncertainty. For the worst-case robustness analysis of aircraft flight control stability, parameters are selected to represent controller channel gains, phase shifts, aerodynamic stability and control

derivatives, dynamic pressure, velocity, angle of attack, and center of gravity location. Contour plots of  $k(m) = \mu$  over parts of the complex  $s$ -plane are found to be equivalent to multiparameter root locus plots. A technique to modify existing airplane simulation codes for use in  $\mu$  analysis has been derived which is useful for stability and control derivative studies. R.R.

**A89-49421#**  
**COMPARISON OF NON-LINEAR PITCH STABILITY THEORY WITH DATA FROM BAFR (BASIC AIRCRAFT FOR FLIGHT RESEARCH)**

L. M. B. C. CAMPOS (Lisboa, Universidade Tecnica, Lisbon, Portugal) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs  
 (AIAA PAPER 89-2041)

Analytical solutions are provided for nonlinear stability problems involving an aircraft beginning a dive at an arbitrary velocity which may differ significantly from either the stable flight speed lying above the minimum drag speed or the unstable speed lying below the minimum drag speed. Results are presented for the pitch control schedule, as a function of both time and distance, required to keep the aircraft on a constant glide slope as it approaches and diverges from these two steady flight speeds. The theoretical pitch control law derived is compared with experimental data obtained using the BAFR, a twin turbo-prop transport aircraft. R.R.

**A89-49585**  
**INVESTIGATIONS OF THE AEROMECHANICAL INSTABILITY OF A HELICOPTER USING FLOQUET THEORY [UNTERSUCHUNGEN ZUR AEROMECHANISCHEN INSTABILITAET EINES HUBSCHRAUBERS MIT HILFE DER FLOQUET-THEORIE]**

JOCHEN EWALD (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 5, 1989, p. T 347-T 350. In German.  
 (Contract BMFT-LFF-84318)

The dynamic behavior of a helicopter is investigated analytically. The system of differential equations with periodic coefficients which arises due to the coupling between the motions of the rotor and the helicopter body is solved by applying multiblade coordinates (time-varying Fourier coordinate transformations) and Floquet theory. Numerical results for a helicopter with a four-blade rotor are presented graphically, and it is shown that the present formulation provides both an accurate assessment of helicopter stability and a simple means for determining the eigenfrequencies of a system with constant coefficients. T.K.

**A89-49832**  
**FIXED-GAIN VERSUS ADAPTIVE HIGHER HARMONIC CONTROL SIMULATION**

KIP P. NYGREN (U.S. Military Academy, West Point, NY) and DANIEL P. SCHRAGE (Georgia Institute of Technology, Atlanta) American Helicopter Society, Journal (ISSN 0002-8711), vol. 34, July 1989, p. 51-58. refs

A computer simulation of helicopter vibration reduction using 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, including stochastic control. The adequacy of fixed-gain as opposed to adaptive control has recently been in question. Both of these HHC methods are simulated in steady and constant-thrust maneuvering flight, as well as in conditions of incorrect transfer matrix initialization. The results indicate fixed-gain control can adequately reduce vibrations for the helicopter modeled, as long as the flight condition is within about 20 knots of the flight condition used to calculate gains. Author

**A89-50058#**  
**ANALYTICAL STUDY OF THE SUBSONIC WING-ROCK PHENOMENON FOR SLENDER DELTA WINGS**

A. H. NAYFEH, J. M. ELZEBDA, and D. T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 805-809. refs  
 (Contract AF-AFOSR-85-0158)

An analytic expression describing the aerodynamic roll moment has been obtained from the numerical simulation of wing rock. This expression is used in the equation governing the rolling motion of a delta wing around its midspan axis. The result is used to construct phase planes, which reveal the general global nature of wing rock-stable limit cycles, unstable foci, saddle points, and domains of initial conditions leading to oscillatory motion and divergence. An asymptotic approximation to the solution of the governing equations is obtained; this result provides expressions for the amplitudes and frequencies of limit cycles. The present analysis provides a penetrating global view of the wing-rock phenomenon. Author

**A89-50061#**  
**ACTIVE AERODYNAMIC STABILIZATION OF A HELICOPTER/SLING-LOAD SYSTEM**

AVIV ROSEN, TUVIA RONEN (Technion - Israel Institute of Technology, Haifa), and REUBEN RAZ (International Conference on Rotorcraft Basic Research, 2nd, College Park, MD, Feb. 16-18, 1988, Proceedings, 12 p.) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 822-828. Previously cited in issue 22, p. 3655, Accession no. A88-51784. refs

**A89-50365**  
**USE OF MULTIPROCESSOR TECHNOLOGY FOR ACTIVE DISTURBANCE VARIABLE SUPPRESSION IN A HELICOPTER [NUTZUNG DER MULTIPROZESSORTECHNIK ZUR AKTIVEN STOERGRÖSSENUNTERDRUECKUNG AM BEISPIEL EINES HUBSCHRAUBERS]**

KLAUS-GERT BESEL, BERND GELHAAR, and HANS-PETER SCHWANECK (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0011-4901), June 1989, p. 34-37. In German.

A modular microprocessor system using transputers as basic components has been developed in order to minimize rotor vibrations in helicopters by higher harmonic control. The computer architecture is new and involves a combination of transputer with the OCCAM language. The realization of this controller and results obtained with it are reported. C.D.

**A89-50585**  
**RIDE-BUMPINESS IN HIGH-SPEED FLIGHT AT LOW ALTITUDE**

J. G. JONES and D. E. FRY (Royal Aerospace Establishment, Farnborough, England) Aeronautical Journal (ISSN 0001-9240), vol. 93, June-July 1989, p. 219-228. refs

Aircraft longitudinal ride-bumpiness during flight at high speed and low altitude is described in terms of the response to discrete gust patterns. Results are expressed statistically in a form that incorporates data from recent turbulence measurements. Effects of basic airframe parameters and of active controls are illustrated and data from a computer-simulation study are used to confirm the validity of the prediction method. Author

**A89-50926**  
**MOTION STABILITY OF A RIGID BODY IN NONSTATIONARY FLOW [OB USTOICHIVOSTI DVIZHENIIA TVERDOGO TELA V NESTATSIONARNOM POTOKE]**

V. S. SERGEEV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), May-June 1989, p. 18-22. In Russian. refs

The problem of rigid body motion in nonstationary flow of a gas is analyzed using a flow model that leads to a system of integro-differential equations. In particular, attention is given to the case where the characteristic exponents of the fundamental

system of solutions to linearized equations contain one zero exponent in addition to negative exponents. The conditions of instability are determined from second-order terms of the right terms of the equations. V.L.

A89-51009

**AIR TRAFFIC CONTROL [UPRAVLENIE VOZDUSHNYM DVIZHENIEM]**

TAT'IANA G. ANODINA, SERGEI V. VOLODIN, VIKTOR P. KURANOV, and VLADIMIR I. MOKSHANOV Moscow, Izdatel'stvo Transport, 1988, 232 p. In Russian. refs

The ATC system is considered as a complex multilevel control system. The principles of the operation and interaction of ground and onboard ATC, navigation, landing, and communication aids are presented along with the principles of flight navigation support. Practical approaches to the development and efficiency evaluation of ATC plans are described. B.J.

A89-51359\* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**HIGH-ALPHA FLIGHT DYNAMICS RESEARCH ON THE X-29 CONFIGURATION USING DYNAMIC MODEL TEST TECHNIQUES**

MARK A. CROOM, RAYMOND D. WHIPPLE, DANIEL G. MURRI, SUE B. GRAFTON, and DAVID J. FRATELLO (NASA, Langley Research Center, Hampton, VA) IN: Advanced aerospace aerodynamics; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 125-138. refs  
(SAE PAPER 881420)

High-angle-of-attack flight dynamics of the X-29 configuration were studied using dynamic model test techniques. These tests identified phenomena including wing rock, spins, and tumbling which dominate the high-alpha behavior of the configuration and define its usable flight envelope. Results of these tests have been used to design flight control concepts to minimize adverse behavior. Planned high-angle-of-attack flight tests of the X-29 airplane will provide an opportunity to validate the model predictions. Author

N89-26857 Department of the Air Force, Washington, DC.

**CONTROL SURFACE DUAL REDUNDANT SERVOMECHANISM Patent**

CLETE M. BOLDRIN, inventor (to AF), RICHARD D. MCCORKLE, inventor (to AF), JIMMY W. RICE, inventor (to AF), and JAMES J. RUSTIK, inventor (to AF) 31 Jan. 1989 6 p Filed 11 Dec. 1984

(AD-D014058; US-PATENT-4,800,798; US-PATENT-APPL-SN-680674) Avail: US Patent and Trademark Office CSCL 09/1

A dual redundant servomechanism for moving aircraft control surfaces is disclosed. The servomechanism is of the type whose input commands, from the pilot of the aircraft, are transmitted electrically. Force fight, which is associated with such dual servomechanisms when they are connected to a common aircraft control surface, is minimized. This is accomplished by providing the control system for each servomechanism with input signals which are electrically summed. Each control system includes electrical transducers which provide a signal indicative of actuator position and the pressure associated with the hydraulic motor used in each servomechanism. GRA

N89-26858 Department of the Air Force, Washington, DC.

**BRAIN O2 RESERVE LIMITER FOR HIGH PERFORMANCE AIRCRAFT Patent**

ROBERT E. VANPATTEN, inventor (to AF) 18 Apr. 1989 6 p Filed 7 Apr. 1987 Supersedes AD-D012902

(AD-D014137; US-PATENT-4,821,982; US-PATENT-APPL-SN-035425; US-PATENT-CLASS-244-76R) Avail: US Patent and Trademark Office CSCL 01/4

A method for controlling an aircraft to prevent high G-caused pilot unconsciousness is disclosed. Data defining a state space of acceleration, rate of change of acceleration and duration of

acceleration at maximum acceleration within which an aircraft may be operated without causing pilot unconsciousness is provided to an aircraft intelligent flight control system. The flight control system continuously monitors the past and present state of the aircraft and compares to the surface boundaries of the defined safe state space. Whenever the aircraft exceeds those boundaries, the flight control system intervenes to unload the aircraft to within those boundaries. Additional data and measurements may be added to define an n-dimensional state space. Another embodiment unloads the aircraft to a baseline acceleration. A simplified embodiment is described which compares current acceleration to a preselected value of acceleration. If the current acceleration exceeds the preselected value, the previous acceleration onset rate is compared to a preselected acceleration onset rate. If it exceeds the preselected onset rate, the duration of time the current and immediately past acceleration has exceeded the preselected value of acceleration is determined. If that value is greater than a preselected duration, the flight control system commands the aircraft to perform an unloading maneuver to reduce the G loading on the aircraft to a preselected baseline acceleration. GRA

N89-26859\*# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.

**DESIGN OF AN ACTIVE HELICOPTER CONTROL EXPERIMENT AT THE PRINCETON ROTORCRAFT DYNAMICS LABORATORY Interim Report, Jan. 1988 - May 1989**

ANDREW M. MARRAFFA and R. M. MCKILLIP, JR. May 1989 106 p

(Contract NAG2-415)

(NASA-CR-185490; NAS 1.26:185490) Avail: NTIS HC A06/MF A01 CSCL 01/3

In an effort to develop an active control technique for reducing helicopter vibrations stemming from the main rotor system, a helicopter model was designed and tested at the Princeton Rotorcraft Dynamics Laboratory (PRDL). A description of this facility, including its latest data acquisition upgrade, are given. The design procedures for the test model and its Froude scaled rotor system are also discussed. The approach for performing active control is based on the idea that rotor states can be identified by instrumenting the rotor blades. Using this knowledge, Individual Blade Control (IBC) or Higher Harmonic Control (HHC) pitch input commands may be used to impact on rotor dynamics in such a way as to reduce rotor vibrations. Discussed here is an instrumentation configuration utilizing miniature accelerometers to measure and estimate first and second out-of-plane bending mode positions and velocities. To verify this technique, the model was tested, and resulting data were used to estimate rotor states as well as flap and bending coefficients, procedures for which are discussed. Overall results show that a cost- and time-effective method for building a useful test model for future active control experiments was developed. With some fine-tuning or slight adjustments in sensor configuration, prospects for obtaining good state estimates look promising. Author

N89-26860\*# Systems Technology, Inc., Hawthorne, CA.

**DESIGN CONSIDERATIONS OF MANIPULATOR AND FEEL SYSTEM CHARACTERISTICS IN ROLL TRACKING Final Report**

DONALD E. JOHNSTON and BIMAL L. APONSO Washington Feb. 1988 240 p

(Contract NAS2-12221)

(NASA-CR-4111; H-1438; NAS 1.26:4111) Avail: NTIS HC A11/MF A01 CSCL 01/3

A fixed-base simulation was performed to identify and quantify interactions between the pilot's hand/arm neuromuscular subsystem and such control system features of typical modern fighter aircraft roll rate command mechanizations as: (1) force versus displacement sensing side-stick type manipulator, (2) feel force/displacement gradient, (3) feel system versus command prefilter dynamic lag, and (4) flight control system effective time delay. The experiment encompassed some 48 manipulator/filter/aircraft configurations. Displacement side-stick experiment results are given and compared with the previous force

## 08 AIRCRAFT STABILITY AND CONTROL

sidestick experiment results. Attention is focused on control bandwidth, excitement (peaking) of the neuromuscular mode, feel force/displacement gradient effects, time delay effects, etc. Section 5 is devoted to experiments with a center-stick in which force versus displacement sensing, feel system lag, and command prefilter lag influences on tracking performance and pilot preference are investigated. Author

**N89-26861\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **AERODYNAMIC PARAMETERS OF AN ADVANCED FIGHTER AIRCRAFT ESTIMATED FROM FLIGHT DATA. PRELIMINARY RESULTS**

VLADISLAV KLEIN, KEVEN P. BRENNEMAN, and THOMAS P. RATVASKY (Joint Inst. for Advancement of Flight Sciences, Hampton, VA.) Jul. 1989 59 p (NASA-TM-101631; NAS 1.15:101631) Avail: NTIS HC A04/MF A01 CSCL 01/3

Preliminary estimates of aerodynamic parameters of an advanced fighter aircraft were obtained from flight data of different values of the angle of attack from 8 to 54 deg. The data were analyzed by a stepwise regression with the ordinary least squares technique. The estimated stability and control derivatives are plotted against the angle of attack and compared with wind tunnel measurement and previous flight results. Also included is the data compatibility check of measured data. The effect of various input forms on the estimates is demonstrated in two examples using simulated data. Author

**N89-26862#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Unternehmensbereich Transportflugzeuge. **ELECTRICAL PRIMARY FLIGHT CONTROL SYSTEM (FLY BY WIRE). FLIGHT CONTROL SYSTEMS OF NEW TECHNOLOGY Final Report, Dec. 1987**

U. B. CARL Jun. 1988 202 p In GERMAN; ENGLISH summary Original contains color illustrations (Contract BMFT-LFL-8360-7) (MBB-UT-122/88; ETN-89-94615) Avail: NTIS HC A10/MF A01

Results of a predevelopment program for Fly by Wire (FBW) flight control systems in civil aircraft are presented. The concept is based on requirements for certification of safety-critical functions, capacity of the computer systems to implement active control function (gust load alleviation, variable camber wing control etc) and a cockpit standard with mini-stick and digital display and operation systems. The experimental system consists of a quad-redundant, fault-tolerant multicomputer system and a quadruplex Actuator Electronic Unit (AEU) providing the redundancy management and force synchronization of parallel-active electrohydraulic servoactuators. The computer-interlane communication is by fiber optics. By A300/310 flight simulator-investigations the control laws with command and flight envelope protections are validated. The experimental system was tested in a rig with aircraft-simulation in the loop. The control and redundancy management-concept for the AEU's and parallel-redundant actuator configurations are verified by test results. ESA

**N89-26863#** Naval Postgraduate School, Monterey, CA. **FEASIBILITY STUDY FOR ENHANCED LATERAL CONTROL OF THE P-3C AIRCRAFT M.S. Thesis**

KIMBERLY K. SMITH Mar. 1989 118 p (AD-A208461) Avail: NTIS HC A06/MF A01 CSCL 01/4

New mission requirements dictate the need to improve the P-3's defensive maneuvering capabilities. Research was conducted to find viable methods of increasing the current roll response of the P-3. First, a flight simulator was used to determine an initial target roll response. Next, a computer code was used to evaluate the aerodynamic effect of varying the size and deflection of the aileron. These results, along with the flight simulator tests, were used to analyze the requirements to reach the target response. Several ways to achieve this goal are discussed. It was found that by increasing the aileron deflection from + or - 20 deg to + or - 25 deg and increasing the aileron chord by 50 percent, a 58

percent increase in  $C_i$  (total rolling moment coefficient) could be realized. This does not reach the goal of a 100 percent increase in  $C_i$ , but, it does yield a large increase in lateral control response. An increase in aileron size and deflection along with some of the other suggested modifications would certainly approach the desired goal. GRA

**N89-27672\*#** Sverdrup Technology, Inc., Cleveland, OH. **STABILITY ROBUSTNESS IMPROVEMENT OF DIRECT EIGENSPACE ASSIGNMENT BASED FEEDBACK SYSTEMS USING SINGULAR VALUE SENSITIVITIES Final Report**

SANJAY GARG Aug. 1989 32 p Presented at the American Control Conference, Pittsburgh, PA, 21-23 Jun. 1989; sponsored in part by American Automatic Control Council (Contract NAS3-25266) (NASA-CR-182302; E-4853; NAS 1.26:182302) Avail: NTIS HC A03/MF A01 CSCL 01/3

A methodology to improve the stability robustness of feedback control systems designed using direct eigenspace assignment techniques is presented. The method consists of considering the sensitivity of the minimum singular value of the return difference transfer matrix at the plant input to small changes in the desired closed-loop eigenvalues and the specified elements of the desired closed-loop eigenvectors. Closed-form expressions for the gradient of the minimum return difference singular value with respect to desired closed-loop eigenvalue and eigenvector parameters are derived. Closed-form expressions for the gradients of the control feedback gains with respect to the specified eigenspace parameters are obtained as an intermediate step. The use of the gradient information to improve the guaranteed gain and phase margins in eigenspace assignment based designs is demonstrated by application to an advanced fighter aircraft. Author

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### RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

**A89-47666\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **ANALYSIS OF VIBRATIONS OF THE NATIONAL TRANSONIC FACILITY MODEL SUPPORT SYSTEM USING A 3-D AEROELASTIC CODE**

WOODROW WHITLOW, JR., ROBERT M. BENNETT, and THOMAS W. STRGANAC (NASA, Langley Research Center, Hampton, VA) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 398-407. refs (AIAA PAPER 89-2207)

Vibrations of the National Transonic Facility model support system were analyzed using Computational Aeroelasticity Program-Transonic Small Disturbance, a three-dimensional transonic small disturbance code designed for aeroelastic analysis of complete aircraft. The model support system was represented as a tunnel-spanning flexible wing whose structural properties were obtained from measured responses. Aeroelastic transients were calculated and analyzed to obtain modal stability characteristics. The results show that there is tendency to exhibit a hump mode instability in one of the modes, and that there are other weakly damped or unstable modes. Most of the motion is in the aft section of the model support system. The close proximity of the solid wind-tunnel diffuser side walls to the model support system is shown to have adverse effects on its aeroelastic stability characteristics. When the effects of the wind-tunnel walls are modeled, the analyses indicate the presence of wind-tunnel

resonance modes which are not present when free-air boundary conditions are used. Author

**A89-48376****AIAA FLIGHT SIMULATION TECHNOLOGIES CONFERENCE AND EXHIBIT, BOSTON, MA, AUG. 14-16, 1989, TECHNICAL PAPERS**

Conference and Exhibit sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 482 p. For individual items see A89-48377 to A89-48438.

Recent advances in the design and application of flight simulators are discussed in reviews and reports. Topics examined include verification and validation, space simulations, simulator sickness and cue synchronization, motion cueing, simulation languages, modeling, visual systems, and crew-station design. Also addressed are computer systems, training systems, computational methods, air-combat simulations, and in-flight simulations. Consideration is given to Space Shuttle payload simulations and astronaut training, the use of vestibular models for design and evaluation of simulator motion, model-based terrain-following displays, synchronization and time tagging in distributed real-time simulation, a voice-operated instructor station, a full-FOV dome display system, eye movement in air-to-air combat tasks, and in-flight simulation of unstable aircraft systems. T.K.

**A89-48377#****A COMPREHENSIVE COLLECTION OF PROCEDURES FOR SIMULATION VERIFICATION**

MATTHEW S. MIDDENDORF, WILLIAM V. JOHNSON, MICHAEL J. GILKEY, and TERRENCE D. MCCLURG (Systems Research Laboratories, Inc., Dayton, OH) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-7. refs (AIAA PAPER 89-3260)

Procedures for verifying the dynamic model and other components of flight simulators and other real-time simulation systems are recommended. Topics discussed include timing integrity, vehicle dynamics, visual-loop and motion-loop delay measurements, motion-device scaling, and communication validation. Consideration is given to verification of the graphics equations, gust spectra and gust filters, control scaling and deadband verification, numerical/mathematical issues, and verification of the scoring algorithm. The need to supplement the quantitative tests presented here with subjective evaluations (e.g., visual inspection of collected time-history plots) is indicated. T.K.

**A89-48379#****USE OF A SIMPLIFIED ESTIMATION SCHEME FOR SIMULATION VALIDATION AND IMPROVEMENT**

ROBERT A. HESS and PETER L. LY (Systems Control Technology, Inc., Flight Simulation Group, Lexington Park, MD) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 14-20.

(AIAA PAPER 89-3262)

This paper discusses the development and use of an estimation scheme imbedded into a simulation environment. This scheme allows the simulation engineer to model errors in the simulation response as intrinsically linear functions of simulation variables by comparing the simulation response to response taken from actual systems. The applicability of this tool is demonstrated. Author

**A89-48380#****FLIGHT RECONSTRUCTION TECHNIQUES FROM FLIGHT RECORDER DATA FOR SIMULATION AND TRAINING**

K. KRISHNAKUMAR, J. E. BAILEY (Alabama, University, Tuscaloosa), and R. K. PRASANTH IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 21-30. refs

(AIAA PAPER 89-3263)

The concept of using limited 'black-box' flight data for simulator flight reconstruction is introduced and the requirements are discussed. An extended linearized continuous Kalman filter design is utilized as a state estimator flight simulator driver. Actual Kalman filter implementation utilizes a UH-60 helicopter nonlinear simulation (linearized aerodynamics) for state propagation to facilitate easy transition between flight reconstruction and manual simulation. System performance in relation to flight recorder data limitations is discussed. The resulting reconstruction system is demonstrated using both simulated data and a UH-60 'black-box' derived data.

Author

**A89-48386#****NEED-BASED EVALUATION OF SIMULATOR FORCE AND MOTION CUEING DEVICES**

YORKE J. BROWN (Cardullo, Brown and Associates, Binghamton, NY), FRANK M. CARDULLO (New York, State University, Binghamton), and JOHN B. SINACORI (John B. Sinacori Associates, Pebble Beach, CA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 78-85. refs (AIAA PAPER 89-3272)

An analytical technique is developed to describe the relationship between an aircraft pilot's sensation of motion cues during specific maneuvers and the sensations produced by a simulator equipped with force and motion cueing devices. The fundamental principles of human motion perception are reviewed; the characteristics of aircraft motion are summarized; a simple model of the signal-processing steps in the perception of aircraft/simulator motion is outlined; and the sample case of Gz cueing is presented in detail. It is shown that correct analysis of the aircraft-motion cues, sensory responses, and simulator capabilities makes it possible to evoke the pilot sensations using presently available or technologically feasible devices. T.K.

**A89-48387\*# Massachusetts Inst. of Tech., Cambridge. THE USE OF VESTIBULAR MODELS FOR DESIGN AND EVALUATION OF FLIGHT SIMULATOR MOTION**

STEVEN R. BUSSOLARI, LAURENCE R. YOUNG (MIT, Cambridge, MA), and ALFRED T. LEE (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 86-93. Previously announced in STAR as N89-12179. refs (Contract NAG2-12) (AIAA PAPER 89-3274)

Quantitative models for the dynamics of the human vestibular system are applied to the design and evaluation of flight simulator platform motion. An optimal simulator motion control algorithm is generated to minimize the vector difference between perceived spatial orientation estimated in flight and in simulation. The motion controller has been implemented on the Vertical Motion Simulator at NASA Ames Research Center and evaluated experimentally through measurement of pilot performance and subjective rating during VTOL aircraft simulation. In general, pilot performance in a longitudinal tracking task (formation flight) did not appear to be sensitive to variations in platform motion condition as long as motion was present. However, pilot assessment of motion fidelity by means of a rating scale designed for this purpose, were sensitive to motion controller design. Platform motion generated with the optimal motion controller was found to be generally equivalent to that generated by conventional linear crossfeed washout. The vestibular models are used to evaluate the motion fidelity of transport category aircraft (Boeing 727) simulation in a pilot performance and simulator acceptability study at the Man-Vehicle Systems Research Facility at NASA Ames Research Center. Eighteen airline pilots, currently flying B-727, were given a series of flight scenarios in the simulator under various conditions of simulator motion. The scenarios were chosen to reflect the flight maneuvers that these pilots might expect to be given during a routine pilot proficiency check. Pilot performance and subjective

## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

rating of simulator fidelity was relatively insensitive to the motion condition, despite large differences in the amplitude of motion provided. This lack of sensitivity may be explained by means of the vestibular models, which predict little difference in the modeled motion sensations of the pilots when different motion conditions are imposed. Author

**A89-48388#**

### **THE DYNAMIC SEAT AS AN ANGULAR CUEING DEVICE - CONTROL OF ROLL AND PITCH VS. THE CONTROL OF ALTITUDE AND HEADING**

JEFFREY D. CRESS, MICHAEL J. GILKEY (Systems Research Laboratories, Inc., Dayton, OH), and GRANT R. MCMILLAN (USAF, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 94-100. refs (AIAA PAPER 89-3336)

The effectiveness of a dynamic seat as a cueing device is investigated experimentally. Six nonpilots with normal vision perform roll, pitch, heading, and altitude control tasks with and without dynamic-seat roll and pitch cues at seat gain levels up to 0.7. It is found that tracking error is reduced when seat motion cues are provided, by 30 percent for pitch, roll, and heading control but only by 8 percent for altitude control. It is also shown that reducing gain to 50 percent of maximum has no adverse effect on task performance, but that further reduction leads to a sharp increase in tracking error. T.K.

**A89-48389#**

### **G-SEAT HEAVE MOTION CUEING FOR IMPROVED HANDLING IN HELICOPTER SIMULATORS**

A. D. WHITE (Royal Aerospace Establishment, Bedford, England) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 101-108. refs (AIAA PAPER 89-3337)

The aim of this investigation was to determine whether a hydraulic g-seat can provide beneficial cueing in a Nap of the Earth (NOE) environment. The g-seat has been evaluated using an agile helicopter model and tasks which emphasize maneuvering in the vertical plane. Results indicate that the seat not only greatly enhances the sense of realism of the simulator, but also enables pilots to control vehicle height more realistically and effectively. Analysis of the data supports pilots' subjective impressions that performance was improved when the g-seat was in operation, typically showing reduced overcontrol and more consistent handling, even in hover. Author

**A89-48394#**

### **DEVELOPMENT OF AN AUTONOMOUS LANDING GUIDANCE SYSTEM SIMULATION MODEL**

JAMES M. ZEH, DANIEL L. YOUNG, and NORMAN J. COUTURE, JR. (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 139-152. (AIAA PAPER 89-3282)

This paper addresses the development and application of an Autonomous Landing Guidance (ALG) simulation. The autonomous landing scenario requires a pilot to locate, designate, and land on a bomb damaged runway using only on-board systems. To accomplish this task the high fidelity S/MTD aircraft simulation was used in the Large Amplitude Multi-mode Aerospace Research Simulator. Approximately 120 hours of pilot-in-the-loop evaluations were conducted to validate and optimize the ALG simulation. Recommendations resulting from this testing were implemented in the S/MTD aircraft flight control computer before actual ALG flight tests. Author

**A89-48396#**

### **MODELING ATMOSPHERIC EFFECTS FOR FLIGHT SIMULATORS**

PAUL A. ROBINSON IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 168-175. refs (AIAA PAPER 89-3284)

This study investigates the degree of complexity required in the simulation of turbulence and thunderstorm downbursts for flight simulation. A turbulence model is presented which contains all the correlations found in homogeneous isotropic turbulence. Several simplifications and alternate models are considered. This paper also presents further developments in the simulation of thunderstorm downbursts. A single ring vortex system and a more complicated triple ring vortex system are compared to Joint Airport Weather Studies (JAWS) data sets. By means of pilot evaluations on the UTIAS B-747 Flight Research Simulator, it was found that the inclusion of the isotropic turbulence correlations did not seem to affect the pilot, and not much difference was perceived among the turbulence models. It was also found that the inclusion of the gust time derivatives in the aircraft equations of motion was an important factor affecting the realism of the simulation. Downburst evaluations showed that both single and triple ring vortex systems were able to simulate actual downbursts (JAWS data). It is suggested that the ring vortex models be expanded upon to include more than one cell. Author

**A89-48398#**

### **NIGHT VISION GOGGLES - TERRAIN AND FEATURE SHADOWING FOR CIG DATABASES**

ROBERT GEER (Evans and Sutherland Computer Corp., Salt Lake City, UT) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 183-187. (AIAA PAPER 89-3286)

Techniques are developed to improve the performance of flight-simulator computer-generated images of night scenes with shadows for pilots wearing night-vision goggles. The problems addressed include moon shadowing, terrain shadowing, feature shadowing, and terrain shadowing of features. It is shown that, with a visual data base constructed using shadow masks photo-repeating texture, and static model systems, currently available image-generation hardware is capable of reproducing the shadowing appropriate for pilots wearing goggles. T.K.

**A89-48399#**

### **STEREOPSIS AS A VISUAL CUE IN FLIGHT SIMULATION**

REED P. TIDWELL (Evans and Sutherland Computer Corp., Salt Lake City, UT) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 188-194. refs (AIAA PAPER 89-3288)

This paper discusses stereopsis, and its role in visual systems for flight simulators. The role of stereopsis as a depth cue, and ways that stereo images may be created and presented are outlined. The limits of stereopsis as a visual cue in the simulated environment are quantified by experiments performed with an Evans and Sutherland ESIG-1000 computer images generator (CIG). The focus of the experiments is to isolate sensitivity to stereoscopic cues. Costs and potential benefits of stereopsis are discussed. Results indicate that stereoscopic cues created by a simulator are valid to distances which would make them valuable for several applications, and that further study with stereoscopic simulators is justified and necessary. Author

**A89-48400#**

### **STEREOPSIS CUEING EFFECTS ON A SIMULATED PRECISION ROTORCRAFT 'HOVER-IN-TURBULENCE' TASK**

S. P. WILLIAMS and R. V. PARRISH IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16,



1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 195-212. refs (AIAA PAPER 89-3289)

The effectiveness of stereopsis depth cuing in flight-simulator visual displays was investigated experimentally. Six experienced U.S. Army helicopter pilots performed a precision hover-in-turbulence task on a simulator with an out-the-window display having either (1) no depth cues other than perspective; (2) realistic size, shape, interposition, and parallax cues; or (3) a hyperstereo view such as that provided by side-mounted FLIR cameras. Also tested was a head-up velocity display. The implementation of the experiment is described in detail; sample displays are shown; and the results are presented in extensive tables and graphs. It is found that the baseline task performance with (1) was improved by either (2) or (3) and further enhanced by the velocity display. The stereo displays also reduced the pilot control effort. T.K.

#### A89-48401#

##### MODEL-BASED TERRAIN-FOLLOWING DISPLAY DESIGN

PAUL G. GONSALVES, EDWARD W. KNELLER, and GREG L. ZACHARIAS (Charles River Analytics, Inc., Cambridge, MA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 213-220. refs (Contract F33615-86-C-0551) (AIAA PAPER 89-3290)

A model-based method for terrain-following cockpit display design and evaluation is presented. Two basic display configurations along with several display enhancements are evaluated via a combined analytical modeling and experimental simulation effort. The method entails the use of an integrated pilot/vehicle/display model to analyze and predict pilot performance trends as a function of display content/format. Model-based display design is supported and evaluated via real-time pilot-in-the-loop simulation. Author

#### A89-48403#

##### THE MODULAR COCKPIT APPROACH TO AIRCREW TRAINING DEVICE DEVELOPMENT

JAMES P. EXTER (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 226-232. (AIAA PAPER 89-3293)

A modular helicopter-crew training simulation system is described. In the modular approach, a basic cockpit containing all the aircraft-specific components can be used for part-task, familiarization, full-mission, and team training, and the visual display environment can also be used with different cockpit modules. Details of the hardware and software development and implementation for the LHX military helicopter are discussed and illustrated with diagrams, with an emphasis on the role of state-of-the-art single-board microprocessors and graphics computers. The modular approach is shown to offer significant savings in hardware and software development, acquisition, and life-cycle costs and to provide a development environment for adding new avionics or weapon systems. It should also be applicable to advanced fixed-wing aircraft. T.K.

#### A89-48404#

##### MAN-IN-THE-LOOP SIMULATION AS A DESIGN TOOL

P. H. CERCHIE (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 233-236. (AIAA PAPER 89-3294)

The application of part-task and full man-in-the-loop (MITL) simulations at early stages of the avionics design process is discussed, with a focus on the case of a night-mission

obstacle-avoidance system (OAS) for military helicopter pilots. An AH-64 engineering simulator with both a dome display and an integrated helmet and display sight system was employed to evaluate combinations of four OAS sensor models and two detection ranges, which were treated as software systems; the visual data base represented a 34-km-long winding canyon with high walls, trees, and obstacles such as power lines. After initial simulation trials of OAS prototypes were performed by software engineers, test pilots tested the OAS versions in a realistic simulation environment. The early use of simulations efficiently identified the most promising OAS versions and reduced the number of full simulations required in the later stages of development. T.K.

#### A89-48405#

##### MODULAR AIRCREW SIMULATION SYSTEMS - 1989 ADVANCES

DAVID E. POWELL and JAMES W. DILLE (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 237-242. (AIAA PAPER 89-3296)

Large scale multiship manned simulations are increasingly necessary for the development of advanced aircraft systems and for effective aircrew training. This paper discusses the development of technologies to achieve this capability in an affordable manner. These technologies include reconfigurable cockpit systems, the rehosting of full fidelity aircraft simulations onto parallel architecture microcomputer systems, and the development of real time simulation networks. Author

#### A89-48406#

##### NAL FLIGHT SIMULATOR REAL-TIME COMPUTER SYSTEMS

AKIRA WATANABE, KAORU WAKAIRO, and HIROYASU KAWAHARA (National Aerospace Laboratory, Chofu, Japan) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 243-251. refs (AIAA PAPER 89-3297)

The Japanese National Aerospace Laboratory flight simulator is described, with special attention given to the synchronization of, and data transfer among, the subsystem computers. The simulator consists of a cockpit (which is similar to that of a STOL research aircraft), a visual system (using the IMAP program to generation visual models through interaction with the digitizer and the display), a 6-DOF-type motion system, and a real-time computer system. Six configurations of the system are described in detail. Data transfer is accomplished using a nonorder and independent repeat method. The system does not require hardware for time synchronization, and the data transfer cycle is several times larger than the task execution cycle in order to decrease the system delay time. R.R.

#### A89-48408#

##### SYNCHRONIZATION AND TIME TAGGING IN DISTRIBUTED REAL TIME SIMULATION

AMNON KATZ, DANIEL M. ALLEN, and JOSEPH S. DICKSON (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 259-261. (AIAA PAPER 89-3300)

A system for synchronization and time tagging for distributed real time simulation is introduced. It is based on three 'times': time of day (TOD), mission time (MT), and dynamic time (DT). All three are relative times reckoned in 'ticks'. TOD runs continuously and synchronously in all components of the simulation. It is used to insure synchronous transitions of all components to and from the RUN state. MT and DT are accumulated in RUN and frozen in other simulator state. MT is the mission clock representing



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time that the simulator is 'flying' and the cumulative time from the (arbitrary) start of the simulated flight. Author

**A89-48412#**

### **AN EXPERIMENTER OPERATOR STATION FOR HELICOPTER FLIGHT SIMULATOR RESEARCH AND TRAINING**

THOMAS A. KAYE (Bell Helicopter Textron, Fort Worth, TX) and L. MICHAEL FREEMAN (Alabama, University, Tuscaloosa) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 293-303.

(AIAA PAPER 89-3304)

A multipurpose research-oriented operator support station for controlling a low-cost helicopter flight simulator while simultaneously monitoring and recording pilot performance data for subsequent display or statistical postprocessing is described. The system is a mouse-oriented menu-driven interactive program, with structured program design methods employed to create a modular software package capable of handling data acquisition and graphic display of flight performance variables at real-time speeds of up to 30 Hz. The system is also designed to handle intermittent user-requested simulator control directives. Recorded data files can be created during simulated flights for subsequent statistical analysis or flight replay, with application to the optimization of simulator pilot training. R.R.

**A89-48416#**

### **NONLINEAR MODEL FOLLOWING CONTROL APPLICATION TO A FLIGHT SIMULATOR CONTROL LOADER**

WAYNE C. DURHAM IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 324-329.

(AIAA PAPER 89-3308)

Perfect explicit model following control laws for a flight simulator control loader problem are developed. The control loader is digitally controlled and uses a direct drive dc motor (torque motor) to simulate airplane control stick forces and displacements. The control laws deal directly with the nonlinearities present in the modeled control system and in the motor, and reduce the problem to one of a second order regulator involving the error. The error dynamics for the nonlinear problem are determined by conventional pole placement methods. The method is illustrated with an example, wherein the simulated control system features breakout forces, nonlinear friction, and hysteresis in the spring forces. Author

**A89-48417#**

### **SIMULATION MADE EASY - THE DEVELOPMENT OF AN INTEGRATED DATA DRIVEN SIMULATION OPERATING SYSTEM**

DAVID A. POOLE (Veda, Inc., Systems Div., California, MD) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 330-335.

(AIAA PAPER 89-3309)

An integrated operating system for a low-cost aerodynamic simulator has been developed which is based on a distributed microprocessor architecture (GENESIS) and which allows the user simple single point access to the many processors in the system. Using the GENESIS simulator, any 6-DOF aerodynamic model can be fully defined through the use of a simple menu system. Such characteristics of the processing pipeline as the transport time, the computational accuracy, and the system bandwidth of the overall simulation are discussed in detail. Other topics considered include the GENESIS processor architecture, the model structure and the coefficient implementation of the data driven operating system, and applications of the system. R.R.

**A89-48420\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **DEVELOPMENT OF A TACTICAL GUIDANCE RESEARCH AND EVALUATION SYSTEM (TGRES)**

KENNETH H. GOODRICH and JOHN W. MCMANUS (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 350-356. refs (AIAA PAPER 89-3312)

The ongoing development of a tool for tactical guidance research and the analysis of airplane system performance in a tactically significant environment are described. The objective of the tool is to provide a means by which researchers can explore and exploit enhancements to high-performance airplane agility. The completed tool will include high-fidelity batch and piloted simulation capabilities, an advanced tactical guidance logic, and a user-friendly interface. While the tool is being developed for the purpose of studying fighter agility, its modularity should make it easily adaptable to the analysis of other technologies and, thus, be of interest to a number of potential users. Author

**A89-48424#**

### **COOPERATIVE SIMULATION EFFECTIVENESS ANALYSIS**

PAUL A. MARCHISOTTO and DAVID A. BLANCETT (Northrop Corp., Aircraft Div., Hawthorne, CA) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 383-389. refs (AIAA PAPER 89-3338)

A multilayered interactive analysis approach is proposed which uses both manned and unmanned simulations to investigate advanced aircraft design concepts and technologies. The manned simulations provide insights into the aircraft design and requirements analysis process through the measurement of situation awareness and the development of new tactics. The unmanned simulations, characterized by flexibility, repeatability, and ease of execution, can be used as a screening process from which the key issues, or driving technologies for mission effectiveness, can be identified for later evaluation in the manned simulation. The unmanned simulations can also be used to identify technologies which are highly dependent on pilot decisions and interaction with the aircraft. R.R.

**A89-48425#**

### **FULL FIELD OF VIEW DOME DISPLAY SYSTEM**

BRIAN A. RENO (USAF, Human Resources Laboratory, Williams AFB, AZ) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 390-394.

(AIAA PAPER 89-3316)

The requirements for a visual system to adequately support a fighter aircraft's missions, particularly the low level and air-to-ground scenarios, are very demanding. Present day visual systems lack the brightness, FOV, and/or resolution to satisfy these requirements. The Full Field of View Dome Display System is an effort to address this problem by providing a display system with higher brightness and resolution than previously attained in a dome simulator over 100 percent of the FOV of a modern day fighter. Author

**A89-48426#**

### **A UNIVERSAL PROJECTOR FOR SIMULATORS DISPLAYS**

RALPH W. FISHER (Evans and Sutherland Computer Corp., Salt Lake City, UT) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 395-399.

(AIAA PAPER 89-3317)

A universal projector consisting of a common platform, application-specific projection lenses, and source coupling optics is described. This projector can be used in configurations ranging

from a simple target projector to an eye-controlled variable acuity visual system. The application of this detector to each of the target, head controlled, and eye controlled concepts is described. It is shown that the universal projector has no size or performance penalties and that is converted from concept to another by interchanging one or two optical modules and reprogramming control software. K.K.

**A89-48428#**  
**THE ENLARGED FIELD OF VIEW FIBER OPTIC HELMET MOUNTED DISPLAY**

M. THOMAS (USAF, Human Resources Laboratory, Williams AFB, AZ), B. BARRETTE (CAE Electronics, Ltd., Saint Laurent, Canada), M. SHENKER, and P. WEISSMAN (Martin Shenker Optical Design, Inc., White Plains, NY) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 403-408. refs (Contract F33615-81-C-0012) (AIAA PAPER 89-3319)

The development of an enlarged field of view (EFOV) fiber optic helmet mounted display (FOHMD) as Phase V of the FOHMD program is discussed. Two oculometers were developed to the point where eye-servoed operation can be evaluated. The eye servo range was increased to +/- 45 deg horizontally by 25 deg vertically. Continued refinements to the optical head tracker enlarged the tracking envelope to totally encapsulate an F-16 cockpit. K.K.

**A89-48430#**  
**NOVOVIEW LCV - BALANCING PERFORMANCE AND COST FOR A 'LOW COST' VISUAL SYSTEM**

JAMES L. DAVIS (Rediffusion Simulation, Ltd., Crawley, England) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 416-421. (AIAA PAPER 89-3321)

The paper describes Novoview LCV, which is a complete visual system package comprised of a computer image generator, generic data base, one of several standardized displays, a visual control console, installation and integration support, and overall product support. It was found that the key to cost reduction lay in: (1) reducing performance to reduce cost, (2) using standardization to reduce nonrecurring costs, and (3) maintaining system flexibility to ensure economies of scale through broad applicability to a large user population. K.K.

**A89-48434#**  
**IN-FLIGHT AND GROUND BASED SIMULATION - CAPABILITIES AND LIMITATIONS**

STEVEN R. MARKMAN (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 441-445. (AIAA PAPER 89-3328)

Flight simulation has become an indispensable portion of the aircraft development process. Two types of simulation are in common use today: on the ground, using the familiar ground based simulator, or in actual flight, using a specially developed variable stability aircraft, commonly called an in-flight simulator. Ground based and in-flight simulation each have unique capabilities and advantages, along with their own limitations. For a specific task, one type may not be the best choice every time. This paper discusses major capabilities and limitations associated with ground based and in-flight simulation. Author

**A89-48435#**  
**IN-FLIGHT SIMULATION OF UNSTABLE AIRCRAFT SYSTEMS**

MASAKI KOMODA (Tokyo Metropolitan Institute of Technology, Japan), NAGAKATSU KAWAHATA (Nihon University, Chiba, Japan), YUKICHI TSUKANO, and KOKI HOZUMI (National

Aerospace Laboratory, Tokyo, Japan) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 446-451. refs (AIAA PAPER 89-3329)

Simulation errors associated with in-flight simulations of linear and unstable aircraft systems are discussed from flight mechanical viewpoint. It is pointed out that response feedback control schemes are desirable for simulating gust response of any models and control response of stable models but are not applicable for simulating control response of unstable models, and that explicit model-follow system must be exclusively used for simulating unstable models. Flight test results using a variable stability and response airplane are included to support the statement. Author

**A89-48436#**  
**VISTA/F-16 DESIGN FEATURES**

M. V. DUNBAR and J. L. DARGAN (USAF, Wright Research Development Center, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 452-461. (Contract F33615-88-C-3611) (AIAA PAPER 89-3330)

The Variable Stability In-flight Simulator Test Aircraft (VISTA)/F-16 is the next generation U.S. in-flight simulator for high-performance aircraft. The host aircraft for VISTA should have sufficient performance to simulate a wide range of aircraft dynamics. Design of an in-flight simulator requires integrating a variable stability system (VSS) with the existing host aircraft flight control system. For VISTA this involves interfacing new VSS computers with the existing F-16 digital fly-by-wire control system. This also requires a new safety system to ensure that the VSS/host aircraft system is as reliable as the host aircraft. Author

**A89-48439#**  
**DEVELOPMENT OF A REALTIME MAN-IN-THE-LOOP SIMULATION INCORPORATING TRANSPORTABLE ADA FLIGHT CONTROL SOFTWARE**

THOMAS J. FARMER, T. MATTHEW MCGRUTHER, STEVEN H. DEGROOTE (McDonnell Aircraft Co., Saint Louis, MO), and GERARD O. GOEKE (Digital Equipment Corp., Saint Louis, MO) AIAA, Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989. 8 p. (AIAA PAPER 89-3277)

The increasing complexity of advanced aircraft software and the growing sensitivity to software cost makes one-time development of system code for design analysis, realtime simulation and flight test a definite asset in the development of aircraft avionics and control systems. A significant challenge facing Flight Simulation in the 1990s is the integration of embedded software systems directly into existing Flight Simulation software. Two primary obstacles in integrating these embedded systems into realtime simulations are: (1) the embedded software must run at the same rate in the simulator as it runs in the flight hardware; and (2) new embedded software systems are typically developed in Ada, and must be integrated into existing FORTRAN-based simulations. Author

**A89-48740#**  
**DEVELOPMENT OF STRAIN GAGE BALANCES WITH AIR FLOW-THROUGH SYSTEM FOR ONERA WIND TUNNELS**

J. P. BECLE and D. GIRARD (Supersonic Tunnel Association, Semi-Annual Meeting, 71st, Burbank, CA, Apr. 3, 4, 1989) ONERA, TP no. 1989-55, 1989, 23 p. refs (ONERA, TP NO. 1989-55)

The design principles of strain gage balances with compressed air flow-through developed for tests in ONERA wind tunnels are examined, and several examples of these balances are described together with procedures used for the calibration of these devices. Results are presented on tests with standard nozzles used to verify the operation of each balance in terms of its amplitude,

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fidelity, and agreement. Presence of secondary parasitic effects is noted. I.S.

**A89-48762#**

### PRODUCTIVITY AND CRYOGENIC WIND TUNNELS

J. CHRISTOPHE (ONERA, Chatillon-sous-Bagneux, France) (Institut von Karman de Dynamique des Fluides, Special Course on Cryogenic Wind Tunnel, Rhode-Saint-Genese, Belgium, June 5-9, 1989) ONERA, TP no. 1989-80, 1989, 15 p. refs (ONERA, TP NO. 1989-80)

The characteristics of five wind tunnels, the ONERA-CERT T2, the NASA Langley 0.3 m TCT, the DFVLR KKK, the NTF, and the future ETW, are addressed. The characteristic values of the nitrogen consumption are examined, and the thermal balance is discussed. Guidelines for the designers of future wind tunnels are suggested, and unconventional wind tunnel schemes are examined. C.D.

**A89-48763#**

### INSTRUMENTATION FOR CRYOGENIC WIND TUNNELS

MAURICE BAZIN (ONERA, Chatillon-sous-Bagneux, France) (Institut von Karman de Dynamique des Fluides, Special Course on Cryogenic Wind Tunnel, Rhode-Saint-Genese, Belgium, June 5-9, 1989) ONERA, TP no. 1989-81, 1989, 32 p. refs (ONERA, TP NO. 1989-81)

The types of instrumentation needed to ensure measurement quality in cryogenic wind tunnels equal to that obtained in large industrial wind tunnels are discussed. Wind tunnel balances, balance calibration rigs, in situ instrumentation, and optical methods are addressed. Instruments which are used for flow visualization around models, thermovision, model attitude measurements, and deformation measurements are examined. C.D.

**A89-48826**

### FLIGHT SIMULATION: RECENT DEVELOPMENTS IN TECHNOLOGY AND USE; PROCEEDINGS OF THE CONFERENCE, LONDON, ENGLAND, APR. 12, 13, 1988

Conference sponsored by the Royal Aeronautical Society, London, Royal Aeronautical Society, 1988, 235 p. For individual items see A89-48827 to A89-48844.

The present conference discusses functionally-distributed simulation, modularity in tactical flight simulation and computing, graphics displays for real-time monitoring in research simulation, mathematical-model identification for flight simulation, the importance of incorporating atmospheric phenomena in flight simulation, and the use of recent developments to achieve zero-flight-time approvals. Also discussed are integrated ground training for the RAF's Tucano basic trainer, an advanced laser camera for low-level mission simulation, projection displays for flight simulators, transport-delay compensation for computer-generated imagery systems, Ada's impact on flight simulator development, the helmet-mounted visual system in flight simulation, and recent developments in air combat simulation. O.C.

**A89-48828**

### ADVANCED TECHNOLOGY FLIGHT AND VISUAL SIMULATION FOR COMMERCIAL AIRCRAFT

WILLIAM DUNCAN (Rediffusion Simulation, Ltd., Crawley, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 8-24.

The present evaluation of the development status of flight simulation systems for airliners gives attention to the applicable computer hardware and modeling software, automated test systems for simulator checkout and diagnosis, and the state-of-the-art in visual image generators and display systems. The hope that emerging fast-graphics systems for CAD/CAM would lead to lower cost flight simulation image generators has foundered on their inability to function in real time, as required by flight simulators; such image generators also lack the dedicated hardware for such essential special effects as fog and airport lights. O.C.

**A89-48829**

### MODULARITY IN TACTICAL FLIGHT SIMULATION AND COMPUTING

MAXWELL L. RUTHERFORD and SORIN AXELRAD (CAE Electronics, Ltd., Saint-Lorent, Canada) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 25-34.

Military flight simulator modularity will involve the digital processing of data from flight controls, whose products are then transmitted to a host computer for use in simulation software modules. Information flows from module to module before being transmitted to the cockpit or visual display device; if standardized interfaces can be defined between simulator software modules, and these are defined identically to aircraft modules, then simulator baselines can be more easily updated to stay abreast of aircraft modifications. Attention is presently given to the application of these principles to the Tornado fighter and Lynx combat helicopter simulator systems. O.C.

**A89-48830**

### CHANGES IN RAF ENGINEERING REQUIREMENTS FOR FLIGHT SIMULATORS - IMPACT ON THE MANUFACTURERS AND THE CSDE TEAMS

BRIAN D. LONGMAN (RAF, London, England) and ALAN THOMPSON (CSDE, Lancing, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 35-45.

An account is given of the roles of the RAF's Air Engineers and Central Servicing Development Establishment (CSDE) in the field of flight simulation, as well as of the changes foreseen by these units in requirements for the design, introduction, and operational support of RAF flight simulators. Attention is given to the CSDE's response to date to trends in flight simulator life cycle costing, technical manpower training, simulator procurement cost control and procurement schedules management, new simulator projects management procedures, simulator R&M schedules, simulator certification procedures, and simulator modifications. O.C.

**A89-48831**

### GRAPHIC DISPLAYS FOR REAL-TIME MONITORING IN RESEARCH SIMULATION

M. R. SOUTHWORTH (British Aerospace, PLC, Military Aircraft Div., Weybridge, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 46-59.

Widely used CAD graphics workstations allow three-dimensional image fields to be displayed on high-resolution color monitors. Attention is presently given to the use of such graphics facilities to furnish real-time imagery for aircraft maneuvers from selected viewpoints. Illustrative cases of this application are the design of the prospective HOTOL vehicle's autopilot and the monitoring of simulated airshow routines for the Experimental Aircraft Program. Substantial economies are anticipated from the extent to which the commercial workstation graphics market is being driven in the areas of resolution, pixel fill rates, and host-computer processing power. O.C.

**A89-48832**

### THE MODERN RESEARCH SIMULATOR - YOUR FLEXIBLE FRIEND

S. P. BOWATER (Royal Aerospace Establishment, Bedford, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 60-71.

The Advanced Flight Simulator (AFS) completed in 1986 at RAE-Bedford is able to undertake research into the flight handling and control characteristics of both rotary and fixed-wing aircraft. The AFS cockpits are of modular construction, allowing the instrument panels and the port and starboard consoles to be

changed between trials. In order to furnish pilots with cues on the acceleration acting on the aircraft during maneuvering, the AFS cockpits incorporate a 'g-seat' through which sustained longitudinal or lateral accelerations can be represented by tilting to realign the gravity vector. O.C.

A89-48835

#### THE USE OF RECENT DEVELOPMENTS IN ACHIEVING ZERO FLIGHT TIME APPROVALS

CHRIS T. BARNES and SOLON L. A. SAOULLIS (British Airways, PLC, Flight Crew Training Centre, London, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 113-127. refs

A computer operating-system upgrading process has been conducted in conjunction with an updating of the requisite aerodynamic data package and the development of an advanced test-harness system, in order to create a B757 airliner flight simulator for zero-flight time training activities. The operating system upgrading has resulted in a real-time computer operational capability; the highest achievable accuracies have been obtained through the digitization of aircraft traces, allowing aircraft flight test data to be used for simulator operation and simulator/aircraft comparisons-by-over-plotting. Flight-validation tests have been performed entirely automatically by means of a combination of open-loop and closed-loop tests. O.C.

A89-48836

#### PROJECT GENESIS - THE DEVELOPMENT OF A LOW COST SIMULATOR

J. A. GILES (ITPS, Ltd., Cranfield, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 128-136.

The development history of the Genesis flight simulator was given its distinctive character by the need to resolve cost/performance problems in every area of the system. The bus structure chosen employs two main system buses, one of which is dedicated to mathematical modeling and secondary displays, while the other is devoted to the 'real-world' graphics system; they are linked by high speed direct-memory access. The main system processors are hung on these buses. The main mathematical model and display routines are automatically run under an interface/control executive, so that the user can employ a single menu system to access all the Genesis functions. O.C.

A89-48837

#### INTEGRATED GROUND TRAINING FOR THE RAF'S NEW BASIC TRAINER - THE TUCANO

PETER W. STANNARD (RAF, London, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 137-142.

After characterizing the comparative performance of the RAF's new Tucano basic trainer with respect to the Jet Provost trainer that it replaces, attention is presently given to the Tucano ground training syllabus, such 'synthetic' teaching aids as a cockpit-procedures trainer and flight simulator, and the systematic integration of ground school, synthetic training, and flight training methods into a cohesive program. A 'cardboard cockpit' is employed for the rote learning of check-procedures prior to students' introduction to the cockpit-procedures trainer. The first flight simulator session is conducted immediately before the first training flight. O.C.

A89-48844\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

#### THE HELMET-MOUNTED VISUAL SYSTEM IN FLIGHT SIMULATION

ANTHONY M. COOK (NASA, Ames Research Center, Moffett Field, CA) IN: Flight simulation: Recent developments in technology

and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 214-232.

An account is given of the application of fiber-optic helmet-mounted display systems to flight simulation tasks for complex combat mission scenarios involving numerous external aircraft, audible communications, and various types of threats. Such helmets, which although custom-made for each pilot are far less expensive than image-projection systems, consist of two 3-in. diameter 'optical pancake windows' mounted in front of the pilot's eyes to which images are transferred through fiber-optic cables from four high-brightness light-valve projectors. Head-position information is provided by an optical tracking system. The pancake window displays are semitransparent and allow cockpit controls and displays to be viewed normally. O.C.

A89-48949#

#### MD-11 DEVELOPMENT FLIGHT DECK SIMULATION

SAMUEL J. STOKES (Douglas Aircraft Co., Long Beach, CA) AIAA, Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 14-16, 1989. 7 p. (AIAA PAPER 89-3327)

The MD-11 flight deck simulator (FDS) will integrate avionics and aircraft systems and verify the two-person MD-11 cockpit. Cockpit controls and displays will connect with the actual aircraft systems, components, and simulated sensors. The high-fidelity MD-11 simulator will allow significant tests to be performed in a realistic environment. This paper describes the system architecture, high-level software, tests, and development of the MD-11 flight deck simulator. Author

A89-49460#

#### FACILITIES AND SUPPORT REQUIREMENT FOR ADVANCED FLIGHT VEHICLES

MICHAEL G. VENACCIO (USAF, Grand Forks AFB, ND) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. (AIAA PAPER 89-2102)

This paper provides an overview of the new facilities and support requirements that must be provided to properly operate and maintain a new aircraft at a designated operating location. The in-shop and ramp facilities that are required are reviewed in detail along with the aircraft systems that drive specific requirements. Reliability and maintainability as related to initial aircraft/system design is discussed from a maintenance perspective. Author

A89-50137

#### EXPERIMENTAL INVESTIGATION OF A HYBRID WIND TUNNEL MODEL

TH. HOTTNER (Stuttgart, Universitaet, Federal Republic of Germany) Experiments in Fluids (ISSN 0723-4864), vol. 7, no. 7, July 1989, p. 464-474. refs

New developments in power electronics (such as the linear motor) may be of great advantage for future economic aerodynamic testing. After a comprehensive review of economical aspects of present wind tunnel technologies, the experimental verification of the hybrid wind tunnel concept will be presented. A scale law is derived to extrapolate the experimental results of the model-HWT to a facility size for simulating full scale Re-numbers. Finally, methods will be discussed by which the flow constancy during the running time may be improved. Author

A89-50819

#### A NEW HIGH ACCURACY INSTRUMENT FOR MEASURING MOMENT OF INERTIA AND CENTER OF GRAVITY

RICHARD BOYNTON and KURT WIENER (Space Electronics, Inc., Meriden, CT) SAWE, Annual Conference, 47th, Detroit, MI, May 23-25, 1988. 18 p. (SAWE PAPER 1827)

A class of high-performance instruments for measuring mass properties are described. The instruments are based on high-speed closed-loop moment sensing. An instrument which measures both moment of inertia and center of gravity is examined in detail. The

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improvements in performance due to the active moment transducer are estimated. It is found that this class of machines has a center of gravity accuracy that is 10 to 100 times better than those of previous instruments. R.B.

**A89-50822**

### THE VOUGHT ULTRA-HIGH TEMPERATURE, HIGH SPEED ROTOR TEST SYSTEM

J. E. BANKS (LTV Aerospace and Defense Co., Vought Missiles and Advanced Programs Div., Dallas, TX) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 24 p. (SAWE PAPER 1830)

Consideration is given to the design and operation of a high temperature, high speed turbine rotor test system to provide rotor temperatures over 3000 F and provide centrifugal loads in excess of 200,000 g. The planned use of the system to develop a turbine rotor from a carbon composite and for the ground-testing of a carbon-based hot section turbojet is discussed. The configurations of the various components of the test system are illustrated. R.B.

**A89-51302#**

### AN ANALYSIS AND WIND TUNNEL TEST OF GUST ALLEVIATION AND GUST LOAD ALLEVIATION FOR AIRCRAFT

H. ARAKAWA, N. TODA, Y. SHIRAI, H. TANEDA, and K. SAKURA (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 160-163.

In the development of active control technology (ACT) for aircraft such as gust alleviation (GA) and gust load alleviation (GLA), wind tunnel testing as well as analysis methods and control law design are important for the verification of the validity of analytical procedures and performance of control system. This report presents an outline of the wind tunnel test for GA/GLA including a general idea of the aeroservoelastic analysis method and its comparison with the test results. The control systems for GA and GLA are designed with the linear feedback theory using accelerometer signals as sensor inputs. The analysis method utilizes the general purpose finite element program MSC/NASTRAN for the structure modeling and the finite dimension method for approximating the aerodynamic forces. Author

**N89-26864#** Concrete Technology Information Analysis Center, Vicksburg, MS.

### EVALUATION OF BARRIER CABLE IMPACT PAD MATERIALS Final Report, Sep. 1983 - Sep. 1984

TONY B. HUSBANDS and DENNIS L. BEAN Apr. 1989 93 p (AD-A207554; CTIAC-84; WES/TR/SL-87-33; WES/TR/SL-89-5) Avail: NTIS HC A05/MF A01 CSCL 01/4

The U.S. Air Force uses an aircraft arresting system on many of their runways for emergency stopping of aircraft. It consists of a 1- or 1-1/4-inch steel cable stretched across the runway connected to a braking mechanism. When aircraft tires impact the cable, considerable damage occurs to concrete and other materials placed underneath the cable. Materials previously used were not performing satisfactorily for various reasons. A survey was made in 1980 for the Air Force Engineering and Services Center (AFESC) to locate materials for evaluation. Five of these were selected for detailed testing. The materials were tested for gel times, peak exotherms, bond strength, abrasion resistivity, ultraviolet degradation, resiliency, hardness, abrasion-impact resistance, effect of curing temperature, and proportioning errors. The materials which showed most promise were field tested at Homestead and Tyndall Air Force Bases. GRA

**N89-26865\*#** Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.

### HIGH-SPEED DATA ACQUISITION FOR THE PRINCETON UNIVERSITY DYNAMIC MODEL TRACK Interim Report, Jan. 1987 - Jan. 1988

MICHAEL G. DEMKO and R. M. MCKILLIP, JR. Jan. 1988 42 p

(Contract NAG2-415)

(NASA-CR-185491; NAS 1.26:185491) Avail: NTIS HC A03/MF A01 CSCL 14/2

Real time analysis of data can reduce the time involved in exploring dynamic systems. The failure of the data acquisition system at the Princeton Dynamic Model Track prompted its replacement with a real time data acquisition system. Data can be obtained from an experiment and analyzed during and immediately following a data run. The new system employs high speed analog to digital conversion and a small computer to collect data. Sampling rates of 1000 hertz over 44 channels (44,000 words/sec) are obtainable. The data can be accessed as it enters the computer's environment where it may be displayed or stored for later processing. The system was tested on a helicopter rotor steep descent experiment. The data collected compares with previous data from a similar experiment. Author

**N89-26866\*#** Stanford Univ., CA. Dept. of Aeronautics and Astronautics.

### DESIGN AND CALIBRATION OF THE MIXING LAYER AND WIND TUNNEL

JAMES H. BELL and RABINDRA D. MEHTA May 1989 36 p (Contract NCC2-55) (NASA-CR-185472; NAS 1.26:185472; JIAA-TR-89) Avail: NTIS HC A03/MF A01 CSCL 01/5

A detailed account of the design, assembly and calibration of a wind tunnel specifically designed for free-shear layer research is contained. The construction of this new facility was motivated by a strong interest in the study of plane mixing layers with varying initial and operating conditions. The Mixing Layer Wind tunnel is located in the Fluid Mechanics Laboratory at NASA Ames Research Center. The tunnel consists of two separate legs which are driven independently by centrifugal blowers connected to variable speed motors. The blower/motor combinations are sized such that one is smaller than the other, giving maximum flow speeds of about 20 and 40 m/s, respectively. The blower speeds can either be set manually or via the Microvax II computer. The two streams are allowed to merge in the test section at the sharp trailing edge of a slowly tapering splitter plate. The test section is 36 cm in the cross-stream direction, 91 cm in the spanwise direction and 366 cm in length. One test section side-wall is slotted for probe access and adjustable so that the streamwise pressure gradient may be controlled. The wind tunnel is also equipped with a computer controlled, three-dimensional traversing system which is used to investigate the flow fields with pressure and hot-wire instrumentation. The wind tunnel calibration results show that the mean flow in the test section is uniform to within plus or minus 0.25 pct and the flow angularity is less than 0.25 deg. The total streamwise free-stream turbulence intensity level is approximately 0.15 pct. Currently the wind tunnel is being used in experiments designed to study the three-dimensional structure of plane mixing layers and wakes. Author

**N89-26867#** Wisconsin Univ., Madison. Applied Superconductivity Center.

### DESIGN AND OPERATION OF A HORIZONTAL LIQUID HELIUM FLOW FACILITY

S. W. VANSCIVER and J. G. WIESEND, II 1988 6 p Presented at the 12th International Cryogenic Engineering Conference and Exhibition, Southampton, United Kingdom, 12-15 Jul. 1988 (Contract DE-AC02-86ER-40306)

(DE89-013482; CONF-880736-6) Avail: NTIS HC A02/MF A01

The University of Wisconsin horizontal liquid helium flow facility (LHFF) consists of a five meter long 20 cm ID horizontal dewar connected to two end boxes. Several heat exchanger inserts have been built to allow variable temperature operation of 1.6 K less than or equal to T less than or equal to 4.2 K. A centrifugal pump is installed at one end of the facility permitting experiments in forced flow liquid helium up to 100 gm/s. The horizontal design allows experimentation on long straight test sections which may be used either to study fundamental properties of heat and mass transfer in helium or prototype cryogenic components under realistic

conditions. A detailed description of the design and operating experience of the LHFF is presented. DOE

**N89-26868#** Federal Aviation Administration, Atlantic City, NJ.  
**EVALUATION OF AN UPDATED DESIGN OF AN INTERNALLY LIGHTED WIND CONE**

ERIC S. KATZ Aug. 1989 14 p  
(DOT/FAA/CT-TN89/45) Avail: NTIS HC A03/MF A01

An updated version of an 18-inch internally lighted wind cone was evaluated. The original model was evaluated at the Federal Aviation Administration (FAA) Technical Center. The results of that evaluation, as detailed in Technical Note DOT/FAA/CT-TN85/4 (February 1985), revealed that the original model of the internally lighted wind cone did not provide adequate wind direction and speed information under low velocity (10 knots or less) wind conditions. The new model was installed in close proximity to the standard externally lighted wind cone at the Atlantic City International Airport, N.J., to permit a comparative evaluation by FAA and general aviation pilots. Results of the testing, accomplished during taxi and flight operations under wind conditions of 10 knots or less, revealed that the updated model still does not provide adequate wind direction and speed information. Participating pilots preferred the standard externally lighted wind cone. Author

**N89-26869\*#** Vigyan Research Associates, Inc., Hampton, VA.  
**THE NASA LANGLEY RESEARCH CENTER 0.3-METER TRANSONIC CRYOGENIC TUNNEL T-P/RE-M CONTROLLER MANUAL**

S. BALAKRISHNA and W. ALLEN KILGORE Jul. 1989 41 p  
(Contract NAS1-17919)  
(NASA-CR-181868; NAS 1.26:181868) Avail: NTIS HC A03/MF A01 CSCL 14/2

A new microcomputer based controller for the 0.3-m Transonic Cryogenic Tunnel (TCT) has been commissioned in 1988 and has reliably operated for more than a year. The tunnel stagnation pressure, gas stagnation temperature, tunnel wall structural temperature and flow Mach number are precisely controlled by the new controller in a stable manner. The tunnel control hardware, software, and the flow chart to assist in calibration of the sensors, actuators, and the controller real time functions are described. The software installation details are also presented. The report serves as the maintenance and trouble shooting manual for the 0.3-m TCT controller. Author

**N89-26870#** Aktiebolaget Rollab, Stockholm (Sweden).  
**ON INTERNAL BENDING-BEAM STRAIN-GAGE WIND TUNNEL BALANCES**

KNUT FRISTEDT Jan. 1989 99 p  
(RR-070; ETN-89-94940) Avail: NTIS HC A05/MF A01

The relative load-carrying capacity of three types of internal balances was compared using information in the literature. The bending-beam balance is superior, when D is less than 35 mm. The capacity of task-balances is equal at larger diameters and the two-shell balance is a competitor, when D is greater than 50 mm. A strength computation model of the bending-beam balance of the Rollab type based on simple engineering theories is presented. The strength of available types of high alloy steels is discussed as well as the expected relations between mechanical stresses and electrical signals. It is shown during the calculation of the 30 mm balance, that the angle deflection of the sting at maximum load is very large, and that it is very beneficial to have access to a sting material with higher modulus of elasticity than steel. The influence of the numerical value of the diameter on the load carrying capacity at constant stress of the current type of balance is discussed, and task and two-shell balances are compared. A mathematical model of 2nd degree, which combines the force system loading the balance with the balance signals is described. This model can be used during calibration and wind-tunnel testing. ESA

**N89-26871#** Ballistic Research Labs., Aberdeen Proving Ground, MD.

**A MULTIDRIVER SHOCK TUBE MODEL OF A LARGE BLAST SIMULATOR Final Report**

EDMUND J. GION May 1989 41 p  
(AD-A208324; BRL-MR-3757) Avail: NTIS HC A03/MF A01 CSCL 20/4

The construction of the BRL Multidriver Shock Tube (MD-ST) Model is documented. The facility is a 1:22 model of the Large Blast Simulator at the Centre d'Etude de Gramat, France, except for a lengthened driven tube to permit observation of the full waveform development without interference from the open-end, reflected rarefaction wave (since the Rarefaction Wave Eliminator was not modeled). It is designed with a good safety factor to withstand driver pressures to 24,000 kPa (3,500 psi). Initial tests to greater than 22,100 kPa (3,200 psi) have been performed, and results are compared to other available data. Additionally, the double diaphragm technique, described, was used to attain the highest shock pressures. GRA

**N89-26872#** Naval Postgraduate School, Monterey, CA.  
**AN INVESTIGATION INTO THE USE OF AN EXISTING SHOCK TUBE AS A DRIVER FOR A HYPERSONIC SHOCK TUNNEL M.S. Thesis**

MICHAEL H. SHERMAN Mar. 1989 152 p  
(AD-A208483) Avail: NTIS HC A08/MF A01 CSCL 01/1

This thesis describes experiments carried out using an existing tube alone, and with the tube connected to two-dimensional wedge nozzle. The range of maximum duration of steady reflected pressure from 3.5 to 5 milliseconds was achieved through tailored operation for incident shock strengths of 3.4 and 2.0, using pure Helium and a 70 percent Helium/30 percent Nitrogen mixture as the driver gas respectively. Spark and continuous light shadowgraph techniques were attempted using an optical window at the Mach 4.3 location. Results demonstrated that the short duration flow phenomena in a shock tunnel can be recorded successfully using existing equipment. Calculations showed that the addition of a Mach 10 nozzle and 15 cu m (6' diameter x 15' long) dump chamber would provide a useful hypersonic facility for instruction and research. GRA

**N89-27673#** Central State Univ., Wilberforce, OH. Dept. of Manufacturing Engineering.

**THEORETICAL MODEL FOR STABILIZATION OF CLAY-SILT AIRPORT PAVEMENT SUBGRADE SYSTEMS. PHASE 1: LABORATORY INVESTIGATION. PHASE 2: RUTTING TESTS Final Report**

WILLIAM A. GRISSOM, ABAYOMI J. AJAYI-MAJEBI, L. SHELBERT SMITH, CARL L. WHITE, MAHMOUD A. ABD-ALLAH, and EUGENE E. JONES (Tractell, Inc., Dayton, OH.) May 1989 327 p  
(Contract DTF A01-84-C-00023)

(DOT/FAA/PM-87/20-PHASE-1/2) Avail: NTIS HC A15/MF A01

Theoretical models for low-volume airport pavement stabilization of clay-silt systems are documented. A non-traditional method of soil stabilization is presented for improving the subgrade strength of poorly graded clay-silt. The research (Phase 1) focuses on: (1) identification of a chemical additive capable of increasing the load bearing strength of clay-silt soil; (2) additive application to a clay-silt soil system leading to increased bearing strength; and (3) development of mathematical models for soil strength prediction. Phase 2 focuses on field validation of the test results through studies of pavement rutting. Among several effective non-traditional organic additives tested in this research, the two-part epoxy system, bisphenol A/epichlorohydrin resin plus a polyamide hardener gave the best result as measured by the dry California Bearing Ratio (CBR) test. The choice of the dry CBR test performed to ASTM specification was motivated by a need to capture optimum moisture content as a variable in addition to percent additive, clay-silt ratio, temperature and dry density, using a full factorial experimental design. The statistical regression models developed support the hypothesis that only additive percentage, moisture content and temperature are significant variables influencing the strength of the clay-silt soil system tested. The nomograph



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developed for CBR prediction enables quick estimates of dry CBR. The marginal increase in CBR values due to a percent increase in epoxy resin application is 11.1 and the marginal degradation of CBR due to a percent increase in moisture level is 5.6. In phase 2, the rutting validation study confirmed the effectiveness of the chemical stabilizing agent identified for strengthening a clay-silt soil at the 4 percent level of additive application. Based on the results of the rutting test conducted on a tire force machine (TFM), the stabilized pavement will sustain an aircraft load of 10,000 lbs applied through 1000 wheel load passes while meeting the 1/2 inch rutting criteria. Author

**N89-27674\*#** Naples Univ. (Italy).  
**AN EVALUATION OF THREE EXPERIMENTAL PROCESSES FOR TWO-DIMENSIONAL TRANSONIC TESTS**  
GENNARO ZUPPARDI Aug. 1989 71 p  
(Contract NCC1-47)  
(NASA-CR-181871; NAS 1.26:181871) Avail: NTIS HC A04/MF A01 CSCL 14/2

The aerodynamic measurements in conventional wind tunnels usually suffer from the interference effects of the sting supporting the model and the test section walls. These effects are particularly severe in the transonic regime. Sting interference effects can be overcome through the Magnetic Suspension technique. Wall effects can be alleviated by: testing airfoils in conventional, ventilated tunnels at relatively small model to tunnel size ratios; treatment of the tunnel wall boundary layers; or by utilization of the Adaptive Wall Test Section (AWTS) concept. The operating capabilities and results from two of the foremost two-dimensional, transonic, AWTS facilities in existence are assessed. These facilities are the NASA 0.3-Meter Transonic Cryogenic Tunnel and the ONERA T-2 facility located in Toulouse, France. In addition, the results derived from the well known conventional facility, the NAE 5 ft x 5 ft Canadian wind tunnel will be assessed. CAST10/D0A2 Airfoil results will be used in all of the evaluations. Author

**N89-27675#** Naval Postgraduate School, Monterey, CA.  
**PARAMETRIC STUDY OF THE AEROTHERMODYNAMICS OF A JET ENGINE TEST FACILITY M.S. Thesis**  
TODD G. RATNER Mar. 1989 128 p  
(AD-A208512) Avail: NTIS HC A07/MF A01 CSCL 01/1

A 3-D numerical analysis of the Jet Engine Hush House located at Naval Air Station Jacksonville, Florida was developed using the PHOENICS computer code. The PHOENICS code was used to determine the steady state aerothermal characteristics in the Hush House produced by a Navy F-4 (Phantom 2) J-79-GE-8 gas turbine engine with afterburner. The PHOENICS generated pressure, velocity, and temperature fields of the test cell facility based on the k-epsilon turbulence model are compared with results generated by a model incorporating a temperature dependent kinematic turbulent viscosity. In addition, for the k-epsilon turbulence model, the effect of augmentor tube length on system behavior was investigated. Lessons learned and recommendations in obtaining a converged solution are included to aid in further applications of the PHOENICS code. GRA

**N89-27676#** General Dynamics Corp., Fort Worth, TX.  
**SMALL SCALE MODEL TESTS IN SMALL WIND AND WATER TUNNELS AT HIGH INCIDENCE AND PITCH RATES. VOLUME 2: SMALL WIND TUNNEL (ADF) DATA BASE Final Report, Sep. 1985 - Sep. 1988**  
ATLEE M. CUNNINGHAM, JR., TODD BUSHLOW, JOHN R. MERCER, TIM A. WILSON, and STEVE N. SCHWOERKE Apr. 1989 149 p  
(Contract N00014-85-C-0419)  
(AD-A208539) Avail: NTIS HC A07/MF A01 CSCL 01/1

Force testing of small-scale models in either a small wind tunnel or a water tunnel was investigated as an inexpensive and quick means to obtain meaningful dynamic force and moment data representative of rapidly maneuvering full-scale aircraft. Force tests of flat-plate semi-span models were conducted in the General Dynamics Aerodynamic Development Facility (ADF) which is a small 14-in. x 14-in. low speed wind tunnel. Oscillatory model motions

up to 48 deg (peak to peak) amplitude were tested at frequencies of 1 to 3 Hz. Force tests of flat and three-dimensional full span models were conducted in G.D.'s Hydroflow Facility (HFF) which is a horizontal flow water tunnel with a 24-in. x 24-in. test section. Pitch/pulse model motions were tested for conditions similar to those tested in the ADF. The test velocities were 100 fps in the ADF and 0.8 fps in the HFF which yielded nominal Reynolds numbers of 0.6 million and 0.06 million respectively (based on root chord). This volume presents the data base generated from tests in the ADF. The normal force, pitching moment and rolling moment data are in plotted and tabulated form for the straked wing, 55 deg and 70 deg delta wings and 70 deg/30 deg cranked wing semi-span models. Steady results along with unsteady results for two frequencies are included for the overall incidence range of 0 deg to 80 deg. Geometric data for the models are also given. GRA

**N89-27677#** Melbourne Univ., Parkville (Australia).  
**COMPACTED-SNOW RUNWAYS: GUIDELINES FOR THEIR DESIGN AND CONSTRUCTION IN ANTARCTICA**  
DAVID S. RUSSELL-HEAD and WILLIAM F. BUDD Apr. 1989 69 p  
(AD-A208910; CRREL-SR-89-10) Avail: NTIS HC A04/MF A01 CSCL 01/5

Only small areas near the margins of the ice cap in Antarctica are ice-free, and only a few of these exposed sites are suitable for the construction of conventional runways. Wheeled aircraft have operated successfully on hard sea ice and exposed glacial ice, and skis have been fitted to a wide range of aircraft for use on snow. There has been a resurgence of interest in making snow runways suitable for use by conventional wheeled aircraft. Laboratory and field work has confirmed that low-density surface snow can be compacted in several ways to yield strong, uniform, load-bearing pavement that can support heavy wheeled aircraft. The Soviets have constructed several full-scale runways in Antarctica. This report provides some of the technical background for the design and construction of compacted-snow runways in Antarctica. The technology is not particularly difficult, and it's likely that the next few decades will see substantial changes to Antarctic air transportation as more snow runways are constructed throughout the continent. GRA

**N89-27678#** Auburn Univ., AL. Dept. of Civil Engineering.  
**A COMPARISON OF RUTTING BEHAVIOR OF ASPHALT CONCRETE UNDER THE F-4C/G AND F-15C/D AIRCRAFT Final Report, Jul. - Dec. 1987**  
JAMES G. MURFEE Jun. 1988 145 p  
(Contract AF PROJ. 2104)  
(AD-A208911; AFESC/ESL-TR-88-48) Avail: NTIS HC A07/MF A01 CSCL 13/2

The effect of the F-4 and the F-15 aircraft on rutting performance of standard airfield bituminous mixtures during hot weather conditions were compared. The comparisons and conclusions herein were drawn from trafficking new 4 inch asphalt concrete overlying 12 inches of Portland cement concrete. The asphalt concrete was produced from Ac-30 asphalt cement and 100 percent crushed limestone of 3/4 inch maximum size. Pavement surface temperatures ranged from 80 to 122 F during traffic. Both test strips were trafficked simultaneously, back and forth, in a channelized manner 6,000 times by loadcars that simulated the heaviest designs of F-4 and F-15 aircraft. In one strip, the F-4 loadcart test wheel was loaded to 27.1 kips with cold tire inflation pressures of 265 psi. In the other strip, the F-15 loadcart test wheel was loaded to 30.5 kips with cold tire inflation pressure of 355 psi. It was learned that it takes 5,000 passes of the F-4 to produce a 0.4 inch rut depth in this particular mix, but only 1,000 passes of the F-15. This rut depth of 0.4 inch was far from failure of the layer and was the maximum reached in the F-4 test strip. The dominant mode of rutting was densification with plastic flow of the mixture estimated to have caused about 12 percent of the rutting. GRA



**N89-27679#** Dayton Univ., OH. Research Inst.  
**EFFECT OF THREE-DIMENSIONAL OBJECT TYPE AND DENSITY IN SIMULATED LOW-LEVEL FLIGHT Interim Report, Aug. 1986 - Dec. 1988**

JAMES A. KLEISS and DAVID C. HUBBARD May 1989 24 p  
 (Contract F33615-84-C-0066; F33615-87-C-0012)  
 (AD-A209756; AFHRL-TR-88-66) Avail: NTIS HC A03/MF A01  
 CSCL 01/2

Altitude control in simulated low-level flight improves significantly when three-dimensional objects are added to simulator visual scenes. However, the limited processing capacity of computer image generators (CIGs) may be used either to increase the density of objects at the expense of individual object detail and realism, or to increase the detail of objects at the expense of object density. The present investigation sought to determine whether object density or object detail is the more important factor in simulated low-level flight. Three types of three-dimensional object were employed: (1) a control condition consisting of inverted tetrahedrons (the simplest possible three-dimensional shape); (2) highly detailed and realistic pine tree; and (3) a mixture of oak trees, pine trees, and bushes. The four levels of object density employed ranged from 3 objects per square mile to 175 objects per square mile. The task required a perceptual judgement to discriminate a change in altitude and a control action to reestablish the initial target altitude. Results indicated that object density had a greater effect on performance. Limited CIG processing capacity may, therefore, be more effectively used by increasing object density rather than individual object detail. GRA

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## 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.

**A89-49059\*#** Rogers and Associates Engineering Corp., Gainesville, FL.

**SPACE SHUTTLE PROPULSION PERFORMANCE RECONSTRUCTION FROM FLIGHT DATA**

ROBERT M. ROGERS (Rogers Engineering and Associates, Gainesville, FL) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 75-82. refs  
 (Contract NAS8-36152)  
 (AIAA PAPER 89-3355)

The application of extended Kalman filtering to estimating Space Shuttle Solid Rocket Booster (SRB) performance, specific impulse, from flight data in a post-flight processing computer program. The flight data used includes inertial platform acceleration, SRB head pressure, and ground based radar tracking data. The key feature in this application is the model used for the SRBs, which represents a reference quasi-static internal ballistics model normalized to the propellant burn depth. Dynamic states of mass overboard and propellant burn depth are included in the filter model to account for real-time deviations from the reference model used. Aerodynamic, plume, wind and main engine uncertainties are included. Author

**A89-51330#**

**THE NASP CHALLENGE - TESTING FOR VALIDATION**

PHILIP T. HARSHA and BARRY J. WALDMAN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 8 p.  
 (AIAA PAPER 89-5005)

Due to the concerted efforts of the National Aero-Space Plane (NASP) program office, NASA, and NASA's contractors, simulation capabilities either currently exist or will exist in the near future for large scale performance validation over the greater part of the NASP technology-validating X-30 vehicle's flight profile. These facilities will be concerned with materials and structural technologies validation testing, as well as aerodynamic testing to define the X-30's lift, drag, stability, and control characteristics and propulsion system simulation testing to verify operability throughout the flight envelope. O.C.

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## CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

**A89-47966**

**RADIATION ATTENUATION BY A WALL LAYER [OSLABLENIE IZLUCHENIIA PRISTENOCHNYM SLOEM]**

A. B. SHIGAPOV, R. KH. BIKMULLIN, R. R. NAZYROVA, and Z. KH. GRUZDEVA Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 59-63. In Russian.

Results of a parametric study of the effect of various factors determining the wall layer characteristics on the attenuation of radiative heat fluxes are reported. The results obtained are examined from the standpoint of the optimization of aircraft engine operation. V.L.

**A89-48011**

**CALCULATION OF THE HEAT OF EVAPORATION OF AVIATION FUELS [RASCHET TEPLoty ISPARENIIA AVIATSIONNYKH TOPLIV]**

S. V. BASHARIN and A. G. KOPEIKIN Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 82. In Russian.

**A89-48084**

**JUSTIFICATION FOR INCREASING OIL CHANGE PERIOD IN AIRCRAFT [OBOSNOVANIE UVELICHENIIA SROKA SMENY MASEL V AVIATSIONNOI TEKHNIKE]**

B. G. BEDRIK, V. A. BAZDERKIN, V. S. UGRIMOV, A. I. ECHIN, and I. S. KRICHINSKII Khimiia i Tekhnologiiia Topliv i Masel (ISSN 0023-1169), no. 6, 1989, p. 24-26. In Russian. refs

The possibility of extending oil change periods for aviation gas turbine engines is examined with reference to data obtained for oils used in real engines for different periods. The analysis allows for the interrelation between the elements of the oil-engine system during service. It is shown that oil viscosity can be stabilized by the fresh oil added to compensate for oil losses from the system; the adaptability of the oil also contributes to the stabilization of oil quality during operation. These factors act to offset the degradation of the antiwear characteristics during service. The discussion is illustrated by results for MS-8p, IPM-10, and B-3V oils. V.L.

**A89-48198**

**FATIGUE CRACK GROWTH BEHAVIOUR OF 7475-T7351 AL ALLOY UNDER CONSTANT AMPLITUDE LOADING**

SHIJIE ZHANG (Institute of Aeronautical Materials, Beijing, People's Republic of China), R. MARISSAN, K. SCHULTE, K. H. TRAUTMANN, and H. NOWACK (DLR, Institut fuer Werkstoff-Forschung, Cologne, Federal Republic of Germany) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 2, May 1989, p. 135-144. refs

The fatigue crack growth behavior of the 7475-T7351 Al alloy under constant-amplitude loading was investigated using center-cracked 8-mm-thick specimens subjected to a wide range of stress ratios and an empirical expression for the crack-opening stress of the material, which was derived from the crack growth-rate

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data. The results of fracture analysis indicate that the transition of fracture from the tensile mode to the shear mode is controlled mainly by the effective stress intensity factor. It was also found that the values of the ratio between the crack opening stress to the maximal stress increase when the fracture undergoes a transition from the tensile mode to the shear mode. I.S.

### A89-48735#

#### NEW HIGH TEMPERATURE RESISTANT NICRAL AND NICRAL + HF FELT MATERIALS

G. LEPRINCE, L. VANDENBULCKE (CNRS, Centre de Recherches sur la Chimie de la Combustion et des Hautes Températures, Orleans, France), S. ALPERINE, and A. WALDER (ONERA, Chatillon-sous-Bagneux, France) (Symposium sur la Corrosion Haute Temperature et les Matériaux Avancées, 2nd, Les Embiez, France, May 22-26, 1989) ONERA, TP no. 1989-50, 1989, 14 p. refs

(ONERA, TP NO. 1989-50)

This paper describes an adaptation of the Vandembulcke and Nciri (1985) low-pressure vapor phase aluminization technique for metallic-felt applications. Results are presented which show that the use of this technique makes it possible to manufacture NiCrAl metallic felts that exhibit high resistance to cyclic oxidation at temperatures as high as 900 C; an addition of small amounts of Hf raises the oxidation resistance by 100 or 150 C. These felts can be used as abradable seals for the hot stages of turboengines at such elevated temperatures. I.S.

### A89-48745#

#### MOLTEN SALT INDUCED HIGH TEMPERATURE DEGRADATION OF THERMAL BARRIER COATINGS

SERGE ALPERINE (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Meeting, 4th, Ottawa, Canada, Apr. 24-26, 1989) ONERA, TP no. 1989-60, 1989, 19 p. refs

(ONERA, TP NO. 1989-60)

This paper examines the degradation modes that can be encountered when engine-protective coatings consisting of partially-stabilized zirconia (PCZ) plasma-sprayed top coat ( $ZrO_2 + CaO$ ,  $MgO$ ,  $Y_2O_3$ , or  $CeO_2$ ) and an MCrAlY (where M = Ni and/or Co and/or Fe) bond coat are exposed to temperatures in the 650-950 C range and sulphur- and/or vanadium-containing atmosphere. The interaction between the PSZ film and a surface film of molten sodium sulfate or sodium vanadate that form upon exposure to heat is threefold. First, a chemical acidic or alkaline dissolution of the zirconia-stabilizing oxide may occur, accompanied by zirconia tetragonal-to-monoclinic phase transformation and subsequent coating spallation upon cooling. Secondly, fused salt may diffuse inside the ceramic microcracks network and solidify on cooling, generating stress inside the coating. Thirdly, fused salt diffused down to the ceramic/bond coat interface may also affect the MCrAlY bond coat. I.S.

### A89-48775

#### POST-IMPACT CHARACTERIZATION OF INTERLEAVED COMPOSITE MATERIALS

G. V. GANDHE and O. H. GRIFFIN, JR. (Virginia Polytechnic Institute and State University, Blacksburg) SAMPE Quarterly (ISSN 0036-0821), vol. 20, July 1989, p. 55-58. Research supported by the American Cyanamid Co., Fiberite, Inc., Allied Fibers Technical Center, and Virginia Institute for Material Systems. refs

Efforts were made to study the improvement in impact resistance of graphite/epoxy composite laminates by incorporation of a thin thermoplastic film (interleaf) between every graphite/epoxy layer. Test specimens of interleaved and non-interleaved graphite/epoxy prepreg were subjected to low velocity instrumented drop weight impact. The extent and nature of the damage was studied using ultrasonic C-scan. Onset and growth of delamination damage was evaluated at a number of impact energy levels. Residual tensile strength of the test specimens was measured. The interleaved laminates exhibited much less delamination damage for a given impact energy. Author

### A89-49473#

#### COMPOSITES AND THE COMMERCIAL JET - A BOEING VIEWPOINT

P. J. HARRADINE and J. T. QUINLIVAN (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 5 p.

(AIAA PAPER 89-2126)

The present evaluation of future performance requirements in composite materials for airliner primary structures notes that tougher composite formulations with significantly improved impact damage and high tolerance to hot, wet environments will be of paramount importance. Toughened thermosetting resins have been developed which, by comparison with thermoplastics, require lower cure temperatures and pressures. The improved mechanical performance of the toughened materials has been confirmed at the scale of large structural panels; characteristics ultimately comparable to those of the 2024 aircraft aluminum alloy are in sight. O.C.

### A89-49474#

#### ADVANCED MATERIALS DEVELOPMENT IN COMMERCIAL AIRCRAFT

M. V. HYATT, R. G. CATON, and D. T. LOVELL (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 12 p.

(AIAA PAPER 89-2127)

Recent developments and projected technically achievable future developments are summarized for aluminum, titanium, steel, and composite structural materials. Use of these new and projected new materials could provide significant cost-effective weight savings on future Boeing aircraft. Corrosion control and materials and process developments in response to new environmental regulations are summarized. Materials needs for a future High Speed Civil Transport (HSCT) are outlined. Author

### A89-49627

#### AEROSPACE MATERIALS FOR THE TWENTY-FIRST CENTURY

F. H. FROES (USAF, Materials Laboratory, Wright-Patterson AFB, OH) (University of the Negev, Technion - Israel Institute of Technology, National Council for Research and Development, et al., IMEC IV - Israel Materials Engineering Conference, 4th, Beersheba, Israel, Dec. 7, 8, 1988) Israel Journal of Technology (ISSN 0021-2202), vol. 24, no. 1-2, 1988, p. 1-41. refs

A historical development characterization and development status evaluation are presented for aerospace materials expected to enter service in the aerospace structures and powerplants fields between the present and the early years of the next century. Attention is given to the prospects for the bearing of service temperature increases anticipated in supersonic and hypersonic vehicle operation and to the general problems of materials-feedstock and processing/fabrication costs. The range of materials that can be tailored from the available variety of reinforcing fibers and their woven forms, on the one hand, and polymeric, metallic, and ceramic matrices, on the other, are discussed. O.C.

### A89-50142

#### COMPARISON OF A FURTHER GROUP OF REACTIVE ACRYLIC ADHESIVES FOR BONDING ALUMINIUM ALLOYS

K. W. ALLEN and N. D. PARRY (City University, London, England) International Journal of Adhesion and Adhesives (ISSN 0143-7496), vol. 9, July 1989, p. 139-141. refs

Six combinations of resin and activator from one manufacturer and one combination from another manufacturer were investigated by single lap-shear strength and wedge tests. The effects of modifications to increase the rate of cure or to reduce the odor were explored and discussed. The reductions in fracture energy caused by immersion in water at room temperature were also determined and shown to be within the limits proposed at

satisfactory for the permanent repair of primary structures in aircraft. Author

**A89-50773****DEVELOPMENTS IN TITANIUM ALLOYS FOR AEROSPACE**

R. E. GOOSEY (IMI Titanium, Ltd., Birmingham, England) Metals and Materials (ISSN 0266-7185), vol. 5, Aug. 1989, p. 451-454.

Over the thirty years that have passed since their first aircraft gas turbine engine applications, Ti alloys' service temperatures have risen from the vicinity of 300 C to 600 C. While early alloys were of alpha-beta type, the creep-resistant alloys developed for service temperatures above 450 C are of near-alpha type, and have been optimized for creep resistance through careful optimization of composition, thermomechanical processing, and heat treatment. The easily weldable IMI 685 and IMI 829 alloys reached operating temperatures of the order of 520 and 550 C, respectively, by linking a novel composition with beta-phase heat treatment for maximum creep strength. IMI 834 reached the 600 C creep-resistant operation level in 1983, on the basis of a beta heat-treatment of a near-alpha composition. Attention is given to airframe structure applications, as well as to superplastic forming and casting techniques using Ti-6Al-4V alloy, and the HIP forming of IMI 829. O.C.

**A89-51251****STRUCTURAL CERAMICS**

JOHN B. WACHTMAN, JR., ED. (Rutgers University, Piscataway, NJ) San Diego, CA, Academic Press, Inc. (Treatise on Materials Science and Technology. Volume 29), 1989, 398 p. For individual items see A89-51252 to A89-51258.

The present work discusses opportunities for application of structural ceramics in heat engines, industrial-wear parts, prosthetics and bearings; conceptual and detailed design principles for structural ceramics; the processing, consolidation, and properties of members of the SiC family of structural ceramics; and the silicon nitride and sialon families of hot-pressed, sintered, and reaction-bonded, structural ceramics. Also discussed are partially-stabilized zirconia and zirconia-toughened ceramics for structural applications, the processing methods and mechanisms of fiber-reinforcement in ceramic-matrix fiber-reinforced composites, and the tribological properties of structural ceramics. O.C.

**A89-51573#****A REVIEW OF ARALL TECHNOLOGY**

L. J. J. KOK (Boeing of Canada, Ltd., de Havilland Div., Downsview) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 35, June 1989, p. 86-94. refs

Arall laminates are composed of a 50-percent fiber-volume reinforced aramid resin, adhesively bonded to two aluminum alloy face-sheets, and cured in such a way that residual stresses hold the metal laminae in tension while the polymer matrix is in compression. Great improvements in fatigue life are thus obtainable in conjunction with weight savings. Attention is presently given to the environmental conditions and fabrication methods that will be encountered in aircraft fuselage and wing-box structural element applications of Arall laminates, in conjunction with Al-Li alloy elements; prospective weight-savings over a conventional 2024 alloy structure of similar design are estimated. O.C.

**N89-26937#** Boeing Advanced Systems Co., Seattle, WA. Propulsion Technology.

**HOT SURFACE IGNITION TESTS OF AIRCRAFT FLUIDS Final Report, May 1987 - May 1988**

A. M. JOHNSON, A. J. ROTH, and N. ALBERT MOUSSA (Blazetech Corp., Winchester, MA.) Nov. 1988 239 p (Contract F33615-84-C-2431) (AD-A207372; AFWAL-TR-88-2101) Avail: NTIS HC A11/MF A01 CSCL 01/3

Five fluids commonly found in aircraft engine components, JP-4 and JP-8 fuels, Mil-H-5606 and Mil-H-83282 hydraulic fluids and Mil-L-7808 lubricating oil, were tested in the Aircraft Engine Nacelle Fire Test simulator (AENFTS) to define their Minimum Hot Surface Ignition Temperature (MHSIT's) when introduced as a spray or

stream onto a hot engine bleed duct. The test employed a simple, uncluttered test section and a realistically simulated portion of the F-16 engine compartment. MHSIT's for all but Mil-H-83282 were consistently found to be higher than the fluids autoignition temperature. GRA

**N89-26962#** Fairchild Republic Div., Farmingdale, NY. **SUPERPLASTIC FORMING OF ALUMINUM, TASK C Final Report, Mar. 1986 - Jan. 1988**

THEODORE RENSCHAW Mar. 1989 100 p (Contract F33615-83-C-3208) (AD-A207282; WRDC-TR-89-3027) Avail: NTIS HC A05/MF A01 CSCL 01/3

This report covers the work under Task C of Contract F33615-83-C-3208. An SPF based A-10 nose landing gear door was designed using Supral 220 alloy. The part count for the basic door was reduced to 4 components as compared to 52 for the conventional construction method. The superplastic pan comprising the stiffening structure of the door was assembled to the external skin using the ultrasonic weldbonding process. Test results show that the two doors are approximately equivalent in strength. Economic analysis indicates that the SPF door is less than half the cost of the conventional door for production quantities larger than 100. GRA

**N89-27005#** National Inst. of Standards and Technology, Gaithersburg, MD. Ceramics Div.

**ADVANCED CERAMICS: A CRITICAL ASSESSMENT OF WEAR AND LUBRICATION Topical Report, Jun. - Oct. 1986**

R. G. MUNRO and S. M. HSU Jan. 1989 109 p Sponsored in part by Pennsylvania State Univ., University Park (Contract GRI-5084-238-1302) (PB89-188569; NISTIR-88/3722; GRI-88/0290; CAM-8901) Avail: NTIS HC A06/MF A01 CSCL 11/3

A critical assessment of the state of the art of the tribology of ceramics is made. To identify the critical technical barriers confronting the utilization of advanced gas-fired engines, data were gathered specifically on the tribology of materials for gas-fired engine applications. Site visits and discussions with a number of contractors in industry were conducted as the first step in identifying critical issues. Then, an extensive review of the technical literature was made to determine what information was available to resolve those issues, and, more importantly, what critical information was not yet available. These data were used to examine the issues for each of the principal engine types (rotary, reciprocating, and turbine). Materials property data for ceramics were then reviewed in the context of the operating environments and conditions for these engines. Thermal, mechanical, and tribological properties were examined, along with the important considerations for lubricating ceramics in engine applications. The analysis of these data considered the impact and relative merits of using various advanced materials and resulted in recommendations for research activities that could have a significant impact on the development of gas-fired prime movers. Author

**N89-27032#** Pennsylvania State Univ., University Park. Coll. of Earth and Mineral Sciences.

**THERMAL STABILITY OF JET FUEL Quarterly Report No. 2, Jan. - Mar. 1989**

SEMIH ESER, JANICE PERISON, RONALD M. COPENHAVER, and HAROLD H. SCHOBERT 1989 71 p (Contract DE-AC22-88PC-88827) (DE89-013516; DOE/PC-88827/T2) Avail: NTIS HC A04/MF A01

Six model compounds have been heat treated in nitrogen and air atmospheres at temperatures between 250 and 450 C for 1 to 4 hours. The treatments were carried out in microautoclave reactors according to the procedure outlined in the previous reports. The thermal treatments in air were carried out under 100 psig cold air pressure at 350 and 400 C. Some observations on the appearance of the reaction products are described. The reaction products from the thermal treatments in nitrogen have been analyzed by gas chromatography-mass spectroscopy (GC-MS). The results of these

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analyses are discussed. The NMR analysis of the reaction products from the treatments in air will be presented in the next report.

DOE

**N89-27834#** Sandia National Labs., Albuquerque, NM.  
**CERAMIC JOINING IN THE UNITED STATES**

RONALD E. LOEHMAN 1988 11 p Presented at the Conference on Interfaces and Ceramic Joining, Petten, Netherlands, 20 Apr. 1988

(Contract DE-AC04-76DP-00789)

(DE89-009323; SAND-88-1112C; CONF-8804256-1) Avail: NTIS HC A03/MF A01

Most U.S. government-funded ceramic joining research and development is sponsored by the US Department of Energy (DOE). Historically, this work has not been funded as a stand-alone effort, but rather as a component of the ceramic engine program sponsored by DOE. That program had its genesis with the Advanced Gas Turbine (AGT) Project, which was conducted by two teams, each consisting of a turbine manufacturer and an automobile company. The successors to the AGT Project are the Automotive Technology Development Program and the Fossil Energy Heat Engines Program, both of which are sponsored by DOE. Most of the DOE ceramic research and development related to heat engines is accomplished as part of the Ceramic Technology for Advanced Heat Engines Project managed by Oak Ridge National Laboratory (ORNL). The ORNL Ceramic Technology Project supports the component development portion of the DOE heat engine program. A small amount of joining R and D is funded by the DOE Office of Energy Utilization Research, Energy Conversion and Utilization Technologies (ECUT) division. Short descriptions and fundings for these various projects is given. K.C.D.

**N89-27859#** Naval Air Development Center, Warminster, PA.  
Aircraft and Crew Systems Technology Directorate.

**AN ADHESIVE FOR FIELD REPAIR OF COMPOSITES Final Report**

R. C. COCHRAN, T. M. DONNELLAN, J. G. WILLIAMS, J. J. KATIALAUS, and NORMAN NEMEROFF Jun. 1988 29 p (AD-A209992; NADC-88072-60) Avail: NTIS HC A03/MF A01 CSDL 11/1

The strength, durability, storage, processability and field adaptability of the NADC adhesive were thoroughly demonstrated, and its stress-strain behavior was well characterized. Representative repairs were successfully fabricated using the adducted adhesive system. Under structural evaluation the adhesive provided comfortable margins of safety for field process variability. Field evaluation has demonstrated the safe application of bonded patches under field conditions using existing common ground support equipment and maintenance personnel. The adhesive was qualified to military specification MIL-A-85705 Adhesive, Aircraft for Structural Repair and was approved for use on the AV-8B aircraft as a structural repair adhesive. GRA

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### 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.

**A89-47521**

**THE SYNTHESIS OF MECHANISMS [SYNTEZA MECHANISMU]**  
MILAN FALTUS Zpravodaj VZLU (ISSN 0044-5355), no. 2, 1989, p. 83-91. In Czech. refs

The basic aspects of the synthesis of mechanisms are reviewed, noting the benefits of mechanism synthesis for design methods. Examples are given of aircraft designs using complex mechanical

coupling. The realization of common plane motion using rotating joints and supplemented by the calculation of flap motion is discussed. The calculation of a quadrinuckle function generator for the design of nonlinear control system mechanisms is examined. Also, consideration is given to undercarriage kinematics design. The use of rotating joints to increase construction reliability is emphasized. R.B.

**A89-47525**

**THE POSSIBLE REALIZATION OF SERVOMECHANISMS IN ACTIVE CONTROL SYSTEMS [MOZNOSTI REALIZACE SERVOMECHANISMU V AKTIVNICH SYSTEMECH RIZENI LETADEL]**

DOBROSLAV RAK Zpravodaj VZLU (ISSN 0044-5355), no. 3, 1989, p. 141-146. In Czech. refs

The principal requirements for introducing servomechanisms into active control systems are summarized for various aircraft categories. Several servomechanism designs are discussed, including those with mechanical and electrical control signal inputs and servomechanisms with three- or four-fold redundancy. The possible applications of these designs in training aircraft are considered. R.B.

**A89-47667#**

**IN-FLIGHT MEASUREMENT OF STATIC PRESSURES AND BOUNDARY LAYER STATE WITH INTEGRATED SENSORS**

E. GREFF (Messerschmitt-Boelkow-Blohm GmbH, Bremen, Federal Republic of Germany) IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 417-427. refs (AIAA PAPER 89-2209)

The reliable, integrated sensors for control-system feedback required by advanced transport aircraft wing designs incorporating adaptive geometry features for load control and performance optimization are presently evaluated. Absolute pressure transducers from various manufacturers were tested and adapted to the flight test environment; both laboratory and flight test results indicate steady measurement capabilities. It is shown that the sensing of pressure fluctuations in the wing-buffet regime will improve the prediction of operational limits. The pressure transducers were also used to investigate the laminar/turbulent transition in the attachment-line flow of a swept wing. A comparison of these results with those of hot film probes shows the transducers' effectiveness. O.C.

**A89-47669\*#** Colorado Univ., Boulder.

**TRANSONIC AEROELASTICITY ANALYSIS FOR ROTOR BLADES**

CHUEN-YEN CHOW (Colorado, University, Boulder), I-CHUNG CHANG (NASA, Ames Research Center, Moffett Field, CA), and LIE-MINE GEA IN: AIAA Applied Aerodynamics Conference, 7th, Seattle, WA, July 31-Aug. 2, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 440-451. refs (Contract NCC2-508) (AIAA PAPER 89-2212)

A numerical method is presented for calculating the unsteady transonic rotor flow with aeroelasticity effects. The blade structural dynamic equations based on beam theory were formulated by FEM and were solved in the time domain, instead of the frequency domain. For different combinations of precone, droop, and pitch, the correlations are very good in the first three flapping modes and the first twisting mode. However, the predicted frequencies are too high for the first lagging mode at high rotational speeds. This new structure code has been coupled into a transonic rotor flow code, TFAR2, to demonstrate the capability of treating elastic blades in transonic rotor flow calculations. The flow fields for a model-scale rotor in both hover and forward flight are calculated. Results show that the blade elasticity significantly affects the flow characteristics in forward flight. Author

**A89-47717\*# Texas A&M Univ., College Station.  
PIEZOELECTRIC PUSHERS FOR ACTIVE VIBRATION  
CONTROL OF ROTATING MACHINERY**

A. B. PALAZZOLO, R. R. LIN, R. M. ALEXANDER (Texas A & M University, College Station), A. F. KASCAK (NASA, Lewis Research Center; U.S. Army, Cleveland, OH), and J. MONTAGUE (Sverdrup Technology, Inc., Middleburg Heights, OH) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 111, July 1989, p. 298-305. Research supported by the Texas A & M Turbomachinery Research Consortium. Previously announced in STAR as N88-23229. refs (Contract NAG3-763)

The active control of rotordynamic vibrations and stability by magnetic bearings and electromagnetic shakers have been discussed extensively in the literature. These devices, though effective, are usually large in volume and add significant weight to the stator. The use of piezoelectric pushers may provide similar degrees of effectiveness in light, compact packages. Tests are currently being conducted with piezoelectric pusher-based active vibration control. Results from tests performed on NASA test rigs as preliminary verification of the related theory are presented.

Author

**A89-47719\*# National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, OH.**

**EFFECT OF DESIGN VARIABLES, TEMPERATURE  
GRADIENTS, AND SPEED ON LIFE AND RELIABILITY OF A  
ROTATING DISK**

E. V. ZARETSKY (NASA, Lewis Research Center, Cleveland, OH), T. E. SMITH, and R. AUGUST (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 111, July 1989, p. 311-316. Previously announced in STAR as N87-13755. refs

A generalized methodology to predict the fatigue life and reliability of a rotating disk such as used for aircraft engine turbines and compressors is advanced. The approach incorporates the computed life of elemental stress volumes to predict system life and reliability. Disk speed and thermal gradients as well as design variables such as disk diameter and thickness and bolt hole size, number and location are considered.

Author

**A89-47862**

**APPLICATION OF SIGNAL ANALYSIS TO ACOUSTIC  
EMISSION FROM A CYCLICALLY LOADED ALUMINUM JOINT  
SPECIMEN**

M. A. FRIESEL (Batelle Pacific Northwest Laboratories, Richland, WA) Materials Evaluation (ISSN 0025-5327), vol. 47, July 1989, p. 842-848. Research supported by DARPA.

Acoustic emission (AE) techniques were applied to a simulated airframe joint specimen. Signals obtained from four sensors at different locations on the test specimen were analyzed and waveform features identified, enabling AE events arising from crack growth to be distinguished from those caused by fretting. Crack signals were found to be identifiable on the basis of feature values derived from pencil-lead break waveforms.

Author

**A89-47941**

**PROCEDURE FOR EVALUATING THE EFFECT OF  
STRUCTURAL PARAMETERS ON THE LIFE OF  
LONGERON-WALL JOINTS [METODIKA OTSENKI VLIANIYA  
KONSTRUKTIVNYKH PARAMETROV NA DOLGOVECHNOST'  
SOEDINENII STENOK LONZHERONIA]**

A. G. GREBENIKOV, V. N. STEBENEV, A. M. TIMCHENKO, and S. V. TRUBAEV Samoletostroenie - Tekhnika Vozdushnogo Flota (ISSN 0581-4634), no. 55, 1988, p. 71-77. In Russian.

A procedure is described for evaluating the effects of the structural parameters of longeron-wall joints on their durability. In particular, the effects of the wall thickness at the joint zone, the interval between the bracing elements, the diameter and the type of brackets, the interval between the reinforcing struts, and the number of cross-section planes at the joint between the longeron wall and the reinforcing belt were evaluated. The values predicted

theoretically were found to agree with experimental findings. Several methods are proposed for increasing the life of the longeron-wall structural elements.

I.S.

**A89-47958**

**THE PROBLEM OF SAFETY FACTOR DETERMINATION [K  
ZADACHE OBOSNOVANIYA KOEFFITSIENTA BEZOPASNOSTI]  
V. P. SAVCHUK Aviatsonnaia Tekhnika (ISSN 0579-2975), no.  
1, 1989, p. 29-32. In Russian. refs**

A method for the statistical estimation of the safety factor is proposed which is based on the Bayes approach to statistical conclusions. The method uses a theoretical strength model, nondestructive test results, and the required reliability level. The application of the method is illustrated by a specific example.

V.L.

**A89-47959**

**EVALUATION OF THE TIGHTNESS OF THE FLANGE JOINTS  
OF THE SHELL ELEMENTS OF AIRCRAFT STRUCTURES [K  
OTSENKE GERMETICHNOSTI FLANTSEVYKH STYKOV  
OBOLOCHICHNYKH ELEMENTOV AVIATSIONNYKH  
KONSTRUKTSII]**

KH. S. KHAZANOV and A. V. KHIVINTSEV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 1, 1989, p. 32-35. In Russian. refs

A method for calculating the tightness of bolted flange joints loaded by internal pressure is presented which employs an elastoplastic model of the gasket. The method allows for the tightening and compliance of the bolts as well as for their discrete arrangement. The method, which uses the finite element approach, has been implemented in computer software written in FORTRAN.

V.L.

**A89-48000**

**PREDICTION OF FATIGUE CRACK PROPAGATION IN PLANE  
SPECIMENS AND THIN-WALLED STRUCTURAL ELEMENTS  
OF AIRCRAFT UNDER REPEATED STATIC LOADING  
[PROGNOZIROVANIE RAZVITIYA USTALOSTNYKH  
TRESHCHIN V PLOSKIKH OBRAZTSAKH I TONKOSTENNYKH  
ELEMENTAKH KONSTRUKTSII SAMOLETA PRI  
POVTORNO-STATICHESKOM NAGRZHENII]**

V. V. BULANOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 58-60. In Russian.

A fatigue fracture criterion is proposed which considers only that part of dissipated energy that is directly responsible for fracture and uses the logarithmic vibration decrement as the criterial parameter. It is shown that such an approach makes it possible to predict the remaining life of a structural element on the basis of a minimum of two observations of the response of this element to a test load. The method is verified experimentally for D16T aluminum alloy and Kh18N10T steel specimens.

V.L.

**A89-48001**

**AN EXPERIENCE IN THE COMPUTERIZED ANALYSIS OF THE  
FATIGUE LIFE OF AIRCRAFT STRUCTURAL ELEMENTS  
[OPYT AVTOMATIZATSII PROTSESSA RASCHETA  
DOLGOVECHNOSTI ELEMENTOV AVIATSIONNYKH  
KONSTRUKTSII]**

A. I. KARTAMYSHEV, A. M. BELOV, A. S. MOSTOVOI, A. G. PROKHOROV, A. V. KIRILLOV et al. Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 2, 1989, p. 60-62. In Russian. refs

An approach to the prediction of the fatigue life of structural elements is presented which is based on linear discrete concepts of fatigue fracture mechanisms. The method has been implemented in a set of application software written in FORTRAN. As an example, fatigue lives calculated for several different structural elements are compared with experimental data.

V.L.

**A89-48304#**

**A FAMILY OF RADARS FOR ADVANCED SYSTEMS**

ENNIO GIACCARI and CARLO ALBERTO PENAZZI (Selenia S.p.A., Rome, Italy) Alta Frequenza (English Edition) (ISSN 0002-6557), vol. 58, Mar.-Apr. 1989, p. 97-114. refs

The military and air traffic control radars developed by Selenia

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are reviewed. The design, production, and testing aspects of the radar development process are discussed, focusing on shipborne, ground based, and air traffic control radars. An overview of radar subsystems is given, including the antenna, transmitter, receiver-exciter, signal processor, data processor, and radar controller subsystems. R.B.

**A89-48469**

### **THE HARMONIC BALANCE METHOD FOR DETERMINING THE VIBRATION PARAMETERS IN DAMPED DYNAMIC SYSTEMS**

W. OSTACHOWICZ (Polska Akademia Nauk, Instytut Maszyn Przeplywowych, Gdansk, Poland) Journal of Sound and Vibration (ISSN 0022-460X), vol. 131, June 22, 1989, p. 465-473. refs

The object of the paper is to present a method of analysis of forced vibration of discrete mechanical systems, taking into account Coulomb friction forces at the dampers. The method relies upon assuming the solution in the form of a Fourier series and applying the harmonic balance method. The approach described in the paper can be used for vibration analysis of gas and steam turbine blades and blades of axial compressors. The analysis is provided with an algorithm and an example of calculations. There is a description of the computer program which was utilized during the calculations. Author

**A89-48663\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **ANALYTICAL FLUTTER INVESTIGATION OF A COMPOSITE PROPFAN MODEL**

K. R. V. KAZA, O. MEHMED (NASA, Lewis Research Center, Cleveland, OH), G. V. NARAYANAN (Sverdrup Technology, Inc., Cleveland, OH), and D. V. MURTHY (Toledo, University, OH) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A, p. 84-97) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 772-780. Previously cited in issue 17, p. 2695, Accession no. A87-40497. refs

**A89-48664#**

### **EFFECTS OF STRUCTURAL NONLINEARITIES ON FLUTTER CHARACTERISTICS OF THE CF-18 AIRCRAFT**

B. H. K. LEE and A. TRON (National Research Council of Canada, Ottawa) Journal of Aircraft (ISSN 0021-8669), vol. 26, Aug. 1989, p. 781-786. refs  
(Contract DND-FE-220786NRC06)

The describing function method is used to analyze the flutter characteristics of the CF-18 aircraft with structural nonlinearities. The first nonlinearity studied is located at the CF-18 wing-fold hinge. From ground test data, this hinge can be represented by a bilinear spring. A flutter sensitivity study is carried out, which shows that when the hinge stiffness is reduced, divergent flutter involving the wing bending and torsion modes is replaced by limit-cycle flutter of the wing torsion and outer wing rotation modes. Another form of nonlinearity at the outboard leading-edge flap is also studied by treating it as a spring with free-play. Limit-cycle oscillations are possible only within a small range of velocities in the vicinity of its linear flutter velocity. The flutter modes remain unchanged and their frequencies are practically constant for hinge-stiffness values ranging from a few percent to its nominal value. Positive aileron angles are found to be more effective in alleviating limit-cycle flutter at the wing-fold than negative angles. Similar observations are made at the outboard leading-edge flap hinge where downward deflection of the aileron gives larger values of the preload and, hence, the equivalent stiffness than upward deflection. Author

**A89-48840**

### **PROJECTION DISPLAYS FOR FLIGHT SIMULATORS**

L. T. TODD, JR. (Projectron, Inc., Lexington, KY) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 164-176. refs

While a variety of available image-projection technologies can

be used in state-of-the-art visual displays for flight simulation, the high brightness/resolution projection CRTs currently employed face intrinsic limitations on further performance improvement. Image projectors reaching superior levels of brightness and resolution will entail the use of such light-valve technologies as the Schlieren optical system and the liquid crystal CRTs, in which resolution and brightness are not coupled. Superior prospects are contemplated for liquid crystal devices able to operate in real time. O.C.

**A89-48841\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **TRANSPORT DELAY COMPENSATION FOR COMPUTER-GENERATED IMAGERY SYSTEMS**

RICHARD E. MCFARLAND (NASA, Ames Research Center, Moffett Field, CA) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 177-202. Previously announced in STAR as N88-17645. refs

In the problem of pure transport delay in a low-pass system, a trade-off exists with respect to performance within and beyond a frequency bandwidth. When activity beyond the band is attenuated because of other considerations, this trade-off may be used to improve the performance within the band. Specifically, transport delay in computer-generated imagery systems is reduced to a manageable problem by recognizing frequency limits in vehicle activity and manual-control capacity. Based on these limits, a compensation algorithm has been developed for use in aircraft simulation at NASA Ames Research Center. For direct measurement of transport delays, a beam-splitter experiment is presented that accounts for the complete flight simulation environment. Values determined by this experiment are appropriate for use in the compensation algorithm. The algorithm extends the bandwidth of high-frequency flight simulation to well beyond that of normal pilot inputs. Within this bandwidth, the visual scene presentation manifests negligible gain distortion and phase lag. After a year of utilization, two minor exceptions to universal simulation applicability have been identified and subsequently resolved. Author

**A89-48920**

### **TRANSIENT THERMAL PROCESSES IN THE POWERPLANTS OF FLIGHT VEHICLES [NESTACIONARNYE TEPLOVYE PROTSESSY V ENERGETICHESKIKH USTANOVKAKH LETATEL'NYKH APPARATOV]**

NIKOLAI D. KOVALENKO, ALEKSANDR A. SHMUKIN, MIKHAIL I. GUZHVA, and VLADIMIR V. MAKHIN Kiev, Izdatel'stvo Naukova Dumka, 1988, 224 p. In Russian. refs

Transient heat and mass transfer processes taking place in the complex multielement structures and components of the powerplants of flight vehicles are investigated numerically and analytically. Particular attention is given to heat and mass transfer processes associated with transient regimes during the start-up, shut-off, and pauses. The mathematical models presented here account for the principal characteristics of the structures and processes, such as geometrical complexity, nonuniform intense heat transfer, and the transient nature of the physical properties and phase states. Solutions are presented for some specific problems. V.L.

**A89-49025**

### **SUBSONIC AND SUPERSONIC LASER VELOCIMETRY [VELOCIMETRIE LASER EN SUBET SUPERSONIQUE]**

A. BOUTIER (ONERA, Chatillon-sous-Bagneux, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 1, 1989, p. 111-120. In French. refs

The various techniques of laser velocimetry used for aerodynamic flow studies are described and ranked into two categories: fringe velocimeters and optical barrier velocimeters. Fringe velocimeters can now simultaneously measure the three components of the local instantaneous velocity vector and provide the whole Reynolds tensor. The measurement quality depends

upon careful localization of the probe volume, quick and accurate calibration using a theodolite on line with a microcomputer, seeding of the flow with calibrated submicron particles (latex balls for instance). Optical barrier velocimeters are well suited for gas turbine engine experiments and under conditions of intense stray light, but when the turbulence rate is rather low, their signal-to-noise ratio is higher than that of a fringe laser velocimeter. Author

**A89-49437\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**STRUCTURES TECHNOLOGY FOR A NEW GENERATION OF ROTORCRAFT**

FELTON D. BARTLETT, JR. (NASA, Langley Research Center; U.S. Army, Aerostructures Directorate, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. (AIAA PAPER 89-2070)

This paper presents an overview of structures research at the U. S. Army Aerostructures Directorate. The objectives of this research are to investigate, explore, and demonstrate emerging technologies that will provide lighter, safer, more survivable, and more cost-effective structures for rotorcraft in the 1990s and beyond. The emphasis of today's R&D is to contribute proven structures technology to the U. S. rotorcraft industry and Army aviation that directly impacts tomorrow's fleet readiness and mission capabilities. The primary contributor toward meeting these challenges is the development of high-strength and durable composites to minimize structural weight while maximizing cost effectiveness. Special aviation issues such as delamination of dynamic components, impact damage to thin skins, crashworthiness, and affordable manufacturing need to be resolved before the full potential of composites technology can be realized. To that end, this paper highlights research into composites structural integrity, crashworthiness, and materials applications which addresses these issues. Author

**A89-49448#**

**AGE FORMING INTEGRALLY STIFFENED, ALUMINUM AEROSPACE STRUCTURES IN AN AUTOCLAVE**

HAROLD M. BREWER (Textron Aerostructures, Nashville, TN) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 13 p. refs (AIAA PAPER 89-2087)

The age-forming of complex, integrally stiffened aluminum panel structures is presently accomplished in an autoclave which applies fluidized deformation forces uniformly throughout a structural component's surface, thereby circumventing the forming limitations conventionally associated with such integrally-machined features as stiffeners, skin tapers, pockets, and window cutouts. In addition, the process enlists the stress relief that occurs during precipitation aging to relax stresses induced during the initial forming stages. Substantially lower residual stresses result. By employing a computer-controlled autoclave, high levels of process repeatability and accuracy are obtainable. Blade-stiffened isogrid panels, wing skins, and fuselage panels have been produced. O.C.

**A89-49450#**

**STRESS INTENSITY FACTORS FOR DAMAGE TOLERANCE EVALUATIONS OF ELLIPTICAL PRESSURE DOME STRUCTURE**

T. DANIEL SHONKA (Boeing Commercial Airplanes, Seattle, WA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 10 p. refs (AIAA PAPER 89-2090)

Problems that may be experienced by aging aircraft were investigated by determining the fatigue- and damage-tolerance characteristics of an elliptically shaped aft fuselage pressure dome of a retired 20-year-old aircraft. Sufficient information was gathered to develop stress-intensity solutions for elliptical pressure dome structures for general use by stress analysis. It was discovered that a radial stiffener in the same lap splice with a radial crack affects the crack growth results to a significant degree, if the crack is not in the same fastener row as the stiffener (little effect

is observed if the crack and the radial stiffener share the same fastener row). It was also observed that collinear cracks in adjacent bays increase the crack-growth rate of a crack. I.S.

**A89-49451#**

**INFLUENCE OF MECHANICAL NONLINEARITIES ON FLUTTER - ANALYTICAL AND COMPUTATIONAL ASPECTS**

GEORGES A. BECUS (Cincinnati, University, OH), CHRISTIAN PETIAU, and PHILIPPE NICOT (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p. Research supported by the Service Technique des Programmes Aeronautiques. refs (AIAA PAPER 89-2091)

Efficient analytical techniques for quantifying the effects of mechanical nonlinearities on the flutter characteristic of an aircraft structure are developed. The major features of the method include the implicit time domain integration with condensation to the finite element DOFs where nonlinearities occur, frequency domain rationalization of transient aerodynamic forces by least-square polynomial approximation, and the use of aeroelastic transfer operators for computation. The method is applied to determine the effect of the fail-safe actuator on the flutter of the horizontal tail of a civilian aircraft. Results indicate that, due to energy dissipation, mechanical nonlinearities have a beneficial effect on flutter (they increase the critical flutter speed) but have detrimental structural effects, in that they increase stress. I.S.

**A89-49453#**

**A NETWORK - THE MISSING ELEMENT**

MARC COHN (Northrop Corp., Pico Rivera, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 11 p. refs (AIAA PAPER 89-2095)

The Advanced Avionics Architecture (A3) of the next generation of avionics systems requires a high-performance, logical interconnect for advanced aircraft. The High Speed Data Bus (HSDB) does not meet the requirements for the A3; a network is the missing element. Here, the limitations of current HSDB approaches are reviewed, and an overview is given of the Fiber Optic Data Distribution Network (FDDN), an alternative to the HSDB for the A3 requirement. The management of the FDDN is discussed. C.D.

**A89-49461#**

**CONSTRAINTS AND ISSUES IN APPLICATION OF R&M 2000 - LESSONS LEARNED**

C. K. GARRETT (Douglas Aircraft Co., Long Beach, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. (AIAA PAPER 89-2103)

The role and application of R&M 2000 reliability, availability and maintainability goals are examined for aircraft design and development in the initial study phases of the acquisition process. Analysis and data are provided which suggest that R&M 2000 goals are not always consistent with overall operational goals and enhanced cost-effectiveness, particularly with respect to pilot training aircraft. Ways to improve the efficiency of applying R&M 2000 concepts to all types of aircraft are offered. Author

**A89-49653**

**COMBINING FRACTURE MECHANICS WITH FRACTOGRAPHY IN THE ANALYSIS OF THE CRACKING OF A HELICOPTER BLADE**

I. ELDROR (Israel Aircraft Industries, Ltd., Metallurgy Group, Lod) (University of the Negev, Technion - Israel Institute of Technology, National Council for Research and Development, et al., IMEC IV - Israel Materials Engineering Conference, 4th, Beersheba, Israel, Dec. 7, 8, 1988) Israel Journal of Technology (ISSN 0021-2202), vol. 24, no. 3-4, 1988, p. 683-687. refs

The present investigation of the cracking of a helicopter main rotor blade during service combines the identification of fractographic features related to a loading-spectrum model with a



Paris diagram that is modified to account for repeated delays in crack propagation over the number of cycles required for critical damage accumulation. The results obtained indicate that current NDI methods fail to detect the surface crack stage that extends over about 95 percent of crack life, and become effective only shortly before catastrophic failure. O.C.

**A89-49826#**

**RADIAL SWIRL FLOWS BETWEEN PARALLEL DISCS AT CRITICAL FLOW RATE**

TOSHIO NAGASHIMA and HIROSHI ITOH Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 425, 1989, p. 267-277. In Japanese, with abstract in English. refs

Flows through the passage between two parallel disks from inner to outer radii accompanying strong circumferential swirl have been investigated in view of flow stability in vaneless diffusers of centrifugal pumps and compressors. Particular concern is with the phenomenon of rotating stall, which is observed as the flow rate is reduced to a critical value. Experiments have been carried out, and the results show (1) diffuser characteristics, (2) streamline and vorticity distributions, (3) loss coefficients, (4) stall cell propagation speed and fluctuation amplitude, and (5) rotating pressure patterns, wherefrom a proposition has been made for explaining the mechanism of stall cell propagation. Author

**A89-49833**

**ANALYTICAL FAILURE PREDICTION OF BOLTED CONNECTIONS IN COMPOSITE SHAFTS**

KENNETH M. FURNES (Sikorsky Aircraft, Stratford, CT) and DANIEL B. GOETSCHEL (Rensselaer Polytechnic Institute, Troy, NY) American Helicopter Society, Journal (ISSN 0002-8711), vol. 34, July 1989, p. 75-79. refs  
(Contract DAAG29-82-K-0093)

Analytical failure prediction and experimental evaluation of bolted connections in composite driveshafts is investigated. The load state and geometry existing in a shaft differ from that typically considered in the flatplate, tension-loaded cases found in the literature. A failure criteria is proposed to predict the connection strength via finite element analysis. The effects of various design parameters on connection strength are investigated. Experimental verification of analytical results is presented for various test configurations. Good correlation between analytical predictions and test results is shown to exist. Author

**A89-50006**

**RECOMBINATION OF TWO VORTEX FILAMENTS AND JET NOISE**

RYUJI TAKAKI (Tokyo University of Agriculture and Technology, Fuchu, Japan) and FAZLE HUSSAIN (Houston, University, TX) IN: Developments in fluid mechanics and space technology. Bangalore, Indian Academy of Sciences, 1988, p. 83-96. refs

The recombination of two vortex filaments in a viscous incompressible fluid is analyzed by the use of the vorticity equation. The analysis is confined to a local flow field, where the recombination process occurs, and is based on several assumptions, such as the conservation of the fluid impulse and spatial symmetry of the flow field. The flow field is expanded as polynomials of coordinates, and variations of their coefficients are obtained by the use of the vorticity equation. It is proven that the process is completed within a short time and that the viscous effect is essential. This result is applied to predict the far-field noise of a circular jet by assuming that the main noise source is the recombination process in deformed vortex rings in the jet near field. Author

**A89-50057\*#** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**RECTANGULAR JETS IN A CROSSFLOW**

M. S. KAVSAOGLU, J. A. SCHETZ, and A. K. JAKUBOWSKI (Virginia Polytechnic Institute and State University, Blacksburg, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Sept. 1989, p. 793-804. Research supported by NASA. refs

Rectangular jets injected from a flat plate into a crossflow at large angles have been studied. Results were obtained as surface pressure distributions, mean velocity vector plots, turbulence intensities, and Reynolds stresses in the jet plume. The length-to-width ratio of the jets was 4, and the jets were aligned streamwise as single and side-by-side dual jets. The jet injection angles were 90 and 60 deg. Surface pressure distribution results were obtained for jet-to-freestream velocity ratios of 2.2, 4, and 8. Mean flow and turbulence flowfield data were obtained for the side-by-side dual jets, mainly for the jet-to-freestream velocity ratio of 4. The jets featured strong negative pressure peaks near the front nozzle corners. The 60-deg jets produced lower magnitude negative pressures, which are distributed over a lesser area when compared to the 90-deg jets. Author

**A89-50124#**

**ENVIRONMENTAL TESTS OF THERMOGRAPHIC PHOSPHORS FOR TURBINE-ENGINE TEMPERATURE MEASUREMENTS**

B. W. NOEL, M. C. BIBBY, H. M. BORELLA, S. E. WOODRUFF (Los Alamos National Laboratory, NM), C. L. HUDSON (EG&G Energy Measurements, Inc., Goleta, CA) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989. 13 p. Research supported by USAF. refs (AIAA PAPER 89-2913)

A method that uses thermographic phosphors (TPs) for remote temperature measurements in hostile environments was developed. Based on the results of environmental tests, the potential for applying the TP method to measuring blade and vane temperatures in operating turbine engines was evaluated. Heat/water-quench tests, burner-rig tests, and a test in an experimental-engine hot section demonstrated that the TPs can be durably bonded to blade and vane surfaces, yet still exhibit usable luminescence after the test. A spin-pit test showed that it was possible to measure the temperature reliably on a heated rotating turbine disk. These tests and their results are described. Author

**A89-50141**

**VOID MINIMIZATION IN ADHESIVE JOINTS**

R. J. CHESTER and J. D. ROBERTS (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) International Journal of Adhesion and Adhesives (ISSN 0143-7496), vol. 9, July 1989, p. 129-138. refs

Large void contents were observed in bonds made with a modified epoxy adhesive and aluminum adherends, while similar joints made under identical conditions but with steel adherends were essentially void free. Experiments involving a range of different surface treatments have demonstrated that moisture, which is readily adsorbed by heavily deformed aluminum surfaces, is the primary cause of these voids. Steel surfaces do not appear to adsorb moisture to the same extent. Several promising techniques for minimizing voids are described. Author

**A89-50152\*** Pennsylvania State Univ., University Park.

**A LINEAR SHOCK CELL MODEL FOR JETS OF ARBITRARY EXIT GEOMETRY**

P. J. MORRIS, T. R. S. BHAT, and G. CHEN (Pennsylvania State University, University Park) Journal of Sound and Vibration (ISSN 0022-460X), vol. 132, July 22, 1989, p. 199-211. refs  
(Contract NAG1-657; AF-AFOSR-87-0334)

The shock cell structures of single supersonic non-ideally expanded jets with arbitrary exit geometry are studied. Both vortex sheets and realistic mean profiles are considered for the jet shear layer. The boundary element method is used to predict the shock spacing and screech tones in a vortex sheet model of a single jet. This formulation enables the calculations to be performed only on the vortex sheet. This permits the efficient and convenient study of complicated jet geometries. Results are given for circular, elliptic and rectangular jets and the results are compared with analysis and experiment. The agreement between the predictions and measurements is very good but depends on the assumptions made to predict the geometry of the fully expanded jet. A finite difference technique is used to examine the effect of finite mixing

layer thickness for a single jet. The finite thickness of the mixing layer is found to decrease the shock spacing by approximately 20 percent over the length of the jet potential core. Author

**A89-50172#**

**MODIFICATION OF K-EPSILON TURBULENCE MODELS FOR COAXIAL SUDDEN-EXPANSION SWIRLING FLOWS**

HAU-CHUNG SOONG and KEH-CHIN CHANG (National Cheng Kung University, Tainan, Republic of China) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731), vol. 10, April 1989, p. 75-80. refs

A successful prediction of turbulent swirling flow, which is important for simulation of gas turbine combustors and ramjet combustors, requires a reliable turbulence model. The standard  $k - \epsilon$  model, which is commonly used for engineering practice, is reported in less satisfactory agreement with the measured results for flows incorporated with high streamline curvature effects. Several modified  $k - \epsilon$  models have been studied and compared with the measurements in literature. It was found that the modified  $k - \epsilon$  models can help improve the predictions of high-swirl-strength flows, but the improvements are not so significant. Reynolds stress models seem to be another potential method to provide satisfactory predictions for high-swirl-strength flow fields. Author

**A89-50174#**

**FLUTTER OF GENERAL LAMINATED PANELS IN SUPERSONIC FLOW**

LI-TEH LU and LE-CHUNG SHIAU (National Cheng Kung University, Tainan, Republic of China) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731), vol. 10, April 1989, p. 93-100. refs

The flutter characteristics of rectangular clamped laminated panel at high supersonic Mach number are examined theoretically. Linear small deflection laminated plate theory and quasi-steady aerodynamic theory are employed. The generalized Fourier's series method is used to obtain approximate solution to the coupled governing equations. Results show that fiber orientations, aerodynamic damping, stacking sequence, inplane normal and shear loads, and direction of airflow have significant effects on the flutter boundaries. Hence, a properly designed laminated panel will improve the flutter stability. Author

**A89-50535#**

**VORTICAL PATTERNS IN THE WAKE OF AN OSCILLATING AIRFOIL**

MANOOCHEHR M. KOOCHESFAHANI (Michigan State University, East Lansing) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1200-1205. Previously cited in issue 08, p. 1097, Accession no. A87-22421. refs  
(Contract AF-AFOSR-84-0120)

**A89-50584**

**ON THE GENERATION OF A SET OF ACCURATE NUMERICAL MODAL FUNCTIONS FOR USE IN THE AEROELASTIC ANALYSIS OF FLEXIBLE ROTOR BLADES**

A. SIMPSON (Bristol, University, England) Aeronautical Journal (ISSN 0001-9240), vol. 93, June-July 1989, p. 207-218. Research supported by the Ministry of Defence and SERC. refs

A comparison is presented of three methods for the generation of numerical, modal approximating functions for use in modal Lagrangian analysis of rotating flexible blades. The methods considered are those based on the use of uniform beam/bar eigenfunctions, smooth bending moment or torque modes, and modes generated by recourse to one stage of the Stodola method. For blades which are highly nonuniform in their specific stiffness and inertial properties, and where the objective is to use a small number of approximating functions, consistent with accurate determination of eigensolutions in the fundamental spectrum, it is demonstrated that direct use of uniform system eigenfunctions is unsatisfactory. On the other hand, it is demonstrated that the use of smooth bending moment modes, even in cases where the variations in sectional inertia properties are very large, can produce

excellent results. The use of 'Stodola modes', however, is shown to offer the advantage of enhanced convergence rate in all cases considered. Author

**A89-50817**

**INTEGRATED INTERCONNECTION SYSTEMS FOR AEROSPACE APPLICATIONS**

KEITH KERFOOT and RICHARD GOHMAN (McDonnell Douglas Helicopter Co., Mesa, AZ) SAWE, Annual Conference, 47th, Detroit, MI, May 23-25, 1988. 19 p.  
(SAWE PAPER 1821)

The application of an integrated interconnection system (IIS), which utilizes flat conductor cables and conventional round wire, to electrical system wiring in aircraft is examined. The advantages of the IIS to present wiring techniques are studied. The implementation of an IIS wiring network on the AH-64A Advanced Attack Helicopter is simulated. The system's weight, reliability, maintainability, performance, and production costs are analyzed. It is noted that the potential production cost savings make the IIS an applicable system for a new electrical wiring design. I.F.

**A89-51044**

**USING THE PROPERTIES OF NONLINEAR VIBRATIONS FOR FLAW DETECTION IN THE REINFORCEMENT ELEMENTS OF THIN-WALLED STRUCTURES [ISPOL'ZOVANIE OSOBNOSTEI NELINEINYKH KOLEBANII DLIA DIAGNOSTIKI POVREZHDENII V PODKREPLIAIUSHCHIKH ELEMENTAKH TONKOSTENNYKH KONSTRUKTSII]**

S. L. TSYFANSKII, A. B. OKS, V. I. BERESNEVICH, and M. A. MAGONE (Rizhskii Politekhnikeskii Institut, Riga, Latvian SSR) Defektoskopiia (ISSN 0130-3082), no. 7, 1989, p. 29-37. In Russian. refs

A new approach to the detection of fatigue cracks in the reinforcement elements of thin-walled structures is proposed which combines the attached mass method with basic concepts of nonlinear vibrational diagnostics. Specific flaw detection procedures based on this approach are presented. It is shown that the sensitivity of the methods proposed here is significantly higher than that of the known modifications of the attached mass method. V.L.

**A89-51045**

**A PORTABLE ACOUSTIC IMPEDANCE FLAW DETECTOR, AD-42I [PORTATIVNYI IMPEDANSNYI AKUSTICHESKII DEFEKTOSKOP AD-42I]**

IU. V. LANGE, E. G. USTINOV, and A. V. SHELENKOV (Nauchno-Issledovatel'skii Institut Introskopii, Moscow, USSR) Defektoskopiia (ISSN 0130-3082), no. 7, 1989, p. 90-93. In Russian. refs

A new impedance flaw detector, AD-42I, has been developed to fill the need for a simple portable instrument that can be conveniently used both at the manufacturing plant and in the field for the inspection of aircraft structures. In contrast to other impedance-type flaw detectors, the AD-42I uses the pulsed version of the impedance method. High sensitivity is achieved through the use of two-parameter amplitude-frequency signal processing. The general design, principal components and performance characteristics of the instrument are discussed. V.L.

**A89-51253**

**DESIGN WITH STRUCTURAL CERAMICS**

ARTHUR F. MCLEAN and DALE L. HARTSOCK (Ford Motor Co., Dearborn, MI) IN: Structural ceramics. San Diego, CA, Academic Press, Inc., 1989, p. 27-97. refs

In considering the use of such structural ceramics as hot-pressed or reaction-bonded silicon nitride and silicon carbide for engineering applications at the conceptual-design stage, a designer must know key physical and mechanical properties and how they compare with metallic alternatives, in order to establish the functional advantages of the ceramics. In the detailed design stage, the methodology of design for a specific structural ceramic becomes of paramount importance, in order to design for the greatest possible reliability at a given level of performance.

## 12 ENGINEERING

Attention is presently given to the illustrative cases of indirect-injection diesel engines, turbocharged diesels, turbochargers, a radial simple-cycle gas turbine engine, and regenerative gas turbine engines. O.C.

### A89-51275 ENCYCLOPEDIA OF FLUID MECHANICS. VOLUME 8 - AERODYNAMICS AND COMPRESSIBLE FLOWS

NICHOLAS P. CHEREMISINOFF, ED. (Exxon Chemical Co., Linden, NJ) Houston, TX, Gulf Publishing Co., 1989, 1228 p. No individual items are abstracted in this volume.

Advanced analytical methods for compressible flows and their application to specific engineering problems are discussed in chapters by leading experts. Topics addressed include fluid viscosity, laminar flow past semiinfinite bodies, the structure of turbulent boundary layers, homogeneous turbulence, turbulent shear flows and jets, vortex patterns on slender bodies, wake interference and vortex shedding, turbulent rough-wall skin friction and heat transfer, FEM iterative solutions of compressible flows, transient natural-convection flows, and direct-contact transfer processes with moving liquid droplets. Consideration is given to artificially thickening turbulent boundary layers, subsonic transitory stalled flows in diffusers, impeller-blade design for centrifugal and axial blowers, transonic cascade flows, high-speed turboprop noise, turbine-blade vibrations, compressible flow in valves, the performance of cryogenic pumps, the structure of turbulent dense-spray jets, and the dynamics of wind machines. T.K.

### A89-51312# BUCKLING WITH IMPERFECTION OF CYLINDRICAL COMPOSITE PANEL

C. S. HONG and S. M. JUN (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 208-211. refs

Buckling behavior of laminated cylindrical composite panels under axial compression is investigated using the finite element method. A finite element program is developed for the nonlinear structural analysis of the laminated shell structure. The eight-node degenerated shell element with 40 degrees of freedom is utilized for the finite element modeling of the laminated shell structure. Various fiber angles of graphite/epoxy laminates are investigated with panel widths. The shape of buckled panel and the buckling mode are presented with fiber angles. Geometrical imperfections, which have buckling mode shapes of perfect panels, are imposed on finite element models to investigate the imperfection sensitivity of the buckling load. Buckling loads of imperfect panels are reduced to 60 percent-80 percent of those panels due to the initial imperfection of the magnitude of 10 percent of the wall thickness. The choice of the shape of the initial imperfection is found to be very important for the conservative estimation of the buckling load of the imperfect composite shell structure. Author

### A89-51313# STATIC AEROELASTIC BEHAVIOR OF VARIOUS PLANFORM WINGS

IN LEE (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) and SEUNG HO KIM IN: Aircraft Symposium, 26th, Sendai, Japan, Oct. 19-21, 1988, Proceedings. Tokyo, Japan Publications Trading Co., 1988, p. 212-215. refs

A static aeroelastic analysis that can calculate aerodynamic loads for deformed shape of the generic wing configuration has been performed. This study enables to predict the interaction between the flexible wing structure and aerodynamic forces. This analysis consists of two methods. One is the finite element method (FEM) for plate structural analysis, and the other is the linear vortex lattice method (VLM) for aerodynamic analysis based on linearized potential theory. The final deformed shape of wing due to applied forces is determined by iterative manner using FEM and VLM. FEM analysis and VLM analysis are related by surface spline interpolation procedure. Three types of wings have been investigated to see the wing flexibility effect, and the effect of

thickness on wing flexibility is examined. The forward swept wing has the most significant flexibility effect. Author

### A89-51334# ENABLING TECHNOLOGIES RESEARCH AND DEVELOPMENT FOR THE NATIONAL AERO-SPACE PLANE

DAVID A. THROCKMORTON (USAF, National Aerospace Plane Joint Program Office, Wright-Patterson AFB, OH) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 6 p. refs (AIAA PAPER 89-5009)

The NASA next-spacecraft generation NASP's 'enabling' technologies encompass CFD for hypersonic and hypervelocity aerothermodynamics, cryogenically-fueled ('slush'-state) airbreathing propulsion, propulsion system/airframe integration, primary airframe structure-applicable refractory materials, and flight control systems. Only the synergy of the advancements achievable in the entire suite of technologies will permit a positive judgment on 'technology readiness' to be eventually reached. Only after this point has been achieved, can the NASA development of the X-30 technology-demonstration vehicle proceed. O.C.

### A89-51487 ADVANCED STRATIFIED CHARGE ROTARY ENGINE DESIGN

ROBERT E. MOUNT and GARY A. LABOUFF (John Deere Technologies International, Inc., Rotary Engine Div., Wood-Ridge, NJ) IN: Rotary engine design: Analysis and developments; Proceedings of the International Congress and Exposition, Detroit, MI, Feb. 27-Mar. 3, 1989. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 1-12. refs (SAE PAPER 890324)

A two-rotor (1.72 liters displacement per rotor), stratified charge rotary engine has been designed, fabricated and tested at the Rotary Engine Division of JDTI, Inc. The paper discusses the general design features, and background related to the model 2034R advanced technology rotary engine and its relationship to the other engine families under development at JDTI, Inc. Test results for three fuels are presented. Author

### A89-51489\* Adiabatics, Inc., Columbus, IN. ANALYSIS AND TEST OF INSULATED COMPONENTS FOR ROTARY ENGINE

PATRICK R. BADGLEY, DOUGLAS DOUP, and ROY KAMO (Adiabatics, Inc., Columbus, IN) IN: Rotary engine design: Analysis and developments; Proceedings of the International Congress and Exposition, Detroit, MI, Feb. 27-Mar. 3, 1989. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 23-37. Research supported by NASA. refs (SAE PAPER 890326)

The direct-injection stratified-charge (DISC) rotary engine, while attractive for aviation applications due to its light weight, multifuel capability, and potentially low fuel consumption, has until now required a bulky and heavy liquid-cooling system. NASA-Lewis has undertaken the development of a cooling system-obviating, thermodynamically superior adiabatic rotary engine employing state-of-the-art thermal barrier coatings to thermally insulate engine components. The thermal barrier coating material for the cast aluminum, stainless steel, and ductile cast iron components was plasma-sprayed zirconia. DISC engine tests indicate effective thermal barrier-based heat loss reduction, but call for superior coefficient-of-thermal-expansion matching of materials and better tribological properties in the coatings used. O.C.

### A89-51531 NUMERICAL METHODS FOR FLUID DYNAMICS III; PROCEEDINGS OF THE CONFERENCE, UNIVERSITY OF OXFORD, ENGLAND, MAR. 21-24, 1988

K. W. MORTON, ED. (Oxford, University, England) and M. J. BAINES, ED. (Reading, University, England) Conference organized by the Institute for Computational Fluid Dynamics; Supported by the Royal Society and USAF. Oxford/New York, Clarendon Press/Oxford University Press (Institute of Mathematics and Its

Applications Conference Series. New Series, No. 17), 1988, 545 p. For individual items see A89-51532 to A89-51568.

Various papers on numerical methods for fluid dynamics are presented. Individual topics addressed include: calculation of unsteady turbomachinery flow, current trends in numerical grid generation, implicit methods in CFD, cell vertex method for steady compressible flow, numerical grid generation in 3-D Euler-flow simulation, lax stability vs. eigenvalue stability of spectral methods, acceleration of compressible Navier-Stokes flow calculations, numerical simulation of unsteady flows using the MUSCL approach. Also discussed are: computation of diffracting shock wave flows, multiple mesh simulation of turbulence, adaptive orthogonal curvilinear coordinates, approximate equidistribution technique for unstructured grids, Cartesian grid methods for irregular regions, multigrid calculations of jet flows, 3D finite element code for industrial applications, evaluation of a parallel conjugate gradient algorithm, moving element methods for time-dependent problems.

C.D.

**N89-26818#** Office National d'Etudes et de Recherches Aérospatiales, Paris (France). Aérodynamique Appliquée.

**DRAG PREDICTION AND ANALYSIS FROM COMPUTATIONAL FLUID DYNAMICS, STATE-OF-THE-ART IN FRANCE**

J. J. THIBERT *In* AGARD, Technical Status Review on Drag Prediction and Analysis from Computational Fluid Dynamics: State of the Art 11 p Jun. 1989 *In* FRENCH; ENGLISH summary Original language document was announced in IAA as A89-29239 Avail: NTIS HC A08/MF A01

Various two-dimensional and three-dimensional inviscid-flow methods for drag component analysis are presented which are based on solving either the potential equation or the Euler equations. Comparison with experimental results demonstrates that coupled methods can predict drag to within a few percent. It is suggested that the pressure term should be replaced in the two-dimensional case by the shock drag term and in the three-dimensional case by the sum of the induced drag and the shock drag.

Author

**N89-27047#** Computer Technology Associates, Inc., McLean, VA.

**EVALUATION OF LOW DATA RATE VOICE CODECS FOR AIR TRAFFIC CONTROL APPLICATIONS Technical Report, Apr. 1988 - May 1989**

JOSEPH CHILD, ROBERT CLEVE, and MARK GRABLE Jun. 1989 47 p

(Contract DTFA-03-86-C-00018)  
(DOT/FAA/CT-TN89/13) Avail: NTIS HC A03/MF A01

The test objectives, methodologies, and results of pre-qualification testing and evaluation of various 4.8 and 2.4 kilo bit per second (kbps) compression rate voice coder/decoders (CODECS) that are being considered for the use in supporting the Federal Aviation Administration's (FAA's) satellite communications technology demonstration program are discussed. The principal objectives of this program are to evaluate the performance of these CODECS for potential air traffic applications and to develop CODEC testing procedures tailored to the specific needs of air traffic control (ATC) communications. A description is given of the relative performance and ranking of the CODECS tested. This information has led to the selection of a quantity of 4.8 and 2.4 kbps CODECS for more comprehensive testing under simulated background noise and satellite channel noise conditions in the CODEC Test Bed Facility.

Author

**N89-27116\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**A REVIEW OF HIGH-SPEED, CONVECTIVE, HEAT-TRANSFER COMPUTATION METHODS**

MICHAEL E. TAUBER Washington Jul. 1989 38 p  
(NASA-TP-2914; A-89042; NAS 1.60:2914) Avail: NTIS HC A03/MF A01 CSCL 20/4

The objective of this report is to provide useful engineering formulations and to instill a modest degree of physical understanding of the phenomena governing convective

aerodynamic heating at high flight speeds. Some physical insight is not only essential to the application of the information presented here, but also to the effective use of computer codes which may be available to the reader. A discussion is given of cold-wall, laminar boundary layer heating. A brief presentation of the complex boundary layer transition phenomenon follows. Next, cold-wall turbulent boundary layer heating is discussed. This topic is followed by a brief coverage of separated flow-region and shock-interaction heating. A review of heat protection methods follows, including the influence of mass addition on laminar and turbulent boundary layers. Also discussed are a discussion of finite-difference computer codes and a comparison of some results from these codes. An extensive list of references is also provided from sources such as the various AIAA journals and NASA reports which are available in the open literature.

Author

**N89-27117\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**HYPERVELOCITY ATMOSPHERIC FLIGHT: REAL GAS FLOW FIELDS**

JOHN T. HOWE Jun. 1989 224 p  
(NASA-TM-101055; A-89011; NAS 1.15:101055) Avail: NTIS HC A10/MF A01 CSCL 20/4

Flight in the atmosphere is examined from the viewpoint of including real gas phenomena in the flow field about a vehicle flying at hypervelocity. That is to say, the flow field is subject not only to compressible phenomena, but is dominated by energetic phenomena. There are several significant features of such a flow field. Spatially, its composition can vary by both chemical and elemental species. The equations which describe the flow field include equations of state and mass, species, elemental, and electric charge continuity; momentum; and energy equations. These are nonlinear, coupled, partial differential equations that have been reduced to a relatively compact set of equations in a self-consistent manner (which allows mass addition at the surface at a rate comparable to the free-stream mass flux). The equations and their inputs allow for transport of these quantities relative to the mass-average behavior of the flow field. Thus transport of mass by chemical, thermal, pressure, and forced diffusion; transport of momentum by viscosity; and transport of energy by conduction, chemical considerations, viscosity, and radiative transfer are included. The last of these complicate the set of equations by making the energy equations a partial integrodifferential equation. Each phenomenon is considered and represented mathematically by one or more developments. The coefficients which pertain are both thermodynamically and chemically dependent. Solutions of the equations are presented and discussed in considerable detail, with emphasis on severe energetic flow fields. Hypervelocity flight in low-density environments where gaseous reactions proceed at finite rates chemical nonequilibrium is considered, and some illustrations are presented. Finally, flight where the flow field may be out of equilibrium, both chemically and thermodynamically, is presented briefly.

Author

**N89-27225#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.

**RESIDUAL STRESS CHANGES IN FATIGUE. VOLUME 1: RESIDUAL STRESS MEASUREMENTS BY X-RAY DIFFRACTION IN NOTCHED TEST SPECIMENS Interim Report, Oct. 1985 - Sep. 1987**

N. E. DOWLING and D. O. DUNN 1 Mar. 1989 88 p  
(Contract N62269-85-C-0256)  
(AD-A208345; NADC-88141-60-VOL-1) Avail: NTIS HC A05/MF A01 CSCL 01/3

An experimental setup is described for performing stress measurements on notched test specimens under load using a TEC series 1600 X-ray diffraction system. Excellent results are being obtained for Ti6Al4V material, but measurements on 7475-t651 Al are complicated by a texturing problem. Also, some unusual effects are observed during plastic deformation which are not yet understood. The performance of the X-ray diffraction system is found to be quite good in general, but some minor problems are noted.

GRA

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**N89-27226#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.

### **RESIDUAL STRESS CHANGES IN FATIGUE. VOLUME 2: A SIMULATION MODEL FOR STRESS MEASUREMENTS IN NOTCHED TEST SPECIMENS BY X-RAY DIFFRACTION**

**Interim Report, Oct. 1985 - Dec. 1987**

K. RANGANATHAN 1 Mar. 1989 111 p

(Contract N62269-85-C-0256; RR02303)

(AD-A208346; NADC-88141-60-VOL-2) Avail: NTIS HC A06/MF A01 CSCL 01/3

The state of stress developed during fatigue testing of notched specimens was modeled analytically. From this model, the X-ray response to the stress state of the specimen was determined with an aim of measuring the X-ray effects that result from residual stresses. This model was also used to estimate the error in stress measurements caused by a stress gradient. The error in the measured stresses caused by the varying radius of curvature of the test specimen was also studied. It was concluded that the stress distribution model for an infinite specimen can be extended to a specimen of finite geometry with an error of approximately 3 percent; that precision in positioning the X-ray beam on the specimen is very important; and that residual stress measurements are feasible along the edge of the specimen. GRA

**N89-27907\*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### **PROCEEDINGS OF THE MOBILE SATELLITE SYSTEM ARCHITECTURES AND MULTIPLE ACCESS TECHNIQUES WORKSHOP**

KHALED DESSOUKY Mar. 1989 116 p Workshop held in Pasadena, CA, 7-8 Mar. 1989

(Contract NAS7-918)

(NASA-CR-184564; JPL-PUBL-89-13; NAS 1.26:184564) Avail: NTIS HC A06/MF A01 CSCL 17/2

The Mobile Satellite System Architectures and Multiple Access Techniques Workshop served as a forum for the debate of system and network architecture issues. Particular emphasis was on those issues relating to the choice of multiple access technique(s) for the Mobile Satellite Service (MSS). These proceedings contain articles that expand upon the 12 presentations given in the workshop. Contrasting views on Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), and Time Division Multiple Access (TDMA)-based architectures are presented, and system issues relating to signaling, spacecraft design, and network management constraints are addressed. An overview article that summarizes the issues raised in the numerous discussion periods of the workshop is also included.

**N89-27918\*#** Stanford Telecommunications, Inc., Santa Clara, CA.

### **AERONAUTICAL MOBILE TDMA/MCTDMA SYSTEM**

THOMAS MAGILL and WAYNE PIERZGA (Arinc Research Corp., Santa Ana, CA.) In Jet Propulsion Lab., California Inst. of Tech., Proceedings of the Mobile Satellite System Architectures and Multiple Access Techniques Workshop p 109-114 Mar. 1989  
Avail: NTIS HC A06/MF A01 CSCL 17/2

A multiple carrier Time Division Multiple Access (TDMA) system capable of supporting voice, stream data, and packet data traffic between aircraft and ground terminals is presented. Demand assignment permits efficient resource sharing for voice and stream data. The bandwidth efficiency of uncoded A Quadrature Phase Shift Keying (AQPSK) is 1 bps/Hz. High time efficiency (approximately equals 83 percent) is achieved through the use of symbol synchronous TDMA. Demodulation is achieved without loop hang-up while requiring only a 16 symbol preamble each burst. A concatenated coding system provides reliable transmission under multipath conditions. Author

**N89-27953#** Illinois Univ., Urbana. Coordinated Science Lab. **ELECTROMAGNETIC SCATTERING FROM A STRUCTURED SLAB COMPRISED OF PERIODICALLY PLACED RESISTIVE CARDS**

ROY E. JORGENSON and RAJ MITTRA May 1989 274 p

(Contract N00014-84-C-0149)

(AD-A210145; UILU-ENG-89-2218) Avail: NTIS HC A12/MF A01 CSCL 20/14

The structured slab, which is constructed by arranging cells composed of thin, lossy, dielectric cards on a one- or two-dimensional lattice, is an important material in the aerospace industry because of its high strength-to-weight ratio. Recently, the structured slab has also been used to reduce the radar cross section of various aircraft. It is important, therefore, to characterize how an electromagnetic wave scatters from this slab. The structured slabs discussed herein are constructed by repeating lossy strips periodically in one dimension or lossy plates in two dimensions. An electric field integral equation is formulated which has as its unknown the electric current flowing in a single unit cell of the structure. The periodicity of the structure is accounted for by using an efficiently calculated periodic Green's function. The loss is modeled by resistive boundary condition. The integral equation is solved by the method of moments using subdomain basis functions. The generalized scattering matrix is calculated and the propagating reflection coefficients are plotted as a function of frequency for various structures. The oblique scattering from one-dimensional arrays of strips is examined for various configurations of unit cells and various resistances. A depolarizing effect of the structure is found to be a function of incident angle and symmetry in the unit cell. The reflection from two-dimensional arrays of plates connected to form slabs of zigzag plates and honeycomb is also examined. GRA

**N89-27954#** Allied-Signal Aerospace Co., Torrance, CA. Airesearch Div.

### **ADVANCED MOTOR AND MOTOR CONTROL DEVELOPMENT Final Report, Dec. 1982 - Dec. 1987**

KENNETH L. WUERTZ and EDWARD D. BEAUCHAMP Aug. 1988 106 p

(Contract F33615-82-C-2233)

(AD-A207332; REPT-88-61112; AFWAL-TR-88-2047) Avail: NTIS HC A06/MF A01 CSCL 09/1

The capability of operating a high speed permanent magnet brushless dc motor with electronic controller over a wide load and speed range was demonstrated. A centrifugal pump was used as the loading mechanism and hydraulic fluid was pumped in simulation of an aircraft engine fuel pump requirement. A motor speed of 45,000 rpm was reached and a maximum output of 68.5 hp was demonstrated. The response of the system to step commands for speed change was established. Reduction of size and weight of electronic control was established as a primary future goal. The program system concept with minor rotating machine improvements is viable for high speed drive applications up to 100-hp level. GRA

**N89-27980\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **EXPERIENCE WITH ADVANCED INSTRUMENTATION IN A HOT SECTION CASCADE**

FREDERICK C. YEH and HERBERT J. GLADDEN 1989 14 p Prepared for presentation at the Winter Annual Meeting of the American Society of Mechanical Engineers, San Francisco, CA, 10-15 Dec. 1989

(NASA-TM-102294; E-4962; NAS 1.15:102294) Avail: NTIS HC A03/MF A01 CSCL 20/4

The Lewis Research Center gas turbine Hot Section Test Facility was developed to provide a real engine environment with known boundary conditions for the aerothermal performance evaluation and verification of computer design codes. This verification process requires experimental measurements in a hostile environment. The research instruments used in this facility are presented, and their characteristics and how they perform in this environment are discussed. The research instrumentation consisted of conventional pressure and temperature sensors, as well as thin-film thermocouples and heat flux gages. The hot gas temperature was measured by an aspirated temperature probe and by a dual-element, fast-response temperature probe. The data acquisition mode was both steady state and time dependent. These

experiments were conducted over a wide range of gas Reynolds numbers, exit gas Mach numbers, and heat flux levels. This facility was capable of testing at temperatures up to 1600 K, and at pressures up to 18 atm. These corresponded to an airfoil exit Reynolds number range of  $0.5 \times 10(6)$  to  $2.5 \times 10(6)$  based on the airfoil chord of 5.55 cm. The results characterize the performance capability and the durability of the instrumentation. The challenge of making measurements in hostile environments is also discussed. The instruments exhibited more than adequate durability to achieve the measurement profile. About 70 percent of the thin-film thermocouples and the dual-element temperature probe survived several hundred thermal cycles and more than 35 hr at gas temperatures up to 1600 K. Within the experimental uncertainty, the steady-state and transient heat flux measurements were comparable and consistent over the range of Reynolds numbers tested. Author

**N89-27992#** Aerospace Corp., El Segundo, CA. Engineering Group.

**A METHOD FOR CALCULATING ASYMMETRIC FLOW THROUGH NOZZLES** Final Report, Jan. - Aug. 1988

RUDOLF X. MEYER Jan. 1989 24 p

(Contract F04701-88-C-0089)

(AD-A209689; TR-0088(4392-11)-1; SD-TR-89-20) Avail: NTIS HC A03/MF A01 CSCL 20/4

The asymmetric steady state, inviscous, adiabatic flow of a perfect gas through a subsonic/supersonic nozzle is considered. The nozzle itself is either of rectangular cross section or is axisymmetric. A first-order small asymmetry induced by an entrance flow which is oblique to the nozzle axis and has a transverse pressure gradient is allowed. The cross section of the nozzle is assumed to vary only slowly as a function of the axial distance; the case considered here is therefore an extension of the well known theory of the quasi-1-D flow of a perfect gas treated in standard textbooks. An integral method is used to obtain approximate results. The method is simple, yet in a test case (supersonic flow at an angle of attack through a rectangular channel) where the exact first-order result is known, a comparison shows surprisingly good agreement. Numerical results are tabulated for axisymmetric nozzles with polynomial Mach number dependence. GRA

**N89-27995\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**PHOTOGRAMMETRIC TECHNIQUE FOR IN-FLIGHT RANGING OF TRAILING VORTICES USING ENTRAINED BALLOONS**

WALTER L. SNOW, ALPHEUS W. BURNER, and WILLIAM K. GOAD 1989 1 p

(NASA-TM-4129; L-16551; NAS 1.15:4129) Avail: NTIS HC A03/MF A01 CSCL 14/5

A method for experimentally determining the radial distance of a probe aircraft from a trailing vortex is described. The method relies on photogrammetric triangulation of targets entrained in the vortex core. The theory and preliminary testing were described using laboratory mock-ups. Solid state video cameras were to provide data at 300 Hz rates. Practical methods for seeding the vortex are under separate investigation and are not addressed. Author

**N89-28034\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**EVALUATION OF A STRAIN-GAGE LOAD CALIBRATION ON A LOW-ASPECT-RATIO WING STRUCTURE AT ELEVATED TEMPERATURE**

LAWRENCE F. REARDON Jun. 1989 39 p

(NASA-TP-2921; H-1331; NAS 1.60:2921) Avail: NTIS HC A03/MF A01 CSCL 20/11

The environmental aspect of elevated temperature and its relationship to the science of strain gage calibrations of aircraft structures are addressed. A section of a wing designed for a high-speed aircraft structure was used to study this problem. This structure was instrumented with strain gages calibrated at both elevated and room temperatures. Load equations derived from a

high-temperature load calibration were compared with equations derived from an identical load calibration at room temperature. The implications of the high temperature load calibration were studied from the viewpoint of applicability and necessity. Load equations derived from the room temperature load calibration resulted in generally lower equation standard errors than equations derived from the elevated temperature load calibration. A distributed load was applied to the structure at elevated temperature and strain gage outputs were measured. This applied load was then calculated using equations derived from both the room temperature and elevated temperature calibration data. It was found that no significant differences between the two equation systems existed in terms of computing this applied distributed load, as long as the thermal shifts resulting from thermal stresses could be identified. This identification requires a heating of the structure. Therefore, it is concluded that for this structure, a high temperature load calibration is not required. However, a heating of the structure is required to determine thermal shifts. Author

**N89-28035\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**RESEARCH AND TECHNOLOGY PLANS FOR FY 1989 AND ACCOMPLISHMENTS FOR FY 1988**

KAY S. BALES Apr. 1989 95 p

(NASA-TM-101592; NAS 1.15:101592) Avail: NTIS HC A05/MF A01 CSCL 20/11

The Objectives, FY 1989 Plans, Approach, and FY 1989 Milestones for the Structural Mechanics Division's research programs are presented. Fiscal year 1988 Accomplishments are presented where applicable. This information is useful in program coordination with other governmental organizations in areas of mutual interest. Author

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## GEOSCIENCES

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

**A89-47971**

**ECOLOGICAL CHARACTERIZATION OF FUELS IN RELATION TO AIRCRAFT OPERATIONS [EKOLOGICHESKAIA KHARAKTERISTIKA TOPLIV PRIMENITEL'NO K EKSPLUATATSII VOZDUSHNYKH SUDOVI]**

V. P. SVINUKHOV, B. N. MEL'NIKOV, P. A. MIKHEICHEV, and S. I. POPLATEEV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 79-83. In Russian. refs

The pollution characteristics of the principal aircraft fuels are estimated with particular reference to the emission of CO, C(x)H(x) and NO(x). These estimates are then analyzed in the context of the international guidelines for aviation engine emissions, and ecological fuel characteristics are proposed which determine the role of aircraft fuels in atmospheric pollution in the vicinity of airports. V.L.

**A89-48750#**

**DESCRIPTION OF ATMOSPHERIC TURBULENCE [DESCRIPTION DE LA TURBULENCE ATMOSPHERIQUE]**

PIERRE-MARIE HUTIN (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Symposium, 73rd, Gol, Norway, May 8-11, 1989) ONERA, TP no. 1989-66, 1989, 15 p. In French. (ONERA, TP NO. 1989-66)

Over one million hours of aircraft flight test data for loading factors in excess of 0.5 g have been analyzed using three different methods in order to model coherent atmospheric turbulence. The Houbolt method (using a rigid body with two degrees of freedom for the aircraft flight mechanics) is found to provide a better description of the atmosphere than either the Pratt method (in



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which turbulence values are obtained from the vertical acceleration of the aircraft) or the Hall method (using only a single degree of freedom for the aircraft motion). The Houbolt method is improved by a calibration using exact calculations for a small number of different aircraft configurations. R.R.

**A89-48834**

### **ATMOSPHERIC PHENOMENA, THEIR IMPORTANCE AND INCORPORATION IN FLIGHT SIMULATION**

K. B. RYAN, T. J. SMITH (GST Professional Services, Ltd., Cambridge, England), D. J. CARRUTHERS, and J. C. R. HUNT (Cambridge Environmental Research Consultants, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 97-112.

The applicability of novel methods for the modeling of atmospheric phenomena over scales of a few miles to flight simulation systems is presently evaluated, in the interest of greater environmental realism. Typical of the atmospheric disturbances pertinent over such scales are the 'microburst' windshear phenomena encountered during takeoffs and landings. Attention is given to state-of-the-art characterizations of topographical features-induced windshears and flowfields. A set of straightforward relationships is also derived for the effect of rain on aircraft performance. O.C.

**A89-49057#**

### **ON THE FLUID-DYNAMIC MODELS OF MICROBURST - REVIEW AND EXTENSION**

SHANGXIANG ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) IN: AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 52-60. Research supported by DFG and Chinese Aeronautical Science and Technology Foundation. refs (AIAA PAPER 89-3353)

The disadvantages of some recommended microburst models are in their unsatisfactory realism in mean wind speeds distribution and lack of reasonable expressions in describing the intensities and scales of turbulence associated with a microburst. A new microburst model is developed that is based on the turbulent impinging-jet concept and the superposition principle of potential flow. The proposed model results in a realistic wind-field. Three wind-speed and nine shear components are expressed in analytical formulas that allow use in a real-time flight simulator. Based on the laboratory measurements of intensities and scales in an impinging jet, the turbulence associated with the microburst is then modeled by using a Monte-Carlo method. Author

**A89-51181**

### **A GENERAL EQUATION FOR THE TERMINAL FALL SPEED OF SOLID HYDROMETEORS**

HANNES P. BOEHM (Zuerich, Eidgenoessische Technische Hochschule, Zurich, Switzerland) Journal of the Atmospheric Sciences (ISSN 0022-4928), vol. 46, Aug. 1, 1989, p. 2419-2427. refs

A comprehensive yet simple formula is presented for the terminal fall velocity of solid precipitation particles. It depends on the following three particle parameters: mass, the mean circumscribed area presented to the flow, and the mean effective projected area presented to the flow. This formula is deduced from a single mean Davies number-Reynolds number relation based on boundary layer theory and therefore includes environmental conditions (air density and temperature). Terminal velocity is predicted with errors of less than about 10 percent for a wide variety of particles, e.g., various planar and columnar crystals, rimed and unrimed aggregates, graupel (lump, conical, and hexagonal), and hail up to over 10 cm in diameter. In view of its general form and the broad base of examination, the formula is felt to be generally applicable to all kinds of natural solid precipitation particles including shapes not tested in this study. Author

### **N89-27273# Lawrence Livermore National Lab., CA. PREVENTING DEPLETION OF STRATOSPHERIC OZONE: IMPLICATIONS ON FUTURE AIRCRAFT EMISSIONS, REVISION 1**

DOUGLAS E. KINNISON and DONALD J. WUEBBLES May 1989 15 p Presented at the 82nd Annual Air and Waste Management Association Meeting and Exhibition, Anaheim, CA, 25-30 Jun. 1989

(Contract W-7405-ENG-48)

(DE89-013779; UCRL-99926-REV-1; CONF-890692-4-REV-1)

Avail: NTIS HC A03/MF A01

There is much renewed interest in the development of faster aircraft for intercontinental passenger flights. Such aircraft would likely spend a large fraction of their flight time in the stratosphere, at altitudes as high as 35 km. It is important, in order to prevent the problems with the proposed supersonic-transport that occurred in the early 1970's, that the aircraft industry work together with the atmospheric science community to insure that future aircraft emissions will not deplete stratospheric ozone. In this study, we have used our two-dimensional model of the troposphere and stratosphere to examine the sensitivity of stratospheric ozone to such emissions. Initial results indicate, for commercial fleets as large as proposed for the original SST and depending on the odd-nitrogen emissions per engine, that substantial decreases in stratospheric ozone could result. The decrease in ozone is sensitive to the altitude and latitude in the emissions. Effects on ozone, for the same emission rate, tend to be larger as altitude increases, until a maximum effect is reached near 30 km. DOE

**N89-27309# National Center for Atmospheric Research, Boulder, CO.**

### **EVOLUTION AND STRUCTURE OF THE BOW ECHO/MICROBURST EVENTS Ph.D. Thesis**

WEN-CHAU LEE 1989 294 p Prepared in cooperation with California Univ., Los Angeles

(Contract NSF ATM-87-09659)

(PB89-174767; NCAR/CT-117) Avail: NTIS HC A13/MF A01

CSCL 04/2

The evolution and structure of several bow echo/microburst events are investigated. Multiple Doppler radar analysis is performed for the primary case of 14 July 1982 during the Joint Airport Weather Study (JAWS) experiment while single Doppler radar analysis is performed in 4 other bow echo/microburst events. Three dimensional wind fields, pressure and buoyance fields, vorticity budget and trajectories are computed for the 14 July 1982 case. Rawinsonde data, damage survey, satellite imagery and cloud photogrammetry are also incorporated in the study. The microburst and bow echo are well known as a potential hazard to aviation safety. When an aircraft penetrates a descending microburst or bow echo, its performance is seriously affected. The aviation hazards are the reason for the study. Author

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## 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.

**A89-47520**

### **THE IDENTIFICATION OF PARAMETERS USING A PRIORI INFORMATION [IDENTIFIKACE PARAMETRU S VYUZITIM APRIORNIH INFORMACI]**

JINDRICH DEDEK Zpravodaj VZLU (ISSN 0044-5355), no. 2, 1989, p. 75-82. In Czech. refs

A general formulation for the identification of model parameters is presented that uses measured data on the object or process described by the model and a priori information on the parameters



to be estimated. Fuzzy set theory is used to express the quality component often contained in the a priori information. The procedure is applied to an example in which the aerodynamic derivatives of longitudinal aircraft motion are identified. R.B.

**A89-47969**

**DEVELOPMENT OF A CLASSIFICATION OF FLIGHT VEHICLE ENGINES [O POSTROENII KLASSIFIKATSII DVIKATELEI LETATEL'NYKH APPARATOV]**

B. D. FISHBEIN *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1989, p. 70-74. In Russian. refs

A classification of flight vehicle engines is developed based on their thrust characteristics, which are determined by the interaction of working medium and energy flows within the engine. All the engines are divided into classes based on the essential structural characteristics of the above flows, and the classes are then combined into types based on similarities between them. The classification approach presented here can also be applied to engine components and other machine systems. V.L.

**A89-48124**

**A CRITIQUE OF SEVERAL FAILURE DETECTION APPROACHES FOR NAVIGATION SYSTEMS**

THOMAS H. KERR (MIT, Lexington, MA) *IEEE Transactions on Automatic Control* (ISSN 0018-9286), vol. 34, July 1989, p. 791, 792. Research supported by USAF. refs

Additional references relating to the work of White and Speyer (1987) are reported and commented on. White and Speyer discussed predecessor studies that dealt with failure detection in navigation applications described by a stochastic time-invariant linear system with additive Gaussian white process and measurement noises, and sought to use Kalman filters tuned in this application context to detect a priori specified failures. It is argued that, since the previous work dealt exclusively with time-invariant deterministic systems devoid of noise terms, the exclusive use of observers would suffice for failure detection in this more benign context. I.E.

**A89-48154#**

**CREW CHIEF - A MODEL OF A MAINTENANCE TECHNICIAN**

JILL A. EASTERLY (USAF, Human Resources Laboratory, Wright-Patterson AFB, OH) *AIAA and NASA, Symposium on the Maintainability of Aerospace Systems*, Anaheim, CA, July 26, 27, 1989. 4 p.

(AIAA PAPER 89-5043)

CREW CHIEF is a computer-aided design model of a military maintenance technician developed by the Air Force. The model interfaces to existing commercial Computer Aided Design (CAD) systems used by aerospace manufacturers and provides designers a tool for early identification of design-related maintainability problems by analyzing the interaction of maintenance technicians' physical capabilities and the design elements related to specific maintenance tasks. Author

**A89-48392#**

**THE SEARCH FOR A NEW FLIGHT SIMULATION SOFTWARE MODELING STANDARD - A MODULAR APPROACH USING FEATURES OF THE ADA PROGRAMMING LANGUAGE**

GLEN GLASELL and KARL FORSSTROM (Northrop Corp., Pico Rivera, CA) *IN: AIAA Flight Simulation Technologies Conference and Exhibit*, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 127-129.

(AIAA PAPER 89-3278)

The Northrop B-2 Division Flight Simulation Laboratory has developed a real time flight simulation program written entirely in MIL-STD 1815A Ada programming language. The goal of the project was to develop a common flight simulation environment that can be used to support Operational Flight Program development written in Ada. With this capability in place on a general purpose flight simulator (computer, cockpit, visual, motion system, etc.), the development, modification and verification of the real aircraft OFPs will be greatly enhanced. Author

**A89-48407#**

**SHARED-MEMORY NETWORKING ARCHITECTURES - SIMPLICITY AND ELEGANCE**

W. LYNN TRAINOR and GARY G. WARDEN (Systran Corp., Dayton, OH) *IN: AIAA Flight Simulation Technologies Conference and Exhibit*, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 252-258.

(AIAA PAPER 89-3298)

Connecting together multiple computers to solve a single real-time problem, such as aircraft simulation, is certainly a very challenging engineering task. This paper addresses some of the unique requirements of distributed computing architectures for simulators, and it summarizes the two major approaches which have been used to date. The concept of a new approach - shared-memory networking - is introduced and compared to the traditional approaches. Next, the design and performance parameters of the first comprehensive shared-memory network implementation are presented. Details of this new design are presented along with implementation considerations. Author

**A89-48414#**

**AN IMPROVED NUMERICAL INTEGRATION METHOD FOR FLIGHT SIMULATION**

R. M. HOWE (Michigan, University; Applied Dynamics International, Inc., Ann Arbor) *IN: AIAA Flight Simulation Technologies Conference and Exhibit*, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 310-316. refs

(AIAA PAPER 89-3306)

A modified form of Euler integration is described which, when applied to the six-degree of freedom flight equations, retains and enhances many of the advantages of AB-2 integration and at the same time eliminates the disadvantages. The scheme is based on the Euler integration formula, but with the state-variable derivative represented at the midpoint of each integration step. It is shown through dynamic error analysis that the modified Euler method has an error coefficient which is one-tenth that associated with AB-2. The method also exhibits minimal output delay in response to transient inputs. The modified Euler method may also be useful in the integration of state and costate equations in real-time mechanization of Kalman filters for navigation and control systems. Author

**A89-48418#**

**AN ALTERNATE APPROACH TO TABLE LOOK-UP ROUTINES FOR REAL-TIME DIGITAL FLIGHT SIMULATION**

MICHAEL K. SINNETT, JAMES E. STECK, BRUCE P. SELBERG, and ROBERT B. OETTING (Missouri-Rolla, University, Rolla) *IN: AIAA Flight Simulation Technologies Conference and Exhibit*, Boston, MA, Aug. 14-16, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 336-340.

(AIAA PAPER 89-3310)

Algorithms for reducing the table search time of real-time digital flight simulations are proposed which perform a top-down search during only the initialization pass. On all subsequent passes, the algorithm returns to the interval where the value will most likely reside. The method involves the tracking of the rate of change of the magnitude and direction of each independent variable as the dependent variable moves through the table. The needed value is then approximated over a subregion of the table by a polynomial which is linear in each of the independent variables. The present algorithms are shown to produce similar numerical results to those of previous methods, but with fewer floating point calculations. R.R.

**A89-48518**

**A COARSE/FINE PRECONDITIONER FOR VERY ILL-CONDITIONED FINITE ELEMENT PROBLEMS**

CHARBEL FARHAT and NAHIL SOBH (Colorado, University, Boulder) *International Journal for Numerical Methods in*

## 15 MATHEMATICAL AND COMPUTER SCIENCES

Engineering (ISSN 0029-5981), vol. 28, July 1989, p. 1715-1723. refs

Consideration is given to the application of the conjugate-gradient method to solve ill-conditioned large algebraic systems of equations resulting from the finite-element discretization of some three-dimensional boundary-value problems. An effective preconditioner for such systems is presented, based on a multigrid technique. Its performance is assessed using examples borrowed from large flexible aerospace structures. Author

**A89-48737#**

### **APPLICATION OF AN AI LAYER TO AN AERODYNAMIC CALCULATION CODE [ASSISTANCE A UN CODE DE CALCUL D'AERODYNAMIQUE PAR UNE COUCHE INTELLIGENCE ARTIFICIELLE]**

MICHEL BARAT, JEAN ERCEAU, and THIEN-HIEP LE (ONERA, Chatillon-sous-Bagneux, France) (Journées Internationales sur les Systèmes Experts et leurs Applications, 9th, Avignon, France, May 29-June 2, 1989) ONERA, TP no. 1989-52, 1989, 18 p. In French. refs  
(ONERA, TP NO. 1989-52)

This paper introduces the theory, development, and functional description of ACCACIA. AI techniques in ACCACIA enable scientists to automatically run a set of different software modules for numeric simulation of the flow around aircraft surfaces. ACCACIA, implemented on a work station, involves the knowledge of simulation conceptualizers and know-how developed in using this complex tool. An oriented object language has been used to implement ACCACIA. Author

**A89-48827**

### **FUNCTIONALLY DISTRIBUTED SIMULATION**

DAVID PARKINSON (Singer Link-Miles, Ltd., Lancing, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 3-7.

Functional distributed simulation has its basis in autonomous major functions which are connected via communications buses to form a loosely coupled distributed-computing system. This functional partitioning ensures modularity, flexibility, and ease of updating. Because a simulator's computing system is becoming an extension of the cockpit, and greater emphasis has come to be placed on stimulating (or emulating) the sophisticated avionics projected for future aircraft, functional partitioning and distributed computing techniques furnish the flexibility to accommodate advancements in cockpit design, computer technology, and overall training-management systems. O.C.

**A89-48842**

### **THE IMPACT OF ADA ON FLIGHT SIMULATOR DEVELOPMENT**

I. C. PYLE (Systems Designers Scientific, Burgess Hill, England) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 203-207.

The benefits of Ada in flight-simulation applications derive from the explicit definition of interfaces for software packages, ensuring consistency of treatment. This allows avionics software to be adequately isolated, so that a flight simulator can be interfaced to an avionics system or may incorporate a simulation or emulation of the avionics suite of the aircraft in question. Flight simulator software quality can be significantly enhanced by software packages' possession of fully defined interfaces with the rest of a system; compiler checks, moreover, apply across an entire program. O.C.

**A89-48843**

### **ADA AS A REAL-TIME DEVELOPMENT TOOL**

GEORGEANNE CHITWOOD (Harris Corp., Computer Systems Div., Fort Lauderdale, FL) IN: Flight simulation: Recent developments in technology and use; Proceedings of the Conference, London, England, Apr. 12, 13, 1988. London, Royal Aeronautical Society, 1988, p. 208-213.

While the Ada Tasking Model (ATM) was designed so that one executable Ada program could accomplish numerous tasks simultaneously, such real-time applications as flight simulation must be repeatedly assessed in a predetermined order while the system responds immediately to external interrupts and gives attention to higher-priority tasks. The ATM does not allow the user to specify specific program times or priorities; this enforced tasking method must be circumvented through 'supply run time environments' which, while meeting real-time criteria, remain within the limits of Ada. Such environments will give access to the operating system of a computer through Ada packages, constructs defining a related group of time-definitions, data declarations, functions, and procedures. O.C.

**A89-49477#**

### **ADAS - A DESIGN SYSTEM FOR AIRCRAFT CONFIGURATION DEVELOPMENT**

C. BIL (Delft, Technische Universiteit, Netherlands) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 9 p. refs  
(AIAA PAPER 89-2131)

This paper gives a description of the Aircraft Design and Analysis System (ADAS). ADAS has been developed to assess the potential of computer-tools in improving aircraft configuration development and design optimization. Automatic parameter sensitivity analysis and multivariate optimization are optional. Only standard and routine tasks have been automated to allow for user initiative and to retain a sufficient level of flexibility and general applicability of the system. Recent improvements relative to the initial pilot-version of ADAS will be highlighted. As an example, ADAS has been applied to a typical design optimization problem based on a hypothetical design specification of a short-haul passenger jet transport. Author

**A89-49479#**

### **THE ROLE OF INTERFACES IN DESIGN INTEGRATION**

JUNE E. GEE (Douglas Aircraft Co., Long Beach, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p. refs  
(AIAA PAPER 89-2133)

A demand-driven interface links a preliminary geometric CAD model and an analysis program to accomplish the task of extracting and transforming information from the model and furnishing it to the analysis program. The interface represents an approach to integrating the design cycle that does not compromise the specificity of any of the design or analysis tools and that strongly fosters modularity. The key characteristics of the Configuration Geometry Data Base-Computer Aided Sizing and Evaluation interface are discussed. Author

**A89-50083#**

### **THE DEVELOPMENT OF AN ITERATIVE ADVANCED COMPOSITE STRUCTURAL DESIGN CAPABILITY**

S. R. HALL and D. L. SIMPSON (National Aeronautical Establishment, Ottawa, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 35, June 1989, p. 72-75. refs

The design process used to define the final structural configuration of an aircraft is complex and usually the result of a series of compromises between conflicting structural and performance requirements. Thus, in the design environment, it is essential that the structural designer has access to iterative analytical tools which permit rapid evaluations of preliminary design concepts. Although many preliminary design packages are available for metallic structures, comparatively few exist for advanced composite structures. In recent years the Structures and Materials Laboratory of the National Aeronautical Establishment (NAE) has sought to address this deficiency with a series of analytical and experimental programs. These programs are supporting the development of a set of computer software packages for use in the advanced composite structures design environment. Great emphasis has been placed on ensuring that the input and output of each program are compatible with one another and with commercially available finite element codes. Author

**A89-50115\*** Arizona State Univ., Tempe.  
**CONTROL AND STABILIZATION OF DECENTRALIZED SYSTEMS**

CHRISTOPHER I. BYRNES (Arizona State University, Tempe), DAVID GILLIAM, and CLYDE F. MARTIN (Texas Tech University, Lubbock) International Journal of Control (ISSN 0020-7179), vol. 49, June 1989, p. 1819-1833. refs  
 (Contract NSF ECS-85-13099; AF-AFOSR-85-0224; NAG2-82; NAG2-203; MDA904-85-H-0009; F29601-85-C-0040)

Proceeding from the problem posed by the need to stabilize the motion of two helicopters maneuvering a single load, a methodology is developed for the stabilization of classes of decentralized systems based on a more algebraic approach, which involves the external symmetries of decentralized systems. Stabilizing local-feedback laws are derived for any class of decentralized systems having a semisimple algebra of symmetries; the helicopter twin-lift problem, as well as certain problems involving the stabilization of discretizations of distributed parameter problems, have just such algebras of symmetries. O.C.

**A89-50782#**  
**A MICROCOMPUTER CONTROLLED OPTIMAL ADAPTIVE FLIGHT SIMULATOR SERVO SYSTEM**

GUONAN FENG and RUI YU (Beijing Polytechnic University, People's Republic of China) Acta Automatica Sinica (ISSN 0254-4156), vol. 15, May 1989, p. 193-200. In Chinese, with abstract in English.

The dry friction and inertia of load referred to the output shaft are variable in a flight simulator servo system. To compensate for these factors, a synthesis method of the optimal adaptive control system is presented. The operation of the servo system shows that the performance of the system is clearly better than that of the linear optimal servo system. C.D.

**A89-50823**  
**AUTOMATED MASS PROPERTIES SYSTEM (AMPS)**

ANTHONY D. BOUCHER and MARK A. WOOD (McDonnell Aircraft Co., Saint Louis, MO) SAWE, Annual Conference, 47th, Plymouth, MI, May 23-25, 1988. 44 p.  
 (SAWE PAPER 1834)

The design AMPS designed to calculate the mass properties of detail parts from CAD/CAM wire frame models is examined. AMPS consists of the interactive weight accounting program, a material table, a menu option area, and area and volume definition modes. The methods employed to calculate area and volume are described. A diagram of the AMPS data flow is presented. AMPS can be used to determine volume, weight, center of gravity, moments of inertia, and radii of gyration. I.F.

**A89-51538**  
**RECENT DEVELOPMENTS OF THE TAYLOR-GALERKIN METHOD FOR THE NUMERICAL SOLUTION OF HYPERBOLIC PROBLEMS**

J. DONEA (CEC, Joint Research Centre, Ispra, Italy), V. SELMIN (Aeritalia S.p.A., Turin, Italy), and L. QUARAPELLE (Milano, Politecnico, Milan, Italy) IN: Numerical methods for fluid dynamics III; Proceedings of the Conference, Oxford, England, Mar. 21-24, 1988. Oxford/New York, Clarendon Press/Oxford University Press, 1988, p. 171-185. refs

Techniques aimed at overcoming the difficulties associated with a straightforward application of the original Taylor-Galerkin (TG) schemes to the solution of nonlinear hyperbolic problems such as the Euler equations of gas dynamics are examined. The second-order accurate TG scheme and its two-step implementation are described, as is a method for introducing a locally modulated dissipation in order to construct a nonoscillatory shock-capturing scheme of the TG type. Numerical results for one- and two-dimensional problems are presented to illustrate the performance of the described methods. C.D.

**N89-27404#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Interdisciplinary Center for Applied Mathematics.

**MODELING AND COMPUTATIONAL ALGORITHMS FOR PARAMETER ESTIMATION AND OPTIMAL CONTROL OF AEROELASTIC SYSTEMS AND LARGE FLEXIBLE STRUCTURES Final Report, 30 Sep. 1985 - 30 Sep. 1988**

JOHN A. BURNS and EUGENE M. CLIFF 15 Feb. 1989 14 p  
 (Contract AF-AFOSR-0287-85; AF PROJ. 2304)  
 (AD-A208274; AFOSR-89-0600TR) Avail: NTIS HC A03/MF A01 CSCL 20/4

The basic goal of this project is the study of computational algorithms for control design of partial functional differential equations that model structural and fluid dynamic systems. We investigated several aspects of the development of computational algorithms for identification and control of distributed parameter systems. We also spent considerable effort on specific applications involving elastic, aeroelastic and viscoelastic systems. Progress was made on many of these problems. However, in this report we shall concentrate on the major accomplishments. GRA

**N89-27416\*#** Integrated Systems, Inc., Palo Alto, CA.  
**AIRCRAFT FLIGHT TEST TRAJECTORY CONTROL Final Report**

P. K. A. MENON and R. A. WALKER Washington Sep. 1988 198 p  
 (Contract NAS2-11877)  
 (NASA-CR-4161; H-1497; NAS 1.26:4161) Avail: NTIS HC A09/MF A01 CSCL 09/2

Two control law design techniques are compared and the performance of the resulting controllers evaluated. The design requirement is for a flight test trajectory control (FTTC) capable of closed-loop, outer-loop control of an F-15 aircraft performing high-quality research flight test maneuvers. The maneuver modeling, linearization, and design methodologies utilized in this research, are detailed. The results of applying these FTTCs to a nonlinear F-15 simulation are presented. Author

**N89-28321#** Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.

**AEROSPACE STRUCTURES DESIGN ON COMPUTERS Final Report, Dec. 1988 - Mar. 1989**

VIPPERLA B. VENKAYYA Mar. 1989 216 p  
 (AD-A208811; WRDC-TR-89-3045) Avail: NTIS HC A10/MF A01 CSCL 12/5

This report, prepared for training, is intended to bring out the elements of structural design optimization on modern computers. The first section gives a cursory description of the requirements and essential disciplines involved in aircraft structural design. The second section is an optimization paper that provides the basis for optimization using large finite element assemblies. The third section provides a summary of design sensitivity analysis which is an essential element of optimization. The two appendices are the descriptions of two training programs for analysis and optimization. Each of these sections has their own references. This is an informal report intended for training and is a collection material entirely from the open literature. GRA

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## 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.

**A89-47720\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**AN EVALUATION OF ACTIVE NOISE CONTROL IN A CYLINDRICAL SHELL**

R. J. SILCOX, H. C. LESTER (NASA, Langley Research Center,

Hampton, VA), and S. B. ABLER (NASA, Langley Research Center; Joint Institute for Advancement of Flight Sciences, Hampton, VA) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 111, July 1989, p. 337-342. Previously announced in STAR as N87-20794. refs

The physical mechanisms governing the use of active noise control in an extended volume of a cylindrical shell are discussed. Measured data was compared with computer results from a previously derived analytical model based on an infinite shell theory. For both the analytical model and experiment, the radiation of the external monopoles is coupled to the internal acoustic field through the radial displacement of the thin, elastic cylindrical shell. An active noise control system was implemented in the cylinder using a fixed array of discrete monopole sources, all of which lie in the plane of the exterior noise sources. Good agreement between measurement and prediction was obtained for both internal pressure response and overall noise reduction. Attenuations in the source plane greater than 15 dB were recorded along with a uniformly quieted noise environment over the entire length of the experimental model. Results indicate that for extended axial forcing distributions or very low shell damping, axial arrays of control sources may be required. Finally, the Nyquist criteria for the number of azimuthal control sources is shown to provide for effective control over the full cylinder cross section. Author

**A89-48953\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**NOISE OF A MODEL COUNTERROTATION PROPELLER WITH SIMULATED FUSELAGE AND SUPPORT PYLON AT TAKEOFF/APPROACH CONDITIONS**

RICHARD P. WOODWARD and CHRISTOPHER E. HUGHES (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 25 p. Previously announced in STAR as N89-24138. refs (AIAA PAPER 89-1143)

Two modern high-speed advanced counterrotation propellers, F7/A7 and F7/A3 were tested in the NASA Lewis Research Center's 9- by 15-foot Anechoic Wind Tunnel at simulated takeoff/approach conditions of 0.2 Mach number. Both rotors were of similar diameter on the F7/A7 propeller, while the aft rotor diameter of the F7/A3 propeller was 85 percent of the forward propeller to reduce tip vortex-aft rotor interaction. The two propellers were designed for similar performance. The propellers were tested in both the clean configuration, and installed configuration consisting of a simulated upstream nacelle support pylon and fuselage section. Acoustic measurements were made with an axially translating microphone probe, and with a polar microphone probe which was fixed to the propeller nacelle and could make both sideline and circumferential acoustic surveys. Aerodynamic measurements were also made to establish propeller operating conditions. The propellers were run at blade setting angles (front angle/rear angle) of 41.1/39.4 deg for the F7/A7 propeller, and 41.1/46.4 deg for the F7/A3 propeller. The forward rotors were tested over a range of tip speeds from 165 to 259 m/sec (540 to 850 ft/sec), and both propellers were tested at the maximum rotor-rotor spacing, based on pitch change axis separation, of 14.99 cm (5.90 in.). The data presented in this paper are for 0 deg propeller axis angle of attack. Results are presented for the baseline, pylon-alone, and strut + fuselage configurations. The presence of the simulated fuselage resulted in higher rotor-alone tone levels in a direction normal to the advancing propeller blade near the fuselage. A corresponding rotor-alone tone reduction was often observed 180 deg circumferentially from this region of increased noise. A significant rotor-alone increase for both rotors was observed diametrically opposite the fuselage. In some cases, interaction tone levels were likewise affected by the simulated installation. Author

**A89-49425\*#** Kansas Univ., Lawrence.

**PRESSURE-TIME HISTORY OF PYLON WAKE SIGNATURE ON A PUSHER PROPELLER IN FLIGHT**

SAEED FAROKHI (Kansas, University, Lawrence) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference,

Seattle, WA, July 31-Aug. 2, 1989. 15 p. refs (Contract NAG1-867) (AIAA PAPER 89-2052)

Miniature, high-frequency, pressure transducers were mounted on a pusher propeller at 3/4 and 90-percent radii. Time-history of fluctuating surface pressure over 700 revolutions and 26 flight conditions reveal intriguing phenomena. The anticipated pylon wake signature manifests itself as a negative pressure pulse over extended portions of the suction surface. The phenomenon further develops into a primarily random turbulence signature at 80-percent chord and interestingly may reevolve as a coherent wake signature further downstream. A new type of periodic disturbance of long time-scale, compared to propeller period-of-revolution, is discovered at positions beyond 0.6 chord on the suction surface in the transonic regime. Author

**A89-50533#**

**ASYMPTOTIC THEORY OF PROPELLER NOISE. I - SUBSONIC SINGLE-ROTATION PROPELLER**

A. B. PARRY (Strathclyde, University, Glasgow, Scotland) and D. G. CRIGHTON (Cambridge, University, England) AIAA Journal (ISSN 0001-1452), vol. 27, Sept. 1989, p. 1184-1190. Research supported by SERC. refs

Asymptotic expressions for the harmonic amplitudes and phases of the far-field acoustic pressure generated by a single-rotation propeller operating at subsonic tip relative Mach number are presented. These expressions are found from asymptotic approximations to integrals of the steady-loading distribution and of the blade thickness distribution over the surface of one blade, under the assumption that the number of blades  $B$  is large (but the harmonic number  $m$  is arbitrary). The asymptotics demonstrate rigorously that in this limit the noise of subsonic propellers is entirely tip generated, and described by very simple formulas giving explicit dependence on harmonic number, Mach number, and radiation angle. Excellent agreement is found between the asymptotic prediction and full numerical evaluation of the acoustic field (and between the latter and experimental data taken by Rolls-Royce in flyovers of a Gannet aircraft). Numerous trends and observations noted in the literature are explained by the asymptotic formulas, which are also extended to predict the acoustic benefit of sweep at subsonic conditions. Author

**A89-51453**

**STRUCTURAL AND ACOUSTIC NOISE GENERATED BY A LARGE-EDDY BREAK-UP DEVICE**

M. S. HOWE (BBN Laboratories, Cambridge, MA) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0080-4630), vol. 424, no. 1867, Aug. 8, 1989, p. 461-486. Research supported by the U.S. Navy. refs

Large-eddy breakup (LEBU) devices act to reduce aerodynamic or hydrodynamic surface friction over an extensive downstream region. An analysis is presently conducted of the sound and structural vibrations generated by a large LEBU consisting of a rigid strip airfoil set at zero angle-of-attack to the mean flow; the wall surface is modeled by a thin plate. Attention is given to underwater applications in which fluid loading is large. Unsteady pressures generated in the vicinity of the LEBU excite plate-bending waves, leading to significant energy transfer from the mean flow to structural vibrations. It is found in the case of a steel plate in water that the acoustic and flexural wave magnitudes developed through the interaction of turbulence with the LEBU can be several orders-of-magnitude greater than would result from an interaction of the turbulent boundary layer with the entire plate, in the absence of the LEBU. O.C.

**N89-27464#** Dayton Univ., OH. Research Inst.

**KC-135R RUMBLE INVESTIGATION Final Report, Oct. 1986 - Jan. 1988**

MICHAEL L. DRAKE and DENNIS G. DAVIS 27 Feb. 1989 242 p (Contract F33615-85-C-5040)

(AD-A207532; UDR-TR-88-04; AFWAL-TR-88-4260) Avail: NTIS HC A11/MF A01 CSCL 01/3

The KC-135R is a modified KC-135A which has had, among other things, the engines changed from the J-57 to the new F-108-CF-100 engines. Shortly after the KC-135R began SAC flight operations, a noise problem perceived as a rumbling sound in the cabin area was found in various aircraft; i.e., Rumble. The Air Force, the aircraft manufacturer and the engine manufacturer studied the problem briefly developing a better definition of the general problem. The forcing function was determined to be the F-108 engine; however, the precise source of the noise and vibration, and the transmission path from the engine to the cabin were unknown. GRA

**N89-27465\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**REDUCTION OF BLADE-VORTEX INTERACTION NOISE USING HIGHER HARMONIC PITCH CONTROL**

THOMAS F. BROOKS, EARL R. BOOTH, JR., J. RALPH JOLLY, JR., WILLIAM T. YEAGER, JR., and MATTHEW L. WILBUR (Army Aviation Systems Command, Hampton, VA.) Jul. 1989 20 p (NASA-TM-101624; AVSCOM-TM-89-B-005; NAS 1.15:101624) Avail: NTIS HC A03/MF A01 CSCL 20/1

An acoustics test using an aeroelastically scaled rotor was conducted to examine the effectiveness of higher harmonic blade pitch control for the reduction of impulsive blade-vortex interaction (BVI) noise. A four-bladed, 110 in. diameter, articulated rotor model was tested in a heavy gas (Freon-12) medium in Langley's Transonic Dynamics Tunnel. Noise and vibration measurements were made for a range of matched flight conditions, where prescribed (open-loop) higher harmonic pitch was superimposed on the normal (baseline) collective and cyclic trim pitch. For the inflow-microphone noise measurements, advantage was taken of the reverberance in the hard walled tunnel by using a sound power determination approach. Initial findings from on-line data processing for three of the test microphones are reported for a 4/rev (4P) collective pitch control for a range of input amplitudes and phases. By comparing these results to corresponding baseline (no control) conditions, significant noise reductions (4 to 5 dB) were found for low-speed descent conditions, where helicopter BVI noise is most intense. For other rotor flight conditions, the overall noise was found to increase. All cases show increased vibration levels.

Author

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**NOISE PRODUCED BY TURBULENT FLOW INTO A ROTOR: THEORY MANUAL FOR ATMOSPHERIC TURBULENCE PREDICTION AND MEAN FLOW AND TURBULENCE CONTRACTION PREDICTION Final Report**

J. C. SIMONICH Jun. 1989 23 p (Contract NAS1-17763) (NASA-CR-181789; NAS 1.26:181789) Avail: NTIS HC A03/MF A01 CSCL 20/1

Prediction of helicopter main rotor noise due to ingestion of atmospheric turbulence was analyzed. The analysis combines several different models that describe the fluid mechanics of the turbulence and the ingestion process. Two models, atmospheric turbulence, and mean flow and turbulence contraction were covered. The third model, covered in a separate report, describes the rotor acoustic mode. The method incorporates the atmospheric turbulence model and a rapid distortion turbulence contraction description to determine the statistics of the anisotropic turbulence at the rotor plane. The analytical basis for a module was provided which was incorporated in NASA's ROTONET helicopter noise prediction program. The mean flow and turbulence statistics associated with the atmospheric boundary layer were modeled including effects of atmospheric stability length, wind speed, and altitude. The turbulence distortion process is modeled as a deformation of vortex filaments (which represent the turbulence field) by a mean flow field due to the rotor inflow. Author

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**EXPERIMENTAL ASSESSMENT OF HELICOPTER ROTOR TURBULENCE INGESTION NOISE IN HOVER Final Report**

J. C. SIMONICH, R. H. SCHLINKER, and R. K. AMIET Jul. 1989 68 p (Contract NAS1-17763) (NASA-CR-181792; NAS 1.26:181792) Avail: NTIS HC A04/MF A01 CSCL 20/1

An experiment was conducted to assess the accuracy of a theory for non-isotropic turbulence ingestion. In order to generate non-isotropic turbulence in a controlled environment, a scale model rotor in a closed chamber was used so that the turbulence generated by the rotor was reingested by the recirculating flow. Simultaneous measurements of turbulence inflow properties and far field acoustics were acquired. Measurements confirmed that the inflow turbulence was highly non-isotropic. The measured aerodynamic properties were used as inputs for the noise prediction procedure. The general agreement between the non-isotropic noise prediction procedure and the experiment was good, although the procedure generally overpredicts the quasi-tonal low to mid range frequencies and underpredicts the higher broadband signals. The predicted sound power level as a function of polar angle was in close agreement with measurements, except near the rotor plane, which is not modeled by the present analysis. It is determined that the most sensitive parameter influencing the predicted noise was the turbulence intensity. Author

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### 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.

**A89-48501**

**THE EXTRATERRITORIAL APPLICATION OF NATIONAL COMPETITION LAWS TO INTERNATIONAL CIVIL AVIATION [ZUR EXTRATERRITORIALEN ANWENDUNG NATIONALER WETTBEWERBSGESETZE IN DER INTERNATIONALEN ZIVILLUFTFAHRT]**

WERNER GULDIMANN Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 38, June 1989, p. 87-99. In German. refs

The legal conflicts which can arise when national antitrust laws are applied to international civil-aviation operations are discussed. Particular attention is given to (1) the U.S. Civil Aeronautics Board show-cause order of June 8, 1978 against the IATA, (2) the antitrust suit filed against a group of transatlantic carriers by the court-appointed administrator after the bankruptcy of Laker Airways in 1982, and (3) the ICAO resolutions of 1983-1986 urging member states to limit the extraterritorial effects of their antitrust laws as applied to aviation. The major legal, economic, and political implications of these cases and decisions are reviewed; the history of the ICAO deliberations is recalled; and the negative reaction of the U.S. to the final resolution is examined critically. T.K.

**A89-48502**

**THE INSURANCE REQUIREMENTS OF THE AIRCRAFT OPERATOR - DISCREPANCIES BETWEEN LAW AND REGULATIONS [ZUR VERSICHERUNGSPFLICHT DES LUFTFAHRZEUGHALTERS - DISKREPANZEN ZWISCHEN GESETZ UND RECHTSVERORDNUNG]**

ELMAR GIEMULLA Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 38, June 1989, p. 114-121. In German. refs

The FRG legal provisions governing the liability and insurance requirements of the commercial owners and operators of aircraft are reviewed, with a focus on the paragraphs of Article 43 of the Air Traffic Law and its implementation in Article 103 of the Air

## 17 SOCIAL SCIENCES

Traffic Regulations. Particular attention is given to the sometimes contradictory provisions regarding the liability and insurance coverage of pilots and other members of the flight crew. It is argued that some provisions of Article 103 (regarding the owner's liability-insurance requirements for actions of crew members) are based on an excessively broad interpretation of Article 43. T.K.

**A89-49415#**

### **INTERNATIONAL COOPERATION ON EFA**

ERWIN OBERMEIER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 13 p.  
(AIAA PAPER 89-2035)

Experience gained during the four-nation European Fighter Aircraft (EFA) program is examined. High-technology large-scale projects will be performed in the framework of international cooperation. A systematic program management is mandatory for complex projects using advanced technology under the constraint of limited budgets. Customer and contractor organizations will be equally responsible for the coordination of the program, while specialized tasks will be carried out at partner companies. Cost estimates require international harmonization with consideration of possible modifications, fixed-price contract requirements, and risk. An examination of issues of industrial policy and relevance to alliances showed that the views are harmonized between the four to six European partners. C.E.

**A89-49416#**

### **AV-8B - AN INTERNATIONAL SUCCESS STORY**

H. WALL (McDonnell Aircraft Co., Saint Louis, MO) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 7 p.  
(AIAA PAPER 89-2036)

An overview of the Harrier family's history is given to provide historical perspective. Communication has been the key to coordinating the activities of the three principal manufacturers (McDonnell Aircraft, British Aerospace, and Rolls Royce). The dedication of these three companies to 'make it happen' along with the dedication of the US Marine Corps, Royal Air Force, Spanish Navy, and Royal Navy to vertical/short takeoff and landing flexibility, provided the Free World with the only V/STOL fixed wing tactical weapon system operational today. The organizational structures and interfaces between the program participants proved to be both flexible and durable, and will form the basis for future development of the Harrier II into the 1990s and beyond. Author

**A89-49417#**

### **EXPERIENCE ON INTERNATIONAL COOPERATION AND LESSONS LEARNED**

BRUCE G. LANE (International Aero Engines AG, East Hartford, CT) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Seattle, WA, July 31-Aug. 2, 1989. 6 p.  
(AIAA PAPER 89-2037)

International cooperation in the design, development, and manufacture of the V2500 turbofan engine is discussed. The V2500, delivering 25,000 pounds of thrust, is used on 40 percent of the A320 aircraft sold to date and is being offered on the A320 Stretch and the MD90 series aircraft. Advantages achieved in international cooperation include greater marketing strength, greater research and development capacity, greater manufacturing capacity, and the sharing of resources to enhance problem solving. Problems related to the development program and the support of the common interests of shareholders are addressed. R.R.

**A89-51331#**

### **THE NASP CHALLENGE - MANAGEMENT INNOVATION**

HERSHEL SAMS (McDonnell Douglas Corp., Saint Louis, MO) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 6 p.  
(AIAA PAPER 89-5006)

The National Aero-Space Plane (NASP) program challenges the American aerospace industry to pursue a new, high level of

technology for the 21st Century. In addition to the technological challenge, the National Program Concept demands innovation in management philosophies and implementation. This paper explores the new concepts of cooperation, trust and teamwork between the government and industry and between contractors. A brief NASP status update is given, as well as a review of innovative management methods used to date on the NASP program. But as the NASP participants look ahead to Phase 3, the building and flight testing of the X-30 experimental vehicle, even more innovation is required. A focusing of effort under one lead contractor is recommended, along with the commitment of all NASP contractors as enthusiastic, supportive team members. Collocation is recommended for the early stages of Phase 3, to facilitate a highly integrated team effort, with work transitioning to individual work centers for detailed design, assembly and test, prior to final assembly and flight testing. Developing and implementing an innovative, cooperative management strategy is critical for the success of this great national effort and will lead to a new method of doing business that will keep America competitive in the world marketplace. Author

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## GENERAL

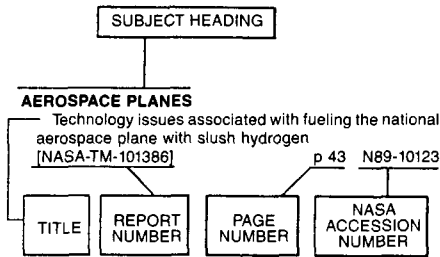
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### **INTERNATIONAL COMPETITION - THE NASP CHALLENGE**

ARMAND J. CHAPUT (General Dynamics Corp., Fort Worth, TX) AIAA, National Aerospace Plane Conference, 1st, Dayton, OH, July 20, 21, 1989. 9 p.  
(AIAA PAPER 89-5018)

Aerospace is the premier export category among U.S. manufacturing sectors. It is responsible for much of the positive trade balance needed to offset the import demand. It is critical that U.S. aerospace maintain its lead in the technological state-of-the-art which determines whether U.S. products are competitive in the international marketplace. For the 21st century, the state-of-the-art will be hypersonic, and U.S. industry has to be prepared to step up to the challenge. Author

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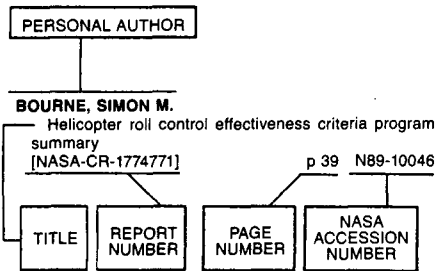
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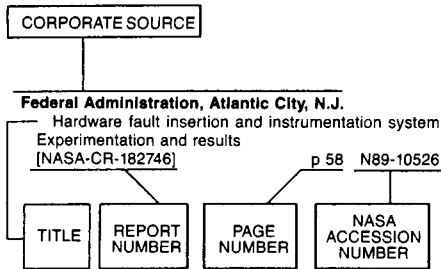
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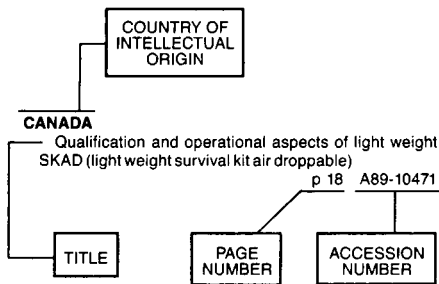
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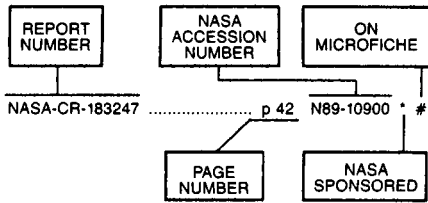
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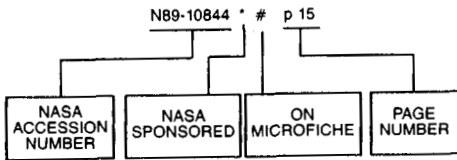
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