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Aeronautical Engineering

A Continuing Bibliography with Indexes

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AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 240)

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 May 1989 in

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

NASA National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Division
Washington, DC 1989

INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 629 reports, journal articles and other documents originally announced in May 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 cummulative index will be published.

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

TABLE OF CONTENTS

TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED

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 SWEPT WINGS Final Report**

AUTHORS → SHAWN H. WOODSON and FRED R. DEJARNETTE Washington Oct. 1988 82 p

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 descretized 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

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 of Aircraft (ISSN 0021-8669), ← JOURNAL TITLE 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. 240)

JUNE 1989

01

AERONAUTICS (GENERAL)

A89-25199*# National Aeronautics and Space Administration, Washington, DC.
RECENT RESULTS IN THE NASA RESEARCH BALLOON PROGRAM
W. VERNON JONES (NASA, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0233)

The NASA Balloon Program has progressed from a total hiatus in the fall of 1985 to an unprecedented flight success rate in the fall of 1988. Using heavy-lift balloons being regularly supplied by two manufacturers, the program has provided a timely response for investigations of Supernova 1987A from Australia, low energy cosmic ray investigations from Canada during periods of near-solar-minimum, and routine domestic turnaround flights for a variety of investigations. Recent re-evaluation of balloon flight-safety have resulted in severe constraints on flights launched from the Palestine, Texas facility. The future program must rely heavily on the use of remote launch sites to meet the growing requirements for more frequent and longer duration flights being planned for the next 3 - 5 years. Author

A89-25428#
THE INTELLIGENT WING - AERODYNAMIC DEVELOPMENTS FOR FUTURE TRANSPORT AIRCRAFT
R. HILBIG and J. SZODRUCH (Messerschmitt-Boelkow-Blohm GmbH, Bremen, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by BMFT. refs
(AIAA PAPER 89-0534)

The development of several aerodynamic technologies related to the speed range of subsonic aircraft are reviewed. The potential benefits of various technologies are analyzed. It is suggested that the variable camber control concept for transonic wings may lead to an L/D improvement of up to 9 pct and a buffet boundary increase of up to 12 pct. It is found that the integration of passive shock boundary layer interaction control in wing designs may reduce total aircraft drag by two to three pct. In addition, it is suggested that the natural laminar flow concept may make drag reductions of 15-20 pct possible. R.B.

A89-26673#
AMBER FOR LONG ENDURANCE
RONALD D. MURPHY (DARPA, Arlington, VA) Aerospace America (ISSN 0740-722X), vol. 27, Feb. 1989, p. 32-34.

In 1984, DARPA awarded a development contract for a long-endurance unmanned air vehicle (UAV), designated Amber, whose fully-integrated gasoline-fueled four-cylinder powerplant module could accommodate either a naturally aspirated air induction system for operation to 30,000 ft, or a turbocharged system for higher altitudes. A pusher-prop configuration is used to facilitate sensor placement near the fuselage nose, as well as to maximize optics' field-of-view. The Amber UAV has demonstrated 38-hour continuous mission endurance. Attention is given to prospective development landmarks. O.C.

A89-26674#
CONDOR FOR HIGH ALTITUDES
ABRAHAM M. S. GOO, NEIL ARNTZ (Boeing Co., Seattle, WA), and RONALD D. MURPHY (DARPA, Arlington, VA) Aerospace America (ISSN 0740-722X), vol. 27, Feb. 1989, p. 36, 37.

The totally autonomous unmanned air vehicle (UAV) designated Condor embodies state-of-the-art advancements in composite primary structures, propulsion, aerodynamics, and autonomous avionics to yield mission endurances of the order of days rather than hours. Such a UAV will be applicable to drug interdiction, border patrol, storm research, mapping, oceanic law enforcement, shore pollution monitoring, and radio/TV relays. The Condor UAV's two 175-hp engines achieve their high propulsion efficiency through the use of two turbocharging stages. O.C.

A89-28204
BUILDING AIRCRAFT ASSEMBLY TOOLS FROM A 3-D DATABASE
PRADEEP K. BHAUMIK (Northrop Corp., Aircraft Div., Hawthorne, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p.
(SAE PAPER 881428)

The use of a data base from an electronic data model of aircraft assembly to produce assembly tools without physical masters is discussed. The assembly tool is designed in three dimensions and the components are numerically controlled, conventionally machined, and inspected on coordinate measuring machines using a data set that is downloaded from the mainframe. The tool is verified using the theodolite, the coordinate measuring machine, or photogrammetry. R.B.

A89-28463*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COCKPIT DISPLAY OF GROUND-BASED WEATHER DATA DURING THUNDERSTORM RESEARCH FLIGHTS
BRUCE D. FISHER, PHILIP W. BROWN, ALFRED J. WUNSCHEL, JR., and JOSEPH W. STICKLE (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA 89-0806)

This paper describes an integrated system for providing ground-based cockpit display, transmitting to an aircraft, upon request via VHF radio, important ground-based thunderstorm data such as radar precipitation reflectivity contours, aircraft ground track, and cloud-to-ground lightning locations. Examples of the airborne X-band weather radar display and the ground-based display are presented for two different missions during the NASA Storm Hazards Program. In spite of some limitation, the system was found to be helpful in the selection of the route of flight, the general ground track to be used, and, occasionally, in clarifying the location of a specific cell of interest. I.S.

N89-16719# RAND Corp., Santa Monica, CA.
AIRCRAFT AIRFRAME COST ESTIMATING RELATIONSHIPS: ALL MISSION TYPES Interim Report
R. W. HESS and H. P. ROMANOFF Dec. 1987 147 p

(Contract F49620-86-C-0008)
(AD-A200262; RAND/N-2283/1-AF) Avail: NTIS HC A07/MF A01 CSCL 05C

This Note is part of a series of Notes that derive a set of equations suitable for estimating the acquisition costs of various types of aircraft airframes in the absence of detailed design and manufacturing information. A single set of equations was selected as being the most representative and applicable to the widest range of estimating situations. For all mission types, the equation set used empty weight types and speed as the basic size-performance variable combination. GRA

N89-16720# RAND Corp., Santa Monica, CA.
AIRCRAFT AIRFRAME COST ESTIMATING RELATIONSHIPS: FIGHTERS Interim Report
R. W. HESS and H. P. ROMANOFF Dec. 1987 151 p
(Contract F49620-86-C-0008)
(AD-A200263; RAND/N-2283/2-AF) Avail: NTIS HC A08/MF A01 CSCL 05C

This note is part of a series of notes that derive a set of equations suitable for estimating the acquisition costs of various types of aircraft airframes in the absence of detailed design and manufacturing information. A single set of equations was selected as being the most representative and applicable to the widest range of estimating situations. For fighters, the equation set uses airframe unit weight as the variable. GRA

N89-16721# RAND Corp., Santa Monica, CA.
AIRCRAFT AIRFRAME COST ESTIMATING RELATIONSHIPS: BOMBERS AND TRANSPORTS Interim Report
R. W. HESS and H. P. ROMANOFF Dec. 1987 63 p
(Contract F49620-86-C-0008)
(AD-A200264; RAND/N-2283/3-AF) Avail: NTIS HC A04/MF A01 CSCL 05C

This note is part of a serious of notes that derive a set of equations suitable for estimating the acquisition costs of various types of aircraft airframes in the absence of detailed design and manufacturing information. A single set of equations was selected as being the most representative and applicable to the widest range of estimating situations. For bombers and transports, no single acceptable estimating relationship could be identified. Estimates for these aircraft should be developed by analogy or by using the equation set developed for all mission types. GRA

N89-16722# RAND Corp., Santa Monica, CA.
AIRCRAFT AIRFRAME COST ESTIMATING RELATIONSHIPS: ATTACK AIRCRAFT Interim Report
R. W. HESS and H. P. ROMANOFF Dec. 1987 60 p
(Contract F49620-86-C-0008)
(AD-A200265; RAND/N-2283/4-AF) Avail: NTIS HC A04/MF A01 CSCL 05C

This note is part of a series of notes that derive a set of equations suitable for estimating the acquisition costs of various types of aircraft airframes in the absence of detailed design and manufacturing information. A single set of equations was selected as being the most representative and applicable to the widest range of estimating situations. For attack aircraft, no single acceptable estimating relationship could be identified because sample sizes were small and not homogeneous. Estimates for these aircraft should be developed by analogy or by using the equation set developed for all mission types. GRA

N89-17564# Army Missile Command, Redstone Arsenal, AL.
REMOTELY PILOTED VEHICLE (RPV) TWO VERSUS THREE LEVEL MAINTENANCE SUPPORT CONCEPT STUDY Final Report
JOSEPH H. NORDMAN, WAYNE M. LEONARD, JR., and ADRIAN A. ABRAMS 15 Jan. 1988 67 p
(AD-A200665; AMSMI/LC-TA-88-01) Avail: NTIS HC A04/MF A01 CSCL 01C

Two maintenance support concepts for selected RPV subsystems lifetime supply and maintenance (S and M) costs are: (1) two levels of support, organizational and depot; and (2) three levels of support, organizational, intermediate (direct support and general support) and depot. Lifetime costs applicable to current peacetime conditions are estimated through the method of the Optimum Supply and Maintenance Model (OSAMM) which uses the supply model, called Selected Essential-Item Stockage for Availability Method (SESAME), as a subroutine. The unique features of OSAMM allows it to simultaneously minimize costs, develop maintenance task distributions, and quantities and placement of test equipment and stockage while achieving a pre-stated operational availability target. Results are presented over a range of operational availability values of interest in which supply quantities are variants. It is concluded that the three level support concept is less expensive than the two level concept for every selected subsystem studied except one - that one exception has a small cost impact. Another interesting conclusion reached for the three level concept is that the operational availability can be significantly improved with small stockage cost increases. GRA

02

AERODYNAMICS

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

A89-24922#
STABILITY AND TRANSITION OF TWO-DIMENSIONAL LAMINAR BOUNDARY LAYERS IN COMPRESSIBLE FLOW OVER AN ADIABATIC WALL
D. ARNAL (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 4, 1988, p. 15-32. refs

Laminar stability theory is applied to two-dimensional boundary-layer profiles on an adiabatic wall, for Mach numbers 0-10. The stability diagrams show complex compressibility effects such as the appearance of multiple unstable modes at supersonic Mach numbers. Some examples are also presented of profiles of fluctuating amplitude. The e exp n method is used for estimating the transition Reynolds numbers for cones or flat plates; these calculations illustrate the difficulties encountered in simulating flight conditions in conventional wind tunnels. Author

A89-24923#
FAST LAMINAR NEAR WAKE FLOW CALCULATION BY AN IMPLICIT METHOD SOLVING THE NAVIER-STOKES EQUATIONS
D. DEVEZEAUX, H. HOLLANDERS, and C. MARMIGNON (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 4, 1988, p. 33-44. Research sponsored by the Delegation Generale pour l'Armement and Aerospatiale. Previously cited in issue 19, p. 3173, Accession no. A88-46328. refs

A89-24925#
AERODYNAMIC VISUALIZATION FOR IMPULSIVELY STARTED AIRFOILS
F. FINAISH and P. FREYMUTH (Colorado, University, Boulder) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 4, 1988, p. 55-62. refs
(Contract F49620-84-C-0065)

An experimental system has been designed which generates and visualizes impulsive starting flow over airfoils in air. The system has been used for a parametric visual study of vortex development over NACA 0015 airfoils at high angles of attack and at low Reynolds numbers. Author

A89-25002#
HYPERSONIC SCRAMJET INLET FLOW INVESTIGATIONS, M1 = 16-26
H. T. NAGAMATSU (Rensselaer Polytechnic Institute, Troy, NY),

K. Y. CHOI, and R. E. SHEER, JR. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0003)

The inlet flow phenomena for a two-dimensional scramjet model describing hypersonic Mach numbers of 10-26 with a stagnation temperature of 1400 K were studied in a combustion driven hypersonic shock tunnel. The effect of viscosity on the shock wave angle, pressure, temperature, density, and Mach number after the shock wave is insignificant at M = 10. It is significant at M in the range of 16-26 for nearly perfect conditions. K.K.

A89-25003#
ZONAL MODELLING OF FLOWS THROUGH MULTIPLE INLETS AND NOZZLES
JAMES A. RHODES and JOHN E. CROXFORD (McDonnell Aircraft Co., Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0005)

A two-dimensional zonal grid generation code, INOZG, and a flow solver, FANSI, have been developed which, when used together, can analyze turbulent flow in complicated multiple passage inlet and nozzle configurations. The grid generation code utilizes algebraic and elliptic techniques and offers flexibility in the manner in which the grids are constructed. Currently, grids containing up to 30 zones can be constructed. Information on the coupling of the various zones and the type of boundaries in each zone is created in the grid code and passed to the flow solver. The flow solver uses a 2nd order upwind scheme to solve either the Euler or Navier-Stokes equations. Author

A89-25016*# Douglas Aircraft Co., Inc., Long Beach, CA.
AN INTERACTIVE BOUNDARY-LAYER PROCEDURE FOR OSCILLATING AIRFOILS INCLUDING TRANSITION EFFECTS
TUNCER CEBECI, HONG-MING JANG (Douglas Aircraft Co., Long Beach, CA), and L. W. CARR (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract F49720-85-C-0063)
(AIAA PAPER 89-0020)

An interactive boundary-layer method previously developed and tested for steady flows is used here in a quasi-steady manner to examine the evolution of the flow behavior around oscillating airfoils operating inlight stall conditions. The calculations encompass the airfoil and wake flows at angles of attack which lead to flow separation. The location of the onset of transition is represented by a correlation based on steady flows. The results show the large effects of the viscous layer on the variation of lift coefficient with angle of attack and reduced frequency. Author

A89-25017#
THEORETICAL AND NUMERICAL STUDIES OF OSCILLATING AIRFOILS
ISMAIL H. TUNCER, JAMES C. WU, and C. M. WANG (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by the U.S. Army and USAF. refs
(AIAA PAPER 89-0021)

Unsteady flow fields around airfoils oscillating in pitch and associated dynamic stall phenomena are investigated. A viscous flow analysis and a simplified vortical flow analysis, both based on the integrodifferential formulation of the Navier-Stokes equations are developed and calibrated. The formulation of the viscous flow analysis confines the computations only to the viscous region of the flow and lead to an efficient zonal solution procedure. In the simplified vortical flow analysis, computational demands are greatly reduced by partial analytic evaluations. Simulated flow fields and computed aerodynamic loads are in good agreement with available experimental data. Author

A89-25018#
A STATE-SPACE MODEL OF UNSTEADY AERODYNAMICS IN A COMPRESSIBLE FLOW FOR FLUTTER ANALYSES
J. GORDON LEISHMAN and GILBERT L. CROUSE, JR. (Maryland, University, College Park) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. Research supported by the U.S. Army. refs
(AIAA PAPER 89-0022)

A method is presented to model the unsteady lift, moment,and drag acting on a two-dimensional airfoil in a compressible flow. Starting from suitable generalizations to indicial aerodynamic functions, the unsteady loads due to an arbitrary forcing are represented in state-space (differential equation) form. The aerodynamic model is validated against various experimental data and computational fluid dynamic solutions for harmonic pitch oscillations at Mach numbers up to 0.875. It is shown that even for transonic flow, the method provides a good approximation to the unsteady lift and moment behavior of an airfoil. The aerodynamic model is coupled to the structural equations of a typical airfoil section with two degrees-of-freedom. The stability of the resulting aeroelastic system is determined both by direct time integration of the state equations and by eigenanalysis of the system state matrix. Author

A89-25019*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLOW VISUALIZATION STUDIES OF THE MACH NUMBER EFFECTS ON THE DYNAMIC STALL OF AN OSCILLATING AIRFOIL
M. S. CHANDRASEKHARA (Navy-NASA Joint Institute of Aeronautics, Monterey, CA) and L. W. CARR (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. Research supported by the U.S. Navy, U.S. Army, and USAF. refs
(AIAA PAPER 89-0023)

Compressibility effects on the dynamic stall of a NACA 0012 airfoil undergoing sinusoidal oscillatory motion were studied using a stroboscopic schlieren system. Schlieren pictures and some quantitative data derived from them are presented and show the influence of free-stream Mach number and reduced frequency on the dynamic-stall vortex. This study shows that a dynamic stall vortex always forms near the leading edge and convects on the airfoil upper surface at approximately 0.3 times the free stream velocity for all cases studied. The results also demonstrate that initiation of the dynamic stall vortex is delayed to higher angles of attack with increased reduced frequency, but that dynamic stall occurs at lower angles of incidence with increasing Mach numbers. Author

A89-25020*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPRESSIBLE STUDIES ON DYNAMIC STALL
J. A. EKATERINARIS (NASA, Ames Research Center; Sterling Federal Systems, Inc., Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research sponsored by the U.S. Navy. refs
(AIAA PAPER 89-0024)

The purpose of this work is to investigate the effects of compressibility on the dynamic stall phenomenon by numerical simulation of the unsteady flow. The full two-dimensional unsteady compressible Navier-Stokes equations are solved for flows over oscillating airfoils and airfoils pitching rapidly to high angles of attack. The free-stream speeds vary from low subsonic with mild compressibility effects, to moderate subsonic where strong compressibility effects appear close to the leading edge at high angles of attack. An Alternating Direction Implicit scheme is implemented for the numerical solution with the viscous terms retained in both directions. The numerical results are compared with available experimental data for a Sikorsky airfoil for compressible high Reynolds number flows. There is good agreement between the computed and measured unsteady lift and pitching moment coefficient time histories. The computed high-speed subsonic unsteady results give a good picture of the entire flow field, and the dynamic stall progression in the compressible flow regime. It was observed that compressibility

effects are more severe close to the leading edge at moderate angles of attack, and that the dynamic stall vortex appears at lower angles of attack as the free-stream speed increases.
Author

A89-25021#
EXTENDED PITCH AXIS EFFECTS ON FLOW ABOUT A PITCHING AIRFOIL
E. J. STEPHEN, J. M. WALKER, J. ROH, T. ELDRED, and M. BEALS (U.S. Air Force Academy, Colorado Springs, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0025)
A pitching NACA 0015 airfoil was tested in the wind tunnel with several pitch axes at locations from 1/2 chord forward of the airfoil to 1/2 chord aft. The results indicated that moving the pitch axis aft delays the dynamic stall. They also indicate that the maximum lift from the pitching airfoil decreases the aft axis movement. Finally, they may indicate that the effects of moving the pitch axis reach a limit as the axis is moved to extreme positions.
Author

A89-25022*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLOW-FIELD CHARACTERISTICS AND NORMAL-FORCE CORRELATIONS FOR DELTA WINGS FROM MACH 2.4 TO 4.6
PETER F. COVELL (NASA, Langley Research Center, Hampton, VA) and GARY F. WESSELMANN (USAF, Arnold Engineering Development Center, Arnold Air Force Station, TN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0026)
An experimental investigation has been conducted to determine the upper-surface flowfield types and the normal-force characteristics of a series of delta wing models at supersonic speeds. Flow-visualization data were used to classify the flowfields into seven primary types: shockless attached flow, separation bubble, classical vortex, vortex with shock, shock with no separation, shock-induced separation, and separation bubble with shock. The pressure distributions were integrated to obtain upper and lower surface normal-force loadings. A minimal effect of sweep was observed on the upper-surface normal force at constant Mach number and a minimal effect of Mach number was noted for the 75 deg delta wing lower-surface normal force. The normal-force coefficients for all test conditions were correlated, and a single empirical equation was formulated from which the normal-force coefficient could be calculated as a function of Mach number, angle of attack, and wing aspect ratio.
C.D.

A89-25023*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EVALUATION OF LEADING- AND TRAILING-EDGE FLAPS ON FLAT AND CAMBERED DELTA WINGS AT SUPERSONIC SPEEDS
GLORIA HERNANDEZ, RICHARD M. WOOD (NASA, Langley Research Center, Hampton, VA), and ROBERT E. COLLINS (Planning Research Corp., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0027)
An experimental investigation has been conducted to evaluate the effectiveness of leading- and trailing-edge flaps on a flat and cambered wing at superconic speeds. Results from the experimental tests showed that highly complex and three-dimensional flow can occur over the wings with leading- and/or trailing-edge flaps deflected. An analysis of the data also showed that flap effectiveness varies significantly between a cambered and flat wing of identical planform and flap geometry. Mach number effects are similar for both flat and cambered wings for all aerodynamic parameters.
Author

A89-25024#
PREDICTION OF SUPERSONIC/HYPERSONIC VISCOUS FLOWS OVER RVS AND DECOYS
DONG JOO SONG, BILAL A. BHUTTA, and CLARK H. LEWIS (VRA, Inc., Blacksburg, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. refs
(AIAA PAPER 89-0028)
The background and applications of a new unified series of codes for predicting large angle-of-attack viscous supersonic/hypersonic flows over spherically blunt reentry vehicles and decoys are discussed. Several test cases are presented for various multiconic and three-dimensional geometries under zero and non-zero angles of attack. The results of these test cases are used to demonstrate the accuracy, efficiency and robustness of the unified solution scheme.
Author

A89-25025*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HEAT TRANSFER AND PRESSURE COMPARISONS BETWEEN COMPUTATION AND WIND TUNNEL FOR A RESEARCH HYPERSONIC AIRCRAFT
PAMELA F. RICHARDSON (NASA, Langley Research Center, Hampton, VA), EDWARD B. PARLETTE (Vigyan Research Associates, Inc., Hampton, VA), JOSEPH H. MORRISON, GEORGE F. SWITZER, A. DOUGLAS DILLEY (Analytical Services and Materials, Inc., Hampton, VA) et al. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0029)
Comparisons between solutions obtained with a perfect gas, thin-layer Navier Stokes code developed at NASA Langley Research Center and wind tunnel results obtained in Calspan's 96-inch shock tunnel on a research hypersonic aircraft will be presented in this paper. Results cover data obtained between Mach 11 and Mach 19. Comparisons shown in this paper include both pressure and heat transfers. Effects of grid refinement on the computational solution and nose bluntness effects on the comparisons will be discussed.
Author

A89-25026*# Analytical Services and Materials, Inc., Hampton, VA.
A NUMERICAL STUDY OF HYPERSONIC PROPULSION/AIRFRAME INTEGRATION PROBLEM
J. R. NARAYAN (Analytical Services and Materials, Inc., Hampton, VA) and A. KUMAR (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0030)
A numerical analysis procedure useful in the propulsion-airframe integration problem has been established. Flow around a generic hypersonic vehicle forebody is solved using Parabolized Navier-Stokes equations and Thin Layer Navier-Stokes equations. Forebody cross sectional geometry corresponds to a two-ellipse configuration. Effect of forebody geometry on the flow structure, especially at the engine inlet location, is analyzed.
Author

A89-25028*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE EFFECT OF EXHAUST PLUME/AFTERBODY INTERACTION ON INSTALLED SCRAMJET PERFORMANCE
T. A. EDWARDS (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 18 p. refs
(AIAA PAPER 89-0032)
An upwind implicit Navier-Stokes code has been used to study hypersonic exhaust plume/afterbody flow fields. It is found that afterbody forces varied linearly with the nozzle exit pressure for moderately underexpanded jets, and that exhaust gases with low isentropic exponents (gamma) contribute up to 25 percent more force than high-gamma exhaust gases. Highly underexpanded jets are shown to create a strong plume shock, and the interaction of this shock with the afterbody produces a complicated pattern of crossflow separation.
R.R.

A89-25031*# Boeing Commercial Airplane Co., Seattle, WA.
STABILITY OF 3D WING BOUNDARY LAYER ON A SST CONFIGURATION

P. G. PARIKH, P. P. SULLIVAN, E. BERMINGHAM, and A. L. NAGEL (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract NAS1-15325; NASA TASK 21)
(AIAA PAPER 89-0036)

Tollmien-Schlichting (TS) and cross-flow (CF) instability growth characteristics were studied in three dimensions, for the case of a Mach 2.4 SST with double-delta planform whose inboard leading-edge is subsonic and outboard leading-edge is supersonic. Attention is given to the requirements for supersonic speed laminarization of both highly swept, rounded leading-edge wings and moderately-swept, sharp leading-edge wings. Suction requirements for the control of both TS and CF instabilities are calculated; it is found that while mild suction and surface cooling are effective in TS-instability damping, the CF influence of such techniques is rather weak. CF instability control must be via pressure-distribution tailoring and suction. O.C.

A89-25037*# North Carolina State Univ., Raleigh.
LASER HOLOGRAPHIC INTERFEROMETRIC MEASUREMENTS OF THE FLOW IN A SCRAMJET INLET AT MACH 4
J. CRAIG MCARTHUR (North Carolina State University, Raleigh), WILLIAM J. YANTA, W. CHARLES SPRING, III, and KIMBERLY UHRICH GROSS (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(Contract NAGW-1072)
(AIAA PAPER 89-0043)

The need for quantitative data is addressed by laser holographic interferometry (LHI) by efficiently recording and reducing high resolution density data. This paper investigates the potential to get quantitative data from an interferogram created from two separate holographic plates. The LHI measurements were made on a scramjet inlet at Mach 4. LHI successfully generated results for both internal and external flows, and demonstrated its ability to map entire flow fields. Of the three data reduction techniques used, the four-bucket method gave better results than the three-bucket or three-by-three methods. This technique requires high quality holograms as well as a good resolution in the digital images to produce good data. Author

A89-25039*# Aerojet TechSystems Co., Sacramento, CA.
CFD SIMULATION OF SQUARE CROSS-SECTION, CONTOURED NOZZLE FLOWS - COMPARISON WITH DATA
MARK J. OSTRANDER (Aerojet TechSystems Co., Sacramento, CA), SCOTT R. THOMAS, RANDALL T. VOLAND, ROBERT W. GUY (NASA, Langley Research Center, Hampton, VA), and SHIVAKUMAR SRINIVASAN (Analytical Services and Materials, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0045)

Computational analyses have been made of the flow in NASA Langley's Arc-Heated Scramjet Test Facility's Mach 4.7 and Mach 6 square cross-section contoured nozzles, for comparison with experimental results. The analyses, which were performed using a three-dimensional RANS computer code assuming a single species gas with constant specific heats, were intended to provide insight into the nature of the flow development in this type of nozzle. The computational results showed the exit flow distribution to be affected by counter-rotating vortices along the centerline of each nozzle sidewall. Calculated flow properties show general, but not complete, agreement with experimental measurements in both nozzles. Author

A89-25040#
UNSTEADY WALL INTERFERENCE IN ROTARY TESTS
MARTIN E. BEYERS (National Aeronautical Establishment, Ottawa, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0046)

The mechanisms of transverse acoustic interference and vortex-wake/wall interaction are identified as the sources of unsteady wind-tunnel wall interference in rotary balance tests. It is suggested that the convective effects associated with vortex-wake/wall interactions are more likely to be a problem when the rotating system is large in relation to the minimum test-section dimension. Related oscillatory results indicate that unsteady wall interference effects can be significant at high angles of attack. R.R.

A89-25071*# Old Dominion Univ., Norfolk, VA.
UNSTEADY NAVIER-STOKES COMPUTATIONS PAST OSCILLATING DELTA WING AT HIGH INCIDENCE
OSAMA A. KANDIL and H. ANDREW CHUANG (Old Dominion University, Norfolk, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract NAG1-648)
(AIAA PAPER 89-0081)

The unsteady, thin-layer, compressible Navier-Stokes equations, written in the moving frame of reference for the flow relative motion, is solved for the steady and unsteady supersonic flow around a round-edged delta wing. For supersonic flow, local conical flow solution has been obtained from the three-dimensional equations. Pseudotime stepping is used for the steady flow, while time-accurate stepping is used for the unsteady flow. The computational scheme is an implicit approximately-factored finite volume scheme which uses explicit and implicit dissipation terms. The scheme is verified for the steady flow solution. The scheme is then applied to a delta wing undergoing rolling oscillation at a reduced frequency of 1.137 with 15- deg maximum amplitude about a mean angle of attack of 10 deg for a Mach number of 2 and a Reynolds number of 500,000. Author

A89-25072*# Pennsylvania State Univ., University Park.
AN EXPERIMENTAL STUDY OF SHOCK WAVE/VORTEX INTERACTION
O. M. METWALLY, G. S. SETTLES (Pennsylvania State University, University Park), and C. C. HORSTMAN (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract NCA2-235)
(AIAA PAPER 89-0082)

The interaction of a supersonic streamwise vortices (of Mach number 2.2, 3.0, and 3.5) with a normal shock wave has been experimentally investigated, and is found to be highly unsteady. Five-hole pressure-probe and temperature measurements ahead of the interaction are used as initial conditions for an axisymmetric Navier-Stokes calculation. The numerical results supports the hypothesis that supersonic vortex breakdown is an important factor in the observed interaction flow pattern. R.R.

A89-25073*# Imperial Coll. of Science and Technology, London (England).
VORTEX/BOUNDARY LAYER INTERACTIONS
A. D. CUTLER and P. BRADSHAW (Imperial College of Science and Technology, London, England) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAGW-581)
(AIAA PAPER 89-0083)

Detailed and high quality measurements with hot-wires and pressure probes are presented for two different interactions between a vortex pair with common flow down and a turbulent boundary layer. The interactions studied have larger values of the vortex circulation parameter than those studied previously. The results indicate that the boundary layer under the vortex pair is thinned by lateral divergence and that boundary layer fluid is entrained into the vortex. The effect of the interaction on the vortex core (other than the inviscid effect of the image vortices behind the surface) is small. Author

A89-25074*# Naval Coastal Systems Center, Panama City, FL.
AN EXPERIMENTAL INVESTIGATION OF DELTA WING VORTEX FLOW WITH AND WITHOUT EXTERNAL JET BLOWING
KENNETH P. IWANSKI (U.S. Navy, Naval Coastal Systems Center,

Panama City, FL), T. TERRY NG (Eidetics International, Inc., Torrance, CA), and ROBERT C. NELSON (Notre Dame, University, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 19 p. Research supported by the University of Notre Dame. refs
(Contract NCA2-162)
(AIAA PAPER 89-0084)

A visual and quantitative study of the vortex flow field over a 70-deg delta wing with an external jet blowing parallel to and at the leading edge was conducted. In the experiment, the vortex core was visually marked with TiCl4, and LDA was used to measure the velocity parallel and normal to the wing surface. It is found that jet blowing moved vortex breakdown farther downstream from its natural position and influenced the breakdown characteristics. R.R.

A89-25075*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INFLUENCE OF WING GEOMETRY ON LEADING-EDGE VORTICES AND VORTEX-INDUCED AERODYNAMICS AT SUPERSONIC SPEEDS
RICHARD M. WOOD, STEVEN X. S. BAUER (NASA, Langley Research Center, Hampton, VA), JAMES E. BYRD, BRIAN E. MCGRATH (Planning Research Corp., Hampton, VA), and GARY F. WESSELMANN (NASA, Langley Research Center, Hampton, VA; USAF, Arnold Engineering Development Center, Arnold AFB, TN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0085)

An assessment of the influence of wing geometry on wing leading-edge vortex flows at supersonic speeds is discussed as well as the applicability of various aerodynamic codes for predicting these results. A series of delta-wing wind-tunnel models were tested in the NASA Langley Research Center Unitary Plan Wind Tunnel over a Mach number range from 1.6 to 4.6. The data show that wing airfoil has a significant impact on the localized loading on the wing. The experimental data for the flat wings were compared with results from full-potential, Euler, and Parabolized Navier-Stokes (PNS) computer codes. The theoretical evaluation showed that the full-potential analysis predicted accurate results for the attached-flow (alpha = 0 deg) conditions and that the Euler and PNS analyses made reasonable predictions for both attached and separated flow conditions. Author

A89-25076#
EFFECTS OF LEADING-EDGE SHAPE AND VORTEX BURST ON THE FLOWFIELD OF A 70-DEGREE-SWEEP DELTA-WING
JEROME T. KEGELMAN and FREDERICK W. ROOS (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0086)

The low-speed flowfields of several thin, flat, 70 degree-sweep delta wings are studied. It is found that the leading-edge shape significantly affects the location of leading-edge vortex bursts. The coupling between vortex burst and lift is not strong for wings with sweep angle of 70 deg or less. Bursting of the leading-edge vortex is noticeably asymmetrical. The primary effect of burst appears to be a slight reduction of the local growth rate of the vortex. The separation characteristics near the leading edge and the strength of the leading-edge vortex appear to be the most important features for determining vortex lift. C.D.

A89-25085#
CONVERGENCE ACCELERATION THROUGH THE USE OF TIME INCLINING
JOHN F. DANNENHOFFER, III (United Technologies Research Center, East Hartford, CT) and MICHAEL B. GILES (MIT, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0096)

The use of time inclining for accelerating the convergence to steady state of inviscid flow computations is examined. This technique, which was originally developed for the efficient computation of time-accurate rotor-stator interactions, is based upon a local inclination in time of the computational cells. For convergence acceleration, these inclinations are chosen so as to balance the time-step restrictions for the upwind- and downwind-running pressure waves. The inclusion of time inclining into Ni's Lax-Wendroff-type integration scheme is discussed in detail, both in terms of the additional transformations required as well as the selection of inclining parameters for near-optimal convergence rates. The technique is very easy to implement due to its local character and thus makes it an ideal candidate for structured as well as unstructured grid calculation procedures. The effectiveness of time inclining is demonstrated in two dimensions with free-stream Mach numbers ranging from 0.2 to 3.0. The results show that while the steady-state accuracy is not affected by inclining, the convergence rate can be more than doubled by optimally inclining the time. Author

A89-25090#
EFFICIENT FINITE-VOLUME PARABOLIZED NAVIER-STOKES SOLUTIONS FOR THREE-DIMENSIONAL, HYPERSONIC, CHEMICALLY REACTING FLOWFIELDS
THOMAS P. GIELDA and RAMESH K. AGARWAL (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0103)

The development of an explicit, three-dimensional, finite-volume, parabolized Navier-Stokes code based on MacCormack's predictor-corrector algorithm is described. The code strongly couples an eight-equation chemical kinetics model with the fluid-dynamics equations for calculating hypersonic, turbulent, chemically reacting flowfields. The code is certified by computing a variety of test cases. The computations compare favorably with experimental data. Author

A89-25099*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN INTERACTIVE THREE-DIMENSIONAL BOUNDARY-LAYER METHOD FOR TRANSONIC FLOW OVER SWEPT WINGS
SHAWN H. WOODSON, JAMES F. CAMPBELL (NASA, Langley Research Center, Hampton, VA), and FRED R. DEJARNETTE (North Carolina State University, Raleigh) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0112)

A three-dimensional laminar/turbulent boundary-layer method is developed for transonic flow over swept wings. The governing equations and curvature terms are written for a nonorthogonal body-oriented curvilinear coordinate system. The viscous method is coupled to the full-potential inviscid code, FLO-30, through a displacement-surface interaction. Typically, for transonic Mach numbers and moderate sweep angles, between 5 and 12 viscous updates are required for convergence. The method is applied to a variety of wing planforms, and the results are also compared to those obtained with the three-dimensional integral inviscid-viscous interaction method TAWFIVE (Streett and Melson, 1983). Author

A89-25100#
SUPERSONIC INLET CALCULATIONS USING AN UPWIND FINITE-VOLUME METHOD ON ADAPTIVE UNSTRUCTURED GRIDS
STEPHEN R. KENNON (Texas, University, Arlington) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0113)

Euler calculations are presented using an upwind finite-volume method on adaptive unstructured grids. The method combines the attractive features of upwind methods with the geometric generality provided by the use of unstructured grids. The flow solver is coupled to an adaptive unstructured grid generation method developed for non-convex domains. Results are presented for representative transonic and supersonic flows including high-speed, complex-geometry inlet flows. Author

A89-25102*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

UNSTEADY EULER AIRFOIL SOLUTIONS USING UNSTRUCTURED DYNAMIC MESHES

JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs

(AIAA PAPER 89-0115)

Two algorithms for the solution of the time-dependent Euler equations are presented for unsteady aerodynamic analysis of oscillating airfoils. Both algorithms were developed for use on an unstructured grid made up of triangles. The first flow solver involves a Runge-Kutta time-stepping scheme with a finite-volume spatial discretization that reduces to central differencing on a rectangular mesh. The second flow solver involves a modified Euler time-integration scheme with an upwind-biased spatial discretization based on the flux-vector splitting of Van Leer. The paper presents descriptions of the Euler solvers and dynamic mesh algorithm along with results which assess the capability. Author

A89-25103#

AN ACCELERATION METHOD FOR SOLVING THE EULER EQUATIONS ON AN UNSTRUCTURED MESH BY APPLYING MULTIGRID ON AN AUXILIARY STRUCTURED MESH

JOHN VASSBERG (Douglas Aircraft Co., Long Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. Research supported by U.S. Navy. refs

(AIAA PAPER 89-0116)

An alternative approach to accelerate the convergence of the two-dimensional Euler equations on an unstructured mesh is presented. The basic Euler equation solver is derived using techniques advocated by Jameson (1986), while the acceleration of the solution is accomplished using multigrid on a sequence of nonbody-conforming structured meshes. The method developed is general and can be extended to three dimensions. Results for Joukowski and NACA 0012 airfoils are presented and compared with exact incompressible solutions and AGARD test-case solutions, respectively. Author

A89-25104#

APPLICATION OF CONTINUOUS VORTICITY PANELS IN THREE-DIMENSIONAL LIFTING FLOWS WITH PARTIAL SEPARATION

MEUNG J. KIM (Northern Illinois University, DeKalb, IL) and D. T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs

(AIAA PAPER 89-0117)

A panel method for studying aerodynamic characteristics over various configurations of lifting surfaces with partial separation is developed. The method uses piecewise linear vorticity distribution over a flat triangular element for the lifting surface and constant circulation vortex filaments for the force-free wakes. The scheme overcomes two major difficulties: the possibility of an ill-posed matrix due to the linear dependence of the divergenceless conditions and tangency condition of surface vorticities. The numerical results predicted by the method for various lifting configurations show good quantitative agreement with experimental data and other numerical results. C.D.

A89-25108*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

LOW REYNOLDS NUMBER NUMERICAL SOLUTIONS OF CHAOTIC FLOW

THOMAS H. PULLIAM (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs

(AIAA PAPER 89-0123)

Numerical computations of two-dimensional flow past an airfoil at low Mach number, large angle of attack, and low Reynolds number are reported which show a sequence of flow states leading from single-period vortex shedding to chaos via the period-doubling mechanism. Analysis of the flow in terms of phase diagrams, Poincare sections, and flowfield variables are used to substantiate these results. The critical Reynolds number for the period-doubling bifurcations is shown to be sensitive to mesh refinement and the influence of large amounts of numerical dissipation. In extreme cases, large amounts of added dissipation can delay or completely eliminate the chaotic response. The effect of artificial dissipation at these low Reynolds numbers is to produce a new effective Reynolds number for the computations. C.D.

A89-25110#

COMPUTATIONAL STUDIES OF A LOCALIZED SUPERSONIC SHEAR LAYER

J. P. BORIS, E. S. ORAN, J. H. GARDNER, K. KAILASANATH, and T. R. YOUNG, JR. (U.S. Navy, Naval Research Laboratory, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. Research supported by the U.S. Navy and DARPA. refs

(AIAA PAPER 89-0125)

A series of two-dimensional time-dependent numerical simulations of shear layers is presented, in which the velocity and the convective Mach number of each stream varies from subsonic to supersonic. The simulations performed are for an ideal gas, gamma = 1.4, at STP with free-stream velocities from + or - 200 to + or - 800 m/s, corresponding to convective Mach numbers Me from 0.6 to 2.4. The calculations show three regimes for the flow: a low (subsonic) Mach-number regime behaving initially like a periodic temporal simulation, but then evolving into a nearly stationary potential flow; a high Mach-number, supersonic shear-layer regime that forms strong shocks associated with inhibited mixing and suppressed vortex formation and growth; and an intermediate regime in which two dynamic shocks arise in the slot whose strength and position vary, apparently chaotically, in time. The dynamics of the flow are analyzed to isolate and study the mixing and high-speed vortex dynamics of each case. Author

A89-25111#

STRUCTURE OF THE COMPRESSIBLE TURBULENT SHEAR LAYER

DIMITRI PAPAMOSCHOU (California Institute of Technology, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. Research sponsored by the Rockwell International Foundation. refs

(Contract N00014-85-K-0646)

(AIAA PAPER 89-0126)

The large-scale structure of the turbulent compressible shear layer is investigated in a two-stream supersonic wind tunnel through a series of experiments. Double-exposure schlieren photography reveals that the two convective Mach numbers, corresponding to each side of the shear layer, are very different, one sonic or supersonic and the other low subsonic. This contradicts the current isentropic model of the structure which predicts them to be equal or very close. It is shown that addition of shock-wave effects to that model allows for the asymmetric trends observed in the experiments. An inclined view of the flow provides sketchy information about the spanwise orientation of the large-scale structure and does not reveal any pronounced obliquity. Attempts to enhance mixing by modifying the trailing edge were unsuccessful. Author

A89-25115*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

THREE-DIMENSIONAL COMPRESSIBLE BOUNDARY LAYER CALCULATIONS TO FOURTH ORDER ACCURACY ON WINGS AND FUSELAGES

VENKIT IYER and JULIUS E. HARRIS (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 18 p. refs

(Contract NAS1-17919)

(AIAA PAPER 89-0130)

Laminar flow control and drag reduction research requires accurate boundary layer solutions as input to the three-dimensional stability analysis procedures currently under development. In support of these major programs, a fourth-order accurate finite difference scheme for solving the three-dimensional, compressible boundary layer equations has been developed and is presented in this paper. The method employs a two-point scheme in the wall normal direction and second order zigzag scheme in the cross flow direction. Accurate procedures to interface with the inviscid results are also presented. The results of applying the procedure to laminar flow on wings and fuselages are presented. Author

A89-25123#
STREAMLINES AND STREAMRIBBONS IN AERODYNAMICS
G. VOLPE (Grumman Corporate Research Center, Bethpage, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p.
(AIAA PAPER 89-0140)

The interpretation and understanding of numerically computed flow fields are facilitated and can be enhanced by the portrayal of streamlines and streamribbons of the flow. The graphical displays of these flow features can be used both as diagnostic tools and as a means of conveying information, not only of a qualitative but also of a quantitative nature, to others. Methods of computing and displaying them are described. Their usefulness in a postprocessing environment and in the creation of instructive and visually striking portraits of aerodynamic flow are illustrated. Author

A89-25133*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLOW QUALITY MEASUREMENTS FOR THE LANGLEY 8-FOOT TRANSONIC PRESSURE TUNNEL LFC EXPERIMENT
GREGORY S. JONES, P. CALVIN STAINBACK, CHARLES D. HARRIS, CUYLER W. BROOKS, JR., and STEVEN J. CLUKEY (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 26 p. refs
(AIAA PAPER 89-0150)

Laminar flow experiments were performed in an 8-foot transonic pressure tunnel which was modified in order to simulate the conditions of an infinite span yawed wing. A liner in the tunnel provided a flow field around the yawed airfoil. The results were evaluated using hot-wire and fluctuating pressure measurements. Data were obtained for root-mean-square fluctuations, their spectra, and various cross product terms. R.R.

A89-25166#
VISUALIZATION MEASUREMENTS OF VORTEX FLOWS
MARTIN V. LOWSON (Bristol, University, England) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0191)

Novel flow-visualization experiments have been used on the separated vortex flow on a delta wing at low speed Re = 3000 -30,000 to give preliminary measurements of flow parameters for comparison with theory. Data on vortex core position, vortex sheet shape, and local velocity magnitude and direction in the core have been determined. The results show divergencies from established theoretical models and suggest areas where care should be taken in extrapolating results at low Re to flight cases. Author

A89-25167*# Notre Dame Univ., IN.
A FLOW VISUALIZATION AND AERODYNAMIC FORCE DATA EVALUATION OF SPANWISE BLOWING ON FULL AND HALF SPAN DELTA WINGS
K. D. VISSER, R. C. NELSON (Notre Dame, University, IN), and T. T. NG (Eidetics International, Inc., Torrance, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 21 p. Research supported by the University of Notre Dame. refs
(Contract NCA2-162)
(AIAA PAPER 89-0192)

A wind-tunnel investigation has been performed to quantify the effects of a jet on the leading-edge vortices generated by a 70-deg-sweep sharp-edged delta wing at low Reynolds numbers. Efforts were made ot optimize the jet nozzle position with respect to maximum lift increments. Both half-span force-balance testing and half- and full-span flow visualization tests were conducted. Two angles of attack were investigated, 30 and 35 deg, at Reynolds numbers of 150,000 and 200,000. Aerodynamic enhancement, including lift and drag gains of about 20 and 17 percent respectively, were measured. Results indicate an optimum jet nozzle location to be close to the leading edge, tangent to the upper wing surface, and in a direction aligned parallel to the leading edge. Nozzle interference effects, especially near the apex, were not negligible. Author

A89-25168#
THE EFFECTS OF A CONTOURED APEX ON VORTEX BREAKDOWN
RONALD L. PANTON (Texas, University, Austin) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by Lockheed Advanced Aeronautics Co. and General Dynamics Corp. refs
(AIAA PAPER 89-0193)

Strong vortices above delta wings break down at high angle-of-attack. Vortex breakdown is sensitive to the exact nature of the vortex structure and to the flow field in which the vortex is embedded. Mathematically, a uniform symmetric isolated vortex can be completely prescribed by radial profiles of total pressure and of stream-wise vorticity. The subject of this paper is to alter these profiles and observe the effect on vortex breakdown. The total pressure was changed by adding friction to the flow as the fluid crosses the leading edge. Three wings with different friction were tested in a water channel. The vorticity distribution was changed by increasing the sweep angle of the apex region. Six plan forms with a variety of apex contours were tested. The vortex breakdown position as a function of angle-of-attack for each wing is reported. Friction always caused breakdown to occur earlier, that is at a lower angle-of-attack. An extended apex delayed breakdown. The maximum delay was 10 degrees. Author

A89-25169*# Notre Dame Univ., IN.
THE SEPARATED FLOW FIELD ON A SLENDER WING UNDERGOING TRANSIENT PITCHING MOTIONS
S. A. THOMPSON, S. M. BATILL, and R. C. NELSON (Notre Dame, University, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. Research sponsored by the University of Notre Dame. refs
(Contract NAG1-727)
(AIAA PAPER 89-0194)

The flow field surrounding a delta wing undergoing a transient pitching motion was studied experimentally. Of particular importance was the location of the leading edge vortices over the surface of the wing. The study was conducted on a 70-deg sweep flat-plate delta wing pitched about its one-half chord position. It is found that the maximum pitch rate is the key factor involved in the amount of lag experienced by the vortex breakdown during the transient pitching motion. K.K.

A89-25170*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL SIMULATION OF VORTEX UNSTEADINESS ON SLENDER BODIES OF REVOLUTION AT LARGE INCIDENCE
LEWIS B. SCHIFF, DAVID DEGANI (NASA, Ames Research Center, Moffett Field, CA), and SHARAD GAVALI (Amdahl Corp., Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0195)

Time-accurate, fine-grid Navier-Stokes solutions were obtained for flow over a slender ogive-cylinder body of revolution at angles of attack ranging from 10 deg to 40 deg. The results indicate the progressive growth of crossflow separation and the development of the leeward side vortex pattern with increasing incidence. The computed flows show good agreement with experimental measurements. As the angle of attack was increased, the flows become less damped, and at 40 deg a nonsteady flow exhibiting self-sustained fluctuations was observed. The nonsteadiness was linked to the presence of small-scale three-dimensional vortices moving along the primary surfaces of crossflow separation. The behavior of the fluctuations with incidence parallels the trend observed in experiments. Author

A89-25172#

ESTIMATES OF OXIDES OF NITROGEN FORMED IN AN INLET AIR STREAM FOR HIGH MACH NUMBER FLIGHT CONDITIONS

L. M. CHIAPPETTA and J. J. SANGIOVANNI (United Technologies Research Center, East Hartford, CT) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by United Technologies Corp. refs
(AIAA PAPER 89-0197)

Estimates of oxides of nitrogen formed in the inlet air stream were made for the forebody and internal sections of a generic inlet operating at high-speed flight conditions. Computational fluid dynamics analyses were used to compute typical inlet flow fields. Oxides of nitrogen levels were calculated using these flow fields together with a reaction rate mechanism and a chemical kinetics code. It was found that significant amounts of these species are produced only in a small region of the air flow captured by the inlet and located near its surfaces. Author

A89-25174*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

A SET OF STRONGLY COUPLED, UPWIND ALGORITHMS FOR COMPUTING FLOWS IN CHEMICAL NONEQUILIBRIUM

GREGORY A. MOLVIK (NASA, Ames Research Center, Moffett Field, CA) and CHARLES L. MERKLE (Pennsylvania State University, University Park) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 21 p. refs
(Contract NCC2-498)
(AIAA PAPER 89-0199)

Two new algorithms have been developed to predict the flow of viscous, hypersonic, chemically reacting gases over three-dimensional bodies. Both take advantage of the benefits of upwind differencing, Total Variation Diminishing (TVD) techniques and of a finite-volume framework, but obtain their solution in two separate manners. The first algorithym is a time-marching scheme, and is generally used to obtain solutions in the subsonic portions of the flow field. The second algorithm is a much less expensive, space-marching scheme and can be used for the computation of the larger, supersonic portion of the flow field. Both codes compute their interface fluxes with a new temporal Riemann solver and the resulting schemes are made fully implicit including the chemical source terms. Author

A89-25178#

PREDICTION OF 3D MULTI-STAGE TURBINE FLOW FIELD USING A MULTIPLE-GRID EULER SOLVER

RON-HO R. NI and JEFFREY C. BOGOIAN (United Technologies Corp., Engineering Div., East Hartford, CT) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0203)

A three-dimensional Euler solver used for the prediction of flow fields through turbomachinery cascades is described. It is based upon the solution algorithm of the explicit multiple-grid scheme for solving the Euler equations presented by Ni (1982). Both the numerical equations for updating the solution at interior nodes and the method for implementing the boundary conditions are given in detail. Two sets of results from turbine flow applications, including a two-stage high pressure turbine, are shown to demonstrate the capability of the Euler solver. Author

A89-25179#

ADAPTIVE GRID EMBEDDING NAVIER-STOKES TECHNIQUE FOR CASCADE FLOWS

ROGER L. DAVIS and JOHN F. DANNENHOFFER, III (United Technologies Research Center, East Hartford, CT) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. Research supported by United Technologies Corp. refs
(AIAA PAPER 89-0204)

A new two-dimensional adaptive grid embedding technique for the efficient and accurate calculation of the Navier-Stokes equations is presented. Steady-state solutions are computed using an explicit, finite volume, time marching technique in which global and embedded meshes are coupled via a multiple-grid algorithm. Solutions are presented for inviscid as well as turbulent viscous flows through quasi-three-dimensional turbomachinery cascades demonstrating that the current procedure can accurately and efficiently track complex flows with multiple length scale phenomena such as shocks, separated flows, shock/boundary layer interactions, trailing edge base flows, and wakes. Author

A89-25182#

EVALUATION OF AN OH GRID FORMULATION FOR VISCOUS CASCADE FLOWS

DAESUNG LEE and CHARLES J. KNIGHT (Avco Research Laboratory, Inc., Everett, MA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research sponsored by Textron Lycoming's Research and Development Program. refs
(AIAA PAPER 89-0207)

A zonal, mixed topology code has been evolved for steady viscous flow in three-dimensional linear cascades. It is based on the scalar or diagonalized form of approximate factorization and features fully implicit coupling between zones. A q-omega turbulence model is used as in prior work, with low Reynolds number source terms allowing sublayer resolution to y(+) of about 1. Detailed comparisons are given for both H and O-H grid topologies, considering two- and three-dimensional configurations. This includes a reexamination of heat transfer predictions for the Langston cascade, and trends in predicted boundary layer transition. Author

A89-25184#

AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF A BASE CAVITY ON THE NEAR-WAKE FLOWFIELD OF A BODY AT SUBSONIC AND TRANSONIC SPEEDS

R. W. KRUISWYK and J. C. DUTTON (Illinois, University, Urbana) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract DAAL03-87-K-0010)
(AIAA PAPER 89-0210)

An experimental investigation has been conducted to study the effects of a base cavity on the near-wake flowfield of a slender, two-dimensional body in the subsonic and transonic speed ranges. Three base configurations were investigated and compared: a blunt base, a shallow rectangular cavity base of depth equal to one-half the base height, and a deep rectangular cavity base of depth equal to one base height. Each configuration was studied at three freestream Mach numbers, ranging from the low to high subsonic range. Schlieren photographs revealed that the basic qualitative structure of the vortex street was unmodified by the presence of a base cavity. However, the vortex street was weakened by the base cavity, apparently due to enhanced fluid mixing occurring at the entrance of the cavity. Author

A89-25186#

MODIFICATION OF COMPRESSIBLE TURBULENT BOUNDARY LAYER STRUCTURES BY STREAMLINED DEVICES

G. A. GEBERT and H. M. ATASSI (Notre Dame, University, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0212)

An analysis is presented for the mechanism by which streamlined devices affect the structures of turbulent compressible boundary layers. The analysis is based on the rapid distortion approximation of turbulence and unsteady aerodynamic theory. The fluctuating velocity downstream of the device is calculated throughout the boundary layer for two-dimensional and three-dimensional harmonic disturbances. The results show that such devices suppress the wall normal fluctuating velocity for a range of eddy structures depending upon the device chord length, its height, and the flow Mach number. Criteria for the effectiveness of a device are thus established based on the magnitude of suppression and the breadth of the frequency range. At higher

Mach number flows the degree of suppression can be greater, but the frequency range for maximum suppression is narrower indicating a higher selectivity for the device. Devices in tandem arrangement produce a definite broadening of the maximum suppression range. Author

A89-25188#

OSCILLATORY FLOW FIELD SIMULATION IN A BLOW-DOWN WIND TUNNEL AND THE PASSIVE SHOCK WAVE/BOUNDARY LAYER CONTROL CONCEPT

HENRY T. NAGAMATSU (Rensselaer Polytechnic Institute, Troy, NY), GREGORY A. NYBERG (McDonnell Aircraft Co., Saint Louis, MO), and TODD J. MITTY AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. Research supported by the U.S. Army. refs
(AIAA PAPER 89-0214)

An apparatus for simulating unsteady helicopter rotor-tip Mach numbers over the upper surface of a Bell FX69-H-098 airfoil section with both solid and porous surfaces was implemented in the R.P.I. 3 x 8-inch Transonic Wind Tunnel. Design and construction of the test facility is discussed, as well as methods of data acquisition. Bottom-wall Mach numbers ranged from 0.45 to 0.85, and oscillation frequencies ranged from 5 Hz to 10 Hz. Results obtained for the solid and porous surfaces from the oscillating wind tunnel operation include: airfoil surveys, cavity pressures, wake total pressure recovery surveys, and section drag coefficients. This work is a fundamental foundation for future investigations into rotor simulation in a blow-down wind tunnel and unsteady flow effects in both shock wave/boundary layer interactions and the passive drag reduction concept. Author

A89-25207*# Vigyan Research Associates, Inc., Hampton, VA.

THREE-DIMENSIONAL FLOW SIMULATION ABOUT THE AFE VEHICLE IN THE TRANSITIONAL REGIME

M. CEVDET CELENLIGIL (Vigyan Research Associates, Inc., Hampton, VA), JAMES N. MOSS, and ROBERT C. BLANCHARD (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0245)

The direct-simulation Monte Carlo technique is used to analyze the hypersonic rarefied flow about the three-dimensional NASA Aeroassist Flight Experiment vehicle. Results are given for typical transitional flows encountered during the vehicle's atmospheric entry from altitudes of 200-100 km with an entry velocity of 9.9 km/s. It is found that dissociation is important at altitudes of 110 km and below, and that transitional effects are significant even at an altitude of 200 km. R.R.

A89-25219*# Queensland Univ., Brisbane (Australia).

THERMODYNAMICS AND WAVE PROCESSES IN HIGH MACH NUMBER PROPULSIVE DUCTS

R. J. STALKER (Queensland, University, Brisbane, Australia) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 27 p. Research supported by the Australian Grants Scheme. refs
(Contract NAGW-674)
(AIAA PAPER 89-0261)

Analysis of the flow in a propulsive duct indicates that, at high Mach numbers, the thermodynamic energy of the fluid is delivered directly into compression and expansion waves. The importance of the resulting wave phenomena is explored by considering the net thrust delivered by a two dimensional convergent-divergent duct with a simplified, planar heat addition zone. It is found that net thrust is reduced when operating at other than the design Mach number, an effect which is most severe for Mach numbers exceeding the design value. An idealized model is developed, involving a self-induced heat injection cycle, and it is seen that the waves produced by this cycle can be the dominant agency in producing thrust. Author

A89-25222#

TRANSONIC EULER SOLUTIONS ON MUTUALLY INTERFERING FINNED BODIES

LAWRENCE E. LIJEWSKI (USAF, Armament Laboratory, Eglin AFB, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0264)

The ability of an Euler code to predict mutual aerodynamic interference in the transonic regime was investigated. One, two, and three body combinations of a cruciform finned configuration were examined at Mach numbers from 0.80 to 1.20 and angles of attack up to ten degrees. Predicted surface pressure distributions were compared with wind tunnel data for the first time on three finned bodies with success. The Euler code was found to predict body pressures well in many interference regions, although shock location often was less accurate due to viscous effects in the strongest interference flowfield near Mach 1. Rigid body physics of the three body combination was investigated from integrated pressure distributions. Force and moment behavior was found to be strongly dependent upon Mach nimber. Author

A89-25223*# Vigyan Research Associates, Inc., Hampton, VA.

UPWIND NAVIER-STOKES SOLUTIONS FOR LEADING-EDGE VORTEX FLOWS

C.-H. HSU (Vigyan Research Associates, Inc., Hampton, VA) and C. H. LIU (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NAS1-18585)
(AIAA PAPER 89-0265)

An incompressible Navier-Stokes solver using an upwind finite-difference algorithm is employed to investigate low-speed, three-dimensional, laminar, leading-edge vortex flows over three round-edged low-aspect-ratio wings. The effects of grid density, Reynolds number, and wing planform on the flowfield structures and integral values are studied. Computed results show good qualitative and quantitative agreement with the available experimental data. Author

A89-25224*# Analytical Services and Materials, Inc., Hampton, VA.

EVALUATION OF AN ANALYSIS METHOD FOR LOW-SPEED AIRFOILS BY COMPARISON WITH WIND TUNNEL RESULTS

RAQUEL EVANGELISTA and CHANDRA S. VEMURU (Analytical Services and Materials, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAS1-18235; NAS1-18599)
(AIAA PAPER 89-0266)

Results obtained by the airfoil analysis method of Drela (1980) for three airfoils are compared with wind tunnel test results. The method is shown to be accurate in predicting the aerodynamic characteristics of low-speed airfoils in the chord Reynolds number range from 200,000 to 3 million. It is noted that a high value for the transition criterion was necessary to accurately study the case of laminar separation. R.R.

A89-25225#

HIGH-LIFT AERODYNAMICS FOR TRANSPORT AIRCRAFT BY INTERACTIVE EXPERIMENTAL AND THEORETICAL TOOL DEVELOPMENT

J. SZODRUCH and H. SCHNIEDER (Messerschmitt-Boelkow-Blohm GmbH, Bremen, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th Reno, NV, Jan. 9-12, 1989. 12 p. Research supported by BMFT. refs
(AIAA PAPER 89-0267)

Advanced high-lift systems design for transport aircraft requires an interactive effort of experiment and theoretical aerodynamics. Selected two- and three-dimensional experiments have been performed according to the wind tunnel program executed during aircraft development. Detailed boundary layer experiments on all configurations were used to improve the modeling of the flow physics and to compare and validate CFD codes. A new two-dimensional CFD method yields improved results even at complex high-lift flow fields. The complementary work of CFD and experiment in future development of high-lift systems is discussed. Author

A89-25226#
ANALYSIS OF THREE-DIMENSIONAL AEROSPACE CONFIGURATIONS USING THE EULER EQUATIONS
N. KROLL, C. C. ROSSOW, S. SCHERR, J. SCHOENE, and G. WICHMANN (DFVLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. Research supported by CNES. refs
(AIAA PAPER 89-0268)

This paper describes the analysis of three-dimensional flow fields around complex aerospace configurations using a method for solving the Euler equations. The numerical procedure is based on a finite-volume method with cell-vertex discretization using an explicit Runge-Kutta time-stepping scheme. The application of the code to flow around four different types of aerospace configurations is presented: (1) the influence of a body on a wing under transonic cruise conditions, (2) the vortex-vortex interaction when a canard is added to a delta wing, (3) the performance of sharp-nosed vehicles in supersonic flowfields, and (4) the flow around a realistic reentry vehicle with supersonic outflow Mach number. Author

A89-25227#
LARGE-ANGLE-OF-ATTACK VISCOUS HYPERSONIC FLOWS OVER COMPLEX LIFTING CONFIGURATIONS
BILAL A. BHUTTA and CLARK H. LEWIS (VRA, Inc., Blacksburg, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 27 p. refs
(AIAA PAPER 89-0269)

A new three-dimensional parabolized Navier-Stokes scheme for studying perfect gas and equilibrium-air viscous hypersonic flows around complex three-dimensional configurations has been developed. This scheme is unconditionally timelike in the subsonic and supersonic flow regions and does not require any sublayer approximation. A predictor-corrector solution scheme and different grid-generation algorithms are used together with an implicit shock-fitting scheme to predict the three-dimensional flowfields around some typical lifting configurations. A new fourth-order accurate smoothing approach is used to enhance solution accuracy. The results show that substantial three-dimensional crossflow effects exist in the predicted flowfields, and that for three-dimensional geometries with convex cross sections, a slightly modified variation of a body-normal grid generation scheme shows the best characteristics. C.D.

A89-25228*# Old Dominion Univ., Norfolk, VA.
EFFECT OF NOSE BLUNTNESS ON FLOW FIELD OVER SLENDER BODIES IN HYPERSONIC FLOWS
D. J. SINGH, S. N. TIWARI (Old Dominion University, Norfolk, VA), and A. KUMAR (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0270)

A parametric study has been conducted to determine the effects of nose bluntness on the enire flowfield over slender bodies under different hypersonic freestream conditions. The analysis is carried out for air under perfect- and equilibrium-gas assumptions. The analyses range from a few simplified approaches to the solution of the complete Navier-Stokes equations. Specific results obtained for spherically blunted cones and ogives demonstrate that there are significant differences in flowfield and surface quantities between sharp and blunted bodies. Depending upon the flow conditions and geometry, the differences are found to persist as far as 260 nose radii downstream. Author

A89-25230#
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) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs
(AIAA PAPER 89-0273)

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 x 10 to the 6th at angles of attack up to 50 degrees. Numerical results are compared with experimental data obtained from the hypersonic wind tunnel tests at NAL. Through these comparisons, it is demonstrated that the present TVD Navier-Stokes code has the excellent capabilities for evaluating total aerodynamic performance and investigating the aerodynamic heating, which are of great significance in the design of a space plane configuration. Author

A89-25231#
AN IMPLICIT FLUX-VECTOR SPLITTING SCHEME FOR THE COMPUTATION OF VISCOUS HYPERSONIC FLOW
D. HAENEL and R. SCHWANE (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0274)

An upwind relaxation method based on flux-vector splitting for the Euler terms, is used for the solution of the three-dimensional Navier-Stokes equations. The numerical method was adopted for the conditions of hypersonic, viscous flows to achieve sufficient convergence and accuracy there. The use of the critical speed of sound for sonic switching and rearrangements of the implicit solution procedure have made the algorithm more robust even for very small values of density or temperature. The spatial accuracy in viscous regions could be improved by using a new split energy flux, and by one-sided upwinding of the tangential velocity in the flux-vector splitting formulation. Applications are shown for hypersonic flows around blunt bodies. Author

A89-25232*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPARISON OF LDV MEASUREMENTS AND NAVIER-STOKES SOLUTIONS IN A TWO-DIMENSIONAL 180-DEGREE TURN-AROUND DUCT
DARYL J. MONSON, H. LEE SEEGMILLER (NASA, Ames Research Center, Moffett Field, CA), and PAUL K. MCCONNAUGHEY (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0275)

Results from an experimental and numerical investigation of turbulent subsonic flow inside a two-dimensional, strongly curved, 180 deg turn-around duct are presented. Data measured with a two-component, two-color laser Doppler velocimeter include profiles of mean axial velocity and local flow angle. Static pressure distributions are also measured. Results are obtained at a Mach number of 0.1, and at Reynolds numbers of 100,000 and a million based on channel height. Numerical calculations are performed using the incompressible Navier-Stokes equations with a Prandtl mixing length zero-equation turbulence model modified for internal flows. Theory and experiment are compared to evaluate the ability of the turbulence model to predict this class of internal flows with strong curvature. Author

A89-25237#
VISCOUS SWIRLING NOZZLE FLOW
CHAU-LYAN CHANG and CHARLES L. MERKLE (Pennsylvania State University, University Park) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by USAF. refs
(AIAA PAPER 89-0280)

Swirling viscous flow in transonic and supersonic propulsion nozzles has been investigated numerically. Central-differenced ADI and flux-vector split upwind algorithms are utilized to solve the thin-layer Navier-Stokes equations for axisymmetric two-dimensional flows with swirl. The effects of swirl on viscous flowfields are studied for nozzles with mild to high expansion ratios. Both flowfield details and integral nozzle performance are compared to previously published inviscid calculations. The results show that the presence of swirl has a significant effect on the flowfield as well as nozzle performance, especially for plug nozzles and high expansion ratio contoured nozzles. Author

A89-25238#
THREE-DIMENSIONAL HYBRID FINITE VOLUME SOLUTIONS TO THE EULER EQUATIONS FOR SUPERSONIC/HYPERSONIC AIRCRAFT
M. J. SICLARI (Grumman Corporate Research Center, Bethpage, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 19 p. refs
(AIAA PAPER 89-0281)
A new, efficient numerical scheme is presented to solve the Euler equations about three-dimensional surfaces for supersonic flows. The unsteady Euler equations are cast in a spherical coordinate system. A node centered, physical space, finite volume, central difference scheme is applied to the crossflow mesh on spherical surfaces. A fully implicit marching scheme is then used to solve for the steady state solution in each spherical crossflow plane using an unsteady, explicit, pseudo-time Runge-Kutta integration scheme. The marching derivatives are treated implicitly using a finite difference upwind discretization in the computational space. This method has been found to be successful in treating both wings and bodies. The present paper extends the application of this method to aircraft configurations with and without inlets. The computed results for four aircraft configurations are presented illustrating both attached and separated flows. Author

A89-25242*# Stanford Univ., CA.
THE EFFECT OF MACH NUMBER ON THE STABILITY OF A PLANE SUPERSONIC WAVE
JACQUELINE H. CHEN, BRIAN J. CANTWELL (Stanford University, CA), and NAGI N. MANSOUR (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 23 p. Research sponsored by Sandia National Laboratories. refs
(AIAA PAPER 89-0285)
The influence of compressibility on the mechanisms governing the various stages of transition in a supersonic wake is investigated. Results from linear stability theory are used to provide physical insights into the observed reduction in growth rate at high Mach numbers. A newly developed hybrid algorithm is used to solve the compressible inviscid linear disturbance equations. Growth rates for both antisymmetric and symmetric modes of two-dimensional and oblique waves are computed for a wide range of Mach numbers. Results from two and three-dimensional direct numerical simulations of a forced compressible time-developing wake are presented in order to understand the nonlinear stages of transition at high Mach numbers. Observed nonlinear growth rate comparisons are made for wakes at two different Mach numbers. The reduction in growth rate at high Mach numbers is explained by examining contour plots of baroclinic torques and the product of dilatation and vorticity. C.D.

A89-25244#
ON THE STRUCTURE OF TWO- AND THREE-DIMENSIONAL SEPARATION
LAURA L. PAULEY (Pennsylvania State University, University Park), PARVIZ MOIN, and WILLIAM C. REYNOLDS (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract N00014-84-K-0232)
(AIAA PAPER 89-0287)
The separation of a laminar boundary layer under the influence of an external adverse pressure gradient was studied in both two and three dimensions. The unsteady incompressible Navier-Stokes equations were solved using a fractional time-step method. In two dimensions, a strong pressure gradient created periodic shedding from the leading separation. A criterion for shedding was established in terms of a general nondimensional pressure gradient. Three-dimensional separation was studied by impulsively applying a three-dimensional adverse pressure gradient to a two-dimensional boundary layer. The separation passed through several different topologies before becoming fully developed. When instantaneous streamlines were used to study the flow, a cross-stream vortex was seen to bend at the centerline and lift away from the wall as the separation developed. Author

A89-25245#
UNSTEADY, SEPARATED FLOW BEHIND AN OSCILLATING, TWO-DIMENSIONAL FLAP
CURTIS F. NELSON, DENNIS J. KOGA, and JOHN K. EATON (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract AF-AFOSR-86-0159)
(AIAA PAPER 89-0288)
Unsteady, separated flow produced behind a two-dimensional, lifting flap was examined in detail using phase-averaged LDA and surface pressure measurements. Both sinusoidal oscillations with reduced frequencies in the range 0.025 to 0.06 and pitch-and-hold motions of the flap were investigated. Phase-averaged vorticity was calculated from the velocity data and the development of the unsteady vortex formed downstream of the flap was analyzed. The dominant mechanism of vorticity transport is shown to be convective, justifying the use of discrete-vortex computations for modeling this flow. Author

A89-25246*# Purdue Univ., West Lafayette, IN.
OSCILLATING AERODYNAMICS AND FLUTTER OF AN AERODYNAMICALLY DETUNED CASCADE IN AN INCOMPRESSIBLE FLOW
HSIAO-WEI D. CHIANG and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. Research sponsored by NASA. refs
(AIAA PAPER 89-0289)
A mathematical model is developed and utilized to demonstrate the enhanced torsion mode stability associated with alternate blade circumferential aerodynamic detuning of a rotor operating in an incompressible flow field. The oscillating cascade aerodynamics, including steady loading effects, are determined by developing a complete first order unsteady aerodynamic analysis. An unsteady aerodynamic influence coefficient technique is then utilized, thereby enabling the stability of both conventional uniformly spaced rotors and detuned nonuniform circumferentially spaced rotors to be determined. To demonstrate the enhanced flutter aeroelastic stability associated with this aerodynamic detuning mechanism, this model is applied to a baseline unstable rotor with a Gostelow flow geometry. Author

A89-25248#
VORTICAL FLOWS PAST NORMAL PLATE AND SPOILER OF TIME DEPENDENT HEIGHT
KALPANA CHAWLA and CHUEN-YEN CHOW (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract F49620-88-C-0098)
(AIAA PAPER 89-0291)
Studied in this paper are unsteady, two-dimensional, vortical flows past normal plates and flat-plate airfoil with a spoiler mounted on the upper surface at the mid-chord position. The height of the plate or that of the spoiler may either be a constant or a sinusoidal function of time. These flow problems are solved using the discrete vortex method. For an accelerating flow past a normal plate of constant height, the computed time history of vortical development agrees very well with that photographed in the laboratory. For the airfoil configuration, the effects of spoiler oscillation on vortical structures as well as on unsteady lift and drag are examined numerically. Author

A89-25252*# Stanford Univ., CA.
LOW SPEED WIND TUNNEL INVESTIGATION OF THE FLOW ABOUT DELTA WING, OSCILLATING IN PITCH TO VERY HIGH ANGLE OF ATTACK
MOHAMMAD-AMEEN M. JARRAH (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(Contract AF-AFOSR-84-0099; NCA2-287)
(AIAA PAPER 89-0295)
Six-component airload histories were obtained for models of aspect ratio 1, 1.5, and 2. Examples are given from data obtained over a range of 'reduced frequency' parameters from 0.01 to 0.08. They include the unsteady response of the leading-edge vortices, as evidenced both by the time-dependent airloads and motion pictures of smoke released from the leading edge and illuminated by a thin sheet of laser light. K.K.

A89-25253#
MOVING SURFACE BOUNDARY-LAYER CONTROL AS APPLIED TO TWO-DIMENSIONAL AIRFOILS
V. J. MODI, F. MOKHTARIAN, M. S. U. K. FERNANDO, and T. YOKOMIZO (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NSERC-A-2181)
(AIAA PAPER 89-0296)
The concept of moving surface boundary layer control, as applied to a Joukowsky airfoil, is studied. The moving surface was provided by rotating cylinders located at the leading edge and upper surface of the airfoil. It is found that the concept can provide a substantial increase in lift and a delay in stall. K.K.

A89-25273#
COMPUTATIONS OF 3D VISCOUS FLOWS IN ROTATING TURBOMACHINERY BLADES
D. CHOI and C. J. KNIGHT (Avco Research Laboratory, Inc., Everett, MA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research sponsored by Textron Lycoming's Research and Development Program. refs
(AIAA PAPER 89-0323)
A thin-layer Navier-Stokes code has been developed to analyze three-dimensional viscous flowfields in rotating turbomachinery blades. This code solves mass, momentum, and energy conservation equations plus two turbulence-model equations, based on rotating curvilinear coordinates, using a time-asymptotic method for steady-state solutions in the relative frame. It employs scalar implicit approximate factorization in time and a finite-volume formulation with second-order upwind TVD differencing in space. For turbulence effects, a two-equation q-omega turbulence model has been used with low-Reynolds-number terms allowing sublayer resolution down to y(+) of about 1. The code has been validated by considering experimental studies on a subsonic centrifugal impeller and a transonic axial compressor. Author

A89-25274*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
GRID REFINEMENT STUDIES OF TURBINE ROTOR-STATOR INTERACTION
N. K. MADAVAN, M. M. RAI (NASA, Ames Research Center, Moffett Field, CA), and S. GAVALI (Amdahl Corp., Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. Research supported by the U.S. Navy. refs
(AIAA PAPER 89-0325)
Results from a three-dimensional, time-accurate Navier-Stokes simulation of rotor-stator interaction in an axial turbine stage are presented. The present study uses a fine grid in the spanwise direction to better resolve endwall and tip cllearance effects and complements coarse-grid calculations that were reported earlier. A realistic turbine stage with 22 stator vanes and 28 rotor blades is simulated as a single-stator, single-rotor airfoil combination with the stator geometry modified to properly account for blockage effects. This is in contrast to the earlier coarse-grid calculations where the rotor geometry was modified. The improved grid resolution and the unmodified rotor geometry result in a more accurate simulation of the flow field, particularly in the rotor channel where the interaction effects are more severe. The numerical results are compared to experimental data wherever possible and to earlier calculations. Author

A89-25276#
MEASUREMENT AND MODELLING OF TURBULENT SPOT GROWTH ON A GAS TURBINE BLADE
D. A. ASHWORTH (Rolls-Royce, PLC, Derby, England) and J. E. LAGRAFF (Syracuse University, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract AF-AFOSR-85-0295)
(AIAA PAPER 89-0328)
The natural transition process on the suction surface of a two-dimensional cascade transonic gas turbine rotor blade has been experimentally investigated, and a new method has been used for the numerical modeling of the development of turbulent spots within a laminar boundary layer. The results show that the unsteady heat transfer data are consistent with Emmons'turbulent spot model of transition and with many low speed observations of spot growth and convection rates even at the transonic condition of these tests. Furthermore, the numerical model based on the Emmons physical model produces results which qualitatively reproduce the unsteady heat transfer behavior and can be used to fit measured intermittency data from other published work. Author

A89-25284*# Vigyan Research Associates, Inc., Hampton, VA.
NAVIER-STOKES SOLUTIONS FOR VORTICAL FLOWS OVER A TANGENT-OGIVE CYLINDER
PETER-M. HARTWICH (Vigyan Research Associates, Inc., Hampton, VA) and R. M. HALL (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAS1-17919)
(AIAA PAPER 89-0337)
Reynolds number (Re) effects on low-speed vortical flows over a 3.5 caliber tangent-ogive cylinders at two angles of attack (alpha = 20 and alpha = 30 degrees) are computationally assessed for Re(D) = 0.2 -3.0 million (D: maximum diameter). The flow field results are steady-state solutions to the three-dimensional, incompressible Navier-Stokes equations in their thin-layer approximation. Using a properly modified algebraic turbulence model, the numerical results are in good to excellent agreement with experiments. Author

A89-25285*# Vigyan Research Associates, Inc., Hampton, VA.
NAVIER-STOKES SOLUTIONS ABOUT THE F/A-18 FOREBODY-LEX CONFIGURATION
FARHAD GHAFFARI, BRENT L. BATES (Vigyan Research Associates, Inc., Hampton, VA), JAMES M. LUCKRING, and JAMES L. THOMAS (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 24 p. refs
(Contract NAS1-17919)
(AIAA PAPER 89-0338)
Three-dimensional viscous flow computations are presented for the F/A-18 forebody-LEX geometry. Solutions are obtained from an algorithm for the compressible Navier-Stokes equations which incorporates an upwind-biased, flux-difference-splitting approach along with longitudinally-patched grids. Results are presented for both laminar and fully turbulent flow assumptions and include correlations with wind tunnel as well as flight-test results. A good quantitative agreement for the forebody surface pressure distribution is achieved between the turbulent computations and wind tunnel measurements at a free-stream Mach number of 0.6. The computed turbulent surface flow patterns on the forebody qualitatively agree well with in-flight surface flow patterns obtained on an F/A-18 aircraft at a free-stream Mach number of 0.34. Author

A89-25286*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

NUMERICAL SIMULATION OF HIGH-INCIDENCE FLOW OVER THE F-18 FUSELAGE FOREBODY

LEWIS B. SCHIFF, RUSSELL M. CUMMINGS, REESE L. SORENSON, and YEHIA M. RIZK (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0339)

As part of the NASA High Alpha Technology Program, fine-grid Navier-Stokes solutions have been obtained for flow over the fuselage forebody and wing leading-edge extension of the F/A-18 High Alpha Research Vehicle at large incidence. The resulting flows are complex and exhibit cross-flow separation from the sides of the forebody and from the leading-edge extension. A well-defined vortex pattern is observed in the leeward-side flow. Results obtained for laminar flow show good agreement with flow visualizations obtained in ground-based experiments. Further, turbulent flows computed at high-Reynolds-number flight-test conditions show good agreement with surface and off-surface visualizations obtained in flight. Author

A89-25288*# Stanford Univ., CA.

NUMERICAL STUDY OF THE EFFECT OF TANGENTIAL LEADING EDGE BLOWING ON DELTA WING VORTICAL FLOW

DAVID T. YEH, DOMINGO A. TAVELLA, LEONARD ROBERTS (Stanford University, CA), and KOZO FUJII (Tokyo, University, Sagamihara, Japan) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NCC2-341)
(AIAA PAPER 89-0341)

A numerical simulation of tangential blowing along the leading edge of a delta wing is analyzed as a means of controlling the position and strength of the leading-edge vortices. The computation is done by numerical solutions of the three-dimensional thin-layer Navier-Stokes equations. Numerical results are shown to compare favorably with experimental measurements. It is found that the use of tangential leading-edge blowing at low to moderate angles of attack tends to reduce the pressure peaks associated with leading-edge vortices and to increase the suction peak around the leading edge, such that the integrated value of the surface pressure remains about the same. Author

A89-25298#

MACH NUMBER DEPENDENCE OF FLOW SEPARATION INDUCED BY NORMAL SHOCK-WAVE/TURBULENT BOUNDARY-LAYER INTERACTION AT A CURVED WALL

P. DOERFFER (Polska Akademia Nauk, Instytut Maszyn Przeplywowych, Gdansk, Poland) and U. DALLMANN (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0353)

The topological flow structures which are induced by a normal shock-wave/turbulent boundary-layer interaction at a Reynolds number of 55,000 and within a Mach number range of 1.35-1.47 are studied experimentally. At a Mach number of 1.35, there are already separated zones adjacent to the side walls. It is found that, for decreasing Mach number value, the length of the time-averaged reversed flow region along the wall center line decreases. K.K.

A89-25299#

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

M. SAJBEN, M. J. MORRIS, T. J. BOGAR, and J. C. KROUTIL (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 18 p. refs
(AIAA PAPER 89-0354)

A steady, nearly two-dimensional interaction of a normal shock with a turbulent boundary layer over a flat surface is investigated experimentally. The approach Mach number is 1.34 and the Reynolds number based on the momentum thickness of the approach boundary layer is 14,600. The experiment is distinguished from similar past studies by the existence of an adverse pressure gradient region downstream of the shock and by a relatively high ratio of the approach boundary layer thickness to the channel height. This combination of features introduces significant differences over interactions taking place in constant-area channels. The time-mean and fluctuating velocity field was explored in detail using laser Doppler velocimetry. Spatial distributions of turbulence kinetic energy, shear stress, and turbulence production are presented. Author

A89-25300#

AN LDV INVESTIGATION OF A MULTIPLE NORMAL SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTION

BRUCE F. CARROLL (Florida, University, Gainesville) and J. CRAIG DUTTON (Illinois, University, Urbana) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0355)

The interaction of a multiple normal shock with a turbulent boundary layer in a rectangular duct has been investigated experimentally using a two-component LDV. Just upstream of the shock system the Mach number was 1.61; the unit Reynolds number was 30 x 10 to the 6th/m; the boundary-layer thickness was 5.4 mm; and the confinement level as characterized by the ratio of the boundary layer thickness to the duct half height was 0.32. The results presented here identify the fluid-dynamic mechanisms involved in the reacceleration process following each shock in the multiple shock system. Author

A89-25301#

AN EXPLORATORY STUDY OF CORNER BLEED ON A FIN GENERATED THREE-DIMENSIONAL SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTION

S. M. BOGDONOFF (Princeton University, NJ) and A. STEVEN TOBY AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract F49620-86-C-0094)
(AIAA PAPER 89-0356)

The effect of a gap at the fin-plate junction was examined for a 20 deg fin-turbulent boundary layer interaction at M = 2.95. Detailed surface pressure distributions and surface flow visualization were used . The results show no sudden changes in the flow field as the gap was varied from zero to more than one-half the boundary layer thickness. The initial part of the interaction moved downstream, but little effect was found downstream of the inviscid shock wave location. Flow-field probing will be required to define any flow-field structural changes. Author

A89-25306*# Vigyan Research Associates, Inc., Hampton, VA.

NUMERICAL SOLUTIONS ON A PATHFINDER AND OTHER CONFIGURATIONS USING UNSTRUCTURED GRIDS AND A FINITE ELEMENT SOLVER

PARESH PARIKH, SHAHYAR PIRZADEH (Vigyan Research Associates, Inc., Hampton, VA), RAINALD LOHNER (George Washington University, Washington, DC), and CLYDE GUMBERT (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. Research supported by DNA, USAF, and U.S. Navy. refs
(Contract NAS1-18419; NAS1-18670)
(AIAA PAPER 89-0362)

A three-dimensional unstructured grid generator and a finite element Euler solver are described. The grid generator uses the advancing front concept, and the flow solver is based on the flux corrected transport ideas. Several examples of computed flows past complete three-dimensional configurations are presented to demonstrate the flexibility and robustness of the programs. Current items requiring further attention are identified, and the progress over the last year toward them is reported. Author

A89-25308*# Analytical Services and Materials, Inc., Hampton, VA.

APPLICATION OF DIRECT SOLVERS TO UNSTRUCTURED MESHES FOR THE EULER AND NAVIER-STOKES EQUATIONS USING UPWIND SCHEMES

V. VENKATAKRISHNAN (Analytical Services and Materials, Inc., Hampton, VA) and TIMOTHY J. BARTH (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0364)

The application of Newton iteration to inviscid and viscous airfoil calculations on unstructured meshes is examined. A cell-centered finite volume scheme is employed on an unstructured mesh consisting of triangles. Roe's flux difference splitting scheme is used to compute the inviscid fluxes. Higher order accuracy is achieved by an interpolation procedure that makes use of auxiliary gradients. The efficient solution of the sparse linear system of equations which arises upon linearization in time is addressed. Results are presented for inviscid and viscous test cases. The complications which arise due to the introduction of nonlinear limiters are addressed. Author

A89-25309#

ADAPTIVE H-REFINEMENT ON 3-D UNSTRUCTURED GRIDS FOR TRANSIENT PROBLEMS

RAINALD LOHNER (George Washington University, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by DNA, USAF, and U.S. Navy. refs
(AIAA PAPER 89-0365)

An adaptive finite element scheme for transient problems is presented. The classic h-enrichment/coarsening is employed in conjunction with a tetrahedral finite element discretization in three dimensions. A mesh change is performed every n timesteps, depending on the Courant-number employed and the number of 'protective layers' added ahead of the refined region. In order to simplify the refinement/coarsening logic and to be as fast as possible, only one level of refinement/coarsening is allowed per mesh change. A high degree of vectorizability has been achieved by pre-sorting the elements and then performing the refinement/coarsening groupwise according to the case at hand. Several examples involving shock-shock interactions and the impact of shocks on structures demonstrate the performance of the method, showing considerable savings in both CPU-time and storage for strongly unsteady flows. Author

A89-25314#

THE COMPRESSIBLE MIXING LAYER - LINEAR THEORY AND DIRECT SIMULATION

N. D. SANDHAM and W. C. REYNOLDS (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by USAF. refs
(AIAA PAPER 89-0371)

The paper presents results from a linear stability analysis for a wide variety of mixing layers, including low-speed layers with variable density and high Mach number mixing layers. It is found that three-dimensional modes are dominant in the high-speed mixing layer above a convective Mach number of 0.06. The results suggest that linear theory can be instrumental for investigating the compressible mixing layer. K.K.

A89-25315#

THE EFFECTS OF WALLS ON A COMPRESSIBLE MIXING LAYER

JEFFREY A. GREENOUGH, JAMES J. RILEY, MOELJO SOETRISNO, and D. SCOTT EBERHARDT (Washington, University, Seattle) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. Research supported by the Johns Hopkins University. refs
(Contract N00014-87-K-0174)
(AIAA PAPER 89-0372)

The stability of confined mixing layers is studied using both linear stability theory and direct numerical simulations. The stability theory is used to examine the linear stability of two-dimensional confined temporal mixing layers for both continuous and discontinuous mean velocity profiles. It is shown that there are two general types of instabilities: confined Kelvin-Helmholtz modes and supersonic wall modes. Furthermore, the relation between eigenfunction shape and physical properties is discussed for both types of modes. The nonlinear evolution of the two types of instabilities is studied using direct numerical simulation. The confined Kelvin-Helmholtz development shows a familiar vortex pairing mechanism plus an interesting nonlinear self-excitation of the third harmonic. The supersonic wall modes develop by a completely new mechanism wherein the role of shocks is important. With regard to the confined three-dimensional problem, the most unstable disturbances for supersonic relative Mach numbers are shown to be truly three-dimensional Kelvin-Helmholtz type instabilities in the cases considered. Author

A89-25317*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

DIRECT NUMERICAL SIMULATION OF COMPRESSIBLE FREE SHEAR FLOWS

SANJIVA K. LELE (NASA, Ames Research Center, Moffett Field; Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs
(AIAA PAPER 89-0374)

Direct numerical simulations of compressible free shear layers in open domains are conducted. Compact finite-difference schemes of spectral-like accuracy are used for the simulations. Both temporally-growing and spatially-growing mixing layers are studied. The effect of intrinsic compressibility on the evolution of vortices is studied. The use of convective Mach number is validated. Details of vortex roll up and pairing are studied. A simple explanation of the stabilizing effect of compressibility is offered. Acoustic radiation from vortex roll up, pairing and shape oscillations is studied and quantified. Author

A89-25319#

NUMERICAL SIMULATION OF THE GROWTH OF INSTABILITIES IN SUPERSONIC FREE SHEAR LAYERS

WEI TANG, NARAYANAN KOMERATH, and LAKSHMI N. SANKAR (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract N00014-87-K-0132)
(AIAA PAPER 89-0376)

The behavior of the initial region of a supersonic plane shear layer is analyzed through numerical solution of the 2-D Navier-Stokes equations, as well as the 3-D equations under the infinite span assumption. Two schemes are employed and compared: a 2nd order ADI procedure, as well as a modified McCormack scheme that is fourth order accurate in space and second order in time. Small amplitude oscillations in the normal velocity are found to grow as they convect downstream, and eventually lead to organized vortical structures. Normal velocity disturbances are found to be more efficient than streamwise or spanwise disturbances. The growth rate of these disturbances, as well as the intensity of velocity fluctuations, are found to decrease as the convective Mach number of the shear layer increases. The Mach number of the vortical structures with respect to the faster stream are found to be considerably less than the theoretical value of the convective Mach number. Author

A89-25326#

EFFECTS OF ENERGY RELEASE ON HIGH-SPEED FLOWS IN AN AXISYMMETRIC COMBUSTOR

K. KAILASANATH, J. H. GARDNER, E. S. ORAN, and J. P. BORIS (U.S. Navy, Naval Research Laboratory, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. Research sponsored by the U.S. Navy. refs
(AIAA PAPER 89-0385)

For the two reactive flow cases discussed in this paper, energy release substantially alters the flow field observed in the nonreactive flow simulations. In the first cycle after ignition, fluid expansion due to energy release quickly destroys the pattern of vortex mergings observed in the cold flow and a new pattern emerges that is dominated by a large vortex. In subsequent cycles, most of the energy release occurs after vortex mergings have produced this large vortex. Energy release in this large vortex is in phase with the pressure oscillation over a substantial region of the combustor and results in the observed amplification of the low-frequency oscillations and leads to combustion instability. The large pressure oscillation also modifies the vortex shedding process. The simulations also show that preenergy release chemistry does not play a dominant role in controlling combustion instabilities in the system considered. Author

A89-25328#
SUPERSONIC SUDDEN-EXPANSION FLOW WITH FLUID INJECTION - AN EXPERIMENTAL AND COMPUTATIONAL STUDY
S. M. CORREA and R. E. WARREN (GE Research and Development Center, Schenectady, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by the General Electric Co. refs
(AIAA PAPER 89-0389)

Nonreacting supersonic flow over a backward-facing step is studied, with and without the injection of air downstream of the step. The objectives are to assess a numerical scramjet combustor model in the relatively simple case of nonreacting flow, and to add to the database on supersonic sudden-expansion flow. The experiments are performed in a variable geometry Mach 1.8-4.0 windtunnel whose test-section measures 6 in x 6 in. Experimental data include Schlieren photography and wall-static pressures. The flow is characterized by minimal spreading of the injected fluid into the supersonic air stream. Author

A89-25363#
CONFLICTING STEPSIZE REQUIREMENTS FOR STABLE PNS COMPUTATIONS
D. D. CLINE and G. F. CAREY (Texas, University, Austin) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0445)

The parabolized Navier Stokes (PNS) equations provide an appropriate model for efficient computation of supersonic flow in two- and three-dimensions. However, these marching solution algorithms have been observed to be sensitive to the flow conditions and there are several open questions related to the choice of appropriate marching stepsize for stable computations. The need to treat the sonic sublayer and ellipticity of the equations together with the use of explicit shock fitting techniques at the outer shock boundary are analyzed here and shown to lead in some instances to conflicting stepsize restrictions. The dependence of these stepsize restrictions on the flow variables is investigated and specific numerical experiments conducted for flows at increasing angles of attack to demonstrate the difficulty. Features of the sublayer models and flow parameters for which the conflicting stepsize requirements are likely to occur are identified. Author

A89-25364*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPUTATIONAL DESIGN ASPECTS OF A NASP NOZZLE/AFTERBODY EXPERIMENT
STEPHEN M. RUFFIN (NASA, Ames Research Center, Moffett Field, CA), ETHIRAJ VENKATAPATHY, EARL R. KEENER, and N. NAGARAJ (Eloret Institute, Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. refs
(AIAA PAPER 89-0446)

This paper highlights the influence of computational methods on design of a wind tunnel experiment which generically models the nozzle/afterbody flow field of the proposed National Aerospace Plane. The rectangular slot nozzle plume flow field is computed using a three-dimensional, upwind, implicit Navier-Stokes solver. Freestream Mach numbers of 5.3, 7.3, and 10 are investigated. Two-dimensional parametric studies of various Mach numbers, pressure ratios, and ramp angles are used to help determine model loads and afterbody ramp angle and length. It was found that the center of pressure on the ramp occurs at nearly the same location for all ramp angles and test conditions computed. Also, to prevent air liquefaction, it is suggested that a helium-air mixture be used as the jet gas for the highest Mach number test case. Author

A89-25365#
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) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract F33615-87-C-3211)
(AIAA PAPER 89-0447)

In predictions of unsteady transonic flow the results are sometimes inaccurate because the mean or time-averaged solution does not agree well with experimental data even though the prediction of the time-dependent oscillations is adequate. In transonic flow computations this error frequently is characterized by a time-dependent oscillation about an inaccurate shock location. The work described in this report is concerned with post-processing the unsteady flow prediction to allow oscillations around an experimentally determined mean flow. The transonic perturbation method is used to implement this idea. The technique is applied to both two- and three-dimensional unsteady flows. Author

A89-25366*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A NUMERICAL STUDY OF THE CONTRAROTATING VORTEX PAIR ASSOCIATED WITH A JET IN A CROSSFLOW
KARLIN R. ROTH (NASA, Ames Research Center, Moffett Field, CA), RICHARD L. FEARN (Florida, University, Gainesville), and SIDDHARTH S. THAKUR AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0448)

An implicit two-factor partially flux split solver for the thin-layer Navier-Stokes equations is used to solve the aerodynamic/propulsive interaction between a subsonic jet exhausting perpendicularly through a flat plat plate into a crossflow. The algorithm is applied to flows with a range of jet to crossflow velocity ratios between 4 and 8. The computed velocity field is analyzed and comparisons are made with experimentally determined properties of the contrarotating vortex pair. K.K.

A89-25367#
NUMERICAL STUDY OF SINGLE IMPINGING JETS THROUGH A CROSSFLOW
J. M. M. BARATA, D. F. G. DURAO (Lisboa, Universidade Tecnica, Lisbon, Portugal), and J. J. MCGUIRK (Imperial College of Science and Technology, London, England) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0449)

The application of three-dimensional finite-difference calculation procedures to the problem of a jet impinging on a flat plate through the influence of a confined crossflow is described. The goal of the work is the development and validation of a computational method based on the solution of time-averaged Navier-Stokes equations and the k-epsilon turbulence model. The method is used to study phenomena influencing VSTOL craft performance and safety, the formation of a vortex that wraps around the impingement point, and the existence of low pressures in the neighborhood of the jet. K.K.

A89-25377*# Stanford Univ., CA.
NONEQUILIBRIUM EFFECTS FOR HYPERSONIC TRANSITIONAL FLOWS USING CONTINUUM APPROACH
ROBERT W. MACCORMACK (Stanford University, CA) and TAHIR GOKCEN AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. Research supported by SDIO. refs
(Contract NCA2-243; NAGW-965; DAAL03-86-K-0139;

F33615-86-C-3015)
(AIAA PAPER 89-0461)

A new thermochemical nonequilibrium formulation for hypersonic transitional flows of air is presented. Air is assumed to have five chemical species (N2, O2, NO, N, O) and three temperatures corresponding to the translational, rotational, and vibrational modes of energy. In the present study, the no-slip boundary conditions are replaced by slip boundary conditions to extend the range of the Navier-Stokes equations to high-speed low-density flows. K.K.

A89-25379*# Old Dominion Univ., Norfolk, VA.
A MULTIGRID AND UPWIND VISCOUS FLOW SOLVER ON 3-D EMBEDDED AND OVERLAPPED GRIDS
OKTAY BAYSAL, KAMRAN FOULADI, and VICTOR R. LESSARD (Old Dominion University, Norfolk, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NAG1-664)
(AIAA PAPER 89-0464)

A numerically efficient method is presented for solving the three-dimensional governing equations of the viscous compressible flow about complex configurations with topologically different components. The physical domain is decomposed into regions for which the grid generation is relatively simple and virtually with no significant restrictions. The Navier-Stokes equations are solved by an implicit, approximately factored, upwind, finite-volume scheme. The block inversions and the diagonalized scalar inversions of the coefficient matrices are modified to allow the holes created in the computational domain by the embedded and overlapped grids. The convergence is accelerated by a multigrid algorithm despite the existence of such holes. The solution for s supersonic flow past a blunt-nose-cylinder at high angle-of-attack is obtained using a C-O grid embedded in a global Cartesian grid. Author

A89-25383*# General Dynamics Corp., Fort Worth, TX.
VISCOUS-INVISCID INTERACTION AND LOCAL GRID REFINEMENT VIA TRUNCATION ERROR INJECTION
BRIAN D. GOBLE (General Dynamics Corp., Fort Worth, TX) and K.-Y. FUNG (Arizona, University, Tucson) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract AF-AFOSR-83-0071; NCA2-36; NCA2-107)
(AIAA PAPER 89-0468)

A methodology is presented which makes it possible to decouple a complex problem having multiple disparate length scales into problems of single length scale so that they can be solved more efficiently on a computer. The method is applied to a viscous transonic flow over an airfoil. It is found that accurate prediction of the flow over an airfoil can be obtained by solving the Euler equations on a relatively coarse global grid with viscous effects computed separately on a boundary-layer type grid and injected into the global grid solution as a combination of vorticity and trucation error. K.K.

A89-25387#
A CELL-VERTEX MULTIGRID EULER SCHEME FOR USE WITH MULTIBLOCK GRIDS
M. T. ARTHUR, T. BLAYLOCK (Royal Aerospace Establishment, Farnborough, England), and J. M. ANDERSON (Glasgow, University, Scotland) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0472)

The feasibility of developing a cell-vertex, finite volume scheme with multigrid acceleration for use in conjunction with multiblock grids is investigated. The aim is to provide a fast, accurate method for calculating the inviscid flow over complex geometries without the need to modify the computer programs for each new case. For the investigation, a method has been developed for two-dimensional flows although a grid generator is available for three-dimensional shapes. The method has been validated by comparing results with those from an equivalent, single-block computer program for a case where that is possible. In addition, results are presented from a calculation using a realistic, multiblock grid for a two-element aerofoil configuration. It is concluded that a cell-vertex, multigrid scheme for use with grids having an irregular, multiblock structure can be developed successfully. However, a degree of flexibility in the flow algorithm is needed if the potential benefits of multigrid and multiblock are to be achieved. Author

A89-25390#
IFM APPLICATIONS TO CAVITY FLOWFIELD PREDICTIONS
A. CENKO, D. CHEN, and R. TURZANSKI (U.S. Navy, Naval Air Development Center, Warminster, PA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0477)

Recently, a wind-tunnel test was conducted to evaluate the separation characteristics, at M = 0.85 and 1.2, of eight MK-82 500-pound bombs densely packed in a cavity with an L/D ratio of 5.38. This cavity was sized to fit in the channel under an F-14 aircraft. Preliminary results indicate that the critical conditions occur at the aft end of a densely packed cavity. Furthermore, it appears that empty cavity grid test data may not be safely used to predict trajectories for conditions where several bombs are still present in the bay. An attempt was also made to apply the Influence Function Method (IFM) to a cavity environment. Although the technique shows some promise, further testing and analysis will be required before it's validity can be demonstrated. Author

A89-25418*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN EFFICIENT, EXPLICIT FINITE-RATE ALGORITHM TO COMPUTE FLOWS IN CHEMICAL NONEQUILIBRIUM
GRANT PALMER (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0522)

An explicit finite-rate code was developed to compute hypersonic viscous chemically reacting flows about three-dimensional bodies. Equations describing the finite-rate chemical reactions were fully coupled to the gas dynamic equations using a new coupling technique. The new technique maintains stability in the explicit finite-rate formulation while permitting relatively large global time steps. K.K.

A89-25420#
AERODYNAMIC PREDICTION RATIONALE FOR ANALYSES OF HYPERSONIC CONFIGURATIONS
M. E. MOORE and J. E. WILLIAMS (McDonnell Douglas Astronautics Co., Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract F33615-86-C-3602)
(AIAA PAPER 89-0525)

The establishment of pressure method selection rationale for the Supersonic/Hypersonic Arbitrary Body Program (S/HABP) to define configuration aerodynamics is discussed. Aerodynamic predictions from S/HABP were compared with wind tunnel and flight test data to evaluate the code's capabilities and limitations over a broad range of hypersonic flight conditions. The effort was limited to vehicle control, where aerodynamic forces and moments are prime considerations. Author

A89-25421#
EFFECT OF DYNAMIC CHANGES IN BODY CONFIGURATION ON SHOCK STRUCTURE
KLAUS A. HOFFMANN, TING-LUNG CHIANG, and WALTER H. RUTLEDGE (Texas, University, Austin) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0526)

A technique is presented for solving the inviscid, chemically-reacting, hypersonic flowfield over axisymmetric blunt bodies. The Euler equations are solved using a fully implicit, flux vector splitting, finite difference scheme. An approximate factorization scheme is also utilized in order to improve computational efficiency. Finite-rate chemical reaction calculations are decoupled from the gasdynamic equations in the current analysis. Complex blunt body shapes, including highly indented nose geometries, are analyzed for Mach numbers from 2 to 18. Author

A89-25424#

SUPERSONIC LOW-DENSITY FLOW OVER AIRFOILS

TSZE C. TAI and MARK S. MORAN (U.S. Navy, David W. Taylor Naval Ship Research and Development Center, Bethesda, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. Research supported by the U.S. Navy. refs

(AIAA PAPER 89-0530)

The slip flow and the nonequilibrium transition flow in a rarefied atmosphere are examined. Two-dimensional, Reynolds-averaged, full Navier-Stokes equations for a perfect gas are solved for supersonic, low-density flow at Reynolds numbers ranging from 400 to 35,000. Slip-velocity boundary conditions based on various Knudsen numbers are introduced. Numerical results are obtained for three symmetric airfoils traveling at supersonic speeds at an angle of attack of 1.25 deg. The effect of the slip velocity becomes important for Knudsen numbers greater than 0.1. Author

A89-25426*# Texas A&M Univ., College Station.

DETERMINATION OF AERODYNAMIC SENSITIVITY COEFFICIENTS IN THE TRANSONIC AND SUPERSONIC REGIMES

HESHAM M. ELBANNA and LELAND A. CARLSON (Texas A & M University, College Station) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs

(Contract NAG1-793)

(AIAA PAPER 89-0532)

The quasi-analytical approach is developed to compute airfoil aerodynamic sensitivity coefficients in the transonic and supersonic flight regimes. Initial investigation verifies the feasibility of this approach as applied to the transonic small perturbation residual expression. Results are compared to those obtained by the direct (finite difference) approach and both methods are evaluated to determine their computational accuracies and efficiencies. The quasi-analytical approach is shown to be superior and worth further investigation. Author

A89-25427#

FLOW MEASUREMENTS OF AN AIRFOIL WITH SINGLE-SLOTTED FLAP

ZEKI Z. CELIK (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by the Boeing Co. refs

(AIAA PAPER 89-0533)

Flow measurements of an airfoil-flap configuration were carried out in a low-speed wind tunnel. The results are presented in the form of a surface pressure distribution, a lift coefficient, and mean velocity distributions in the boundary layer and wake at various flap deflections and gaps. Oil-flow studies revealed that the flow on the air-foil and the flap are two-dimensional along the whole span except in the vicinity of the side-walls for model angles of attack of less than 8 deg. K.K.

A89-25430#

TIP VORTEX/AIRFOIL INTERACTION FOR A CANARD//WING CONFIGURATION AT LOW REYNOLDS NUMBERS

FARUKH A. KHAN and THOMAS J. MUELLER (Notre Dame, University, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. Research supported by the University of Notre Dame. refs

(Contract N00014-83-K-0239)

(AIAA PAPER 89-0536)

The effects of the vortical wake shed by a finite span canard on a low Reynolds number airfoil were examined. Aerodynamic performance was evaluated through direct measurements of lift, drag and 1/4-chord pitching moment. Spanwise static pressure and surface film visualization data were also acquired. A reduction in the downstream airfoil drag coefficient and an increase in its lift/drag were noted in the presence of the canard for a wide range of configurations. Static pressure and surface visualization data provided indication of some of the boundary layer characteristics responsible for the drag behavior. Author

A89-25431*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

NUMERICAL SIMULATION OF VORTICAL FLOWS ON FLEXIBLE WINGS

GURU P. GURUSWAMY (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs

(AIAA PAPER 89-0537)

A procedure to simultaneously solve the Navier-Stokes equations and modal structural equations of motion is presented for computing aeroelastic responses of wings. The Navier-Stokes flow equations are solved by a finite-difference scheme with dynamic grids. The coupled aeroelastic equations of motion are solved using the linear-acceleration method. The aeroelastic, configuration-adaptive dynamic grids are time-accurately generated using the aeroelastically deformed shape of the wing. The unsteady flow calculations are validated with the experiment. Present development is demonstrated for computing vortical flows over flexible wings. Author

A89-25432#

AN EXPERIMENTAL EVALUATION OF A LOW-REYNOLDS NUMBER HIGH-LIFT AIRFOIL WITH VANISHINGLY SMALL PITCHING MOMENT

M. SHEPSHELOVICH, D. KOSS (Israel Aircraft Industries, Ltd., Lod), I. WYGNANSKI, and A. SEIFERT (Tel Aviv University, Israel) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs

(AIAA PAPER 89-0538)

This paper describes an experimental evaluation of a new airfoil, designed for the purpose of generating high-lift, vanishingly small pitching moment and mild stall characteristics at low Reynolds numbers ranging from 10 to the 5th to 10 to the 6th. The experimental program included active and passive methods for lift enhancement in the very low end of the Reynolds number range of operation. A technique for reduction and elimination of hysteresis loops was also investigated. Author

A89-25441#

AN IMPROVED UPWIND FINITE VOLUME RELAXATION METHOD FOR HIGH SPEED VISCOUS FLOWS

ARTHUR C. TAYLOR, III, WING-FAI NG, and ROBERT W. WALTERS (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs

(AIAA PAPER 89-0549)

An upwind relaxation algorithm for the Navier-Stokes equations has been developed and is applied to two test problems of high-speed viscous flows. A lower-upper factorization method is applied to the elliptic region(s) identified near each solid wall boundary, and the results are coupled to a standard line Gauss-Seidel relaxation sweep across the entire domain in the primary flow direction. For the cases of both a high-speed inlet and a shock/boundary layer interaction on a flat plate, the present method is found to be much more efficient than the standard alternating forward/backward vertical line Gauss-Seidel algorithm. R.R.

A89-25443*# Old Dominion Univ., Norfolk, VA.

NAVIER-STOKES COMPUTATIONS OF SEPARATED VORTICAL FLOWS PAST PROLATE SPHEROID AT INCIDENCE

TIN-CHEE WONG, OSAMA A. KANDIL (Old Dominion University, Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs

(Contract NAS1-18584)

(AIAA PAPER 89-0553)

The problem of steady incompressible viscous flow past prolate spheroids at incidence is formulated using the unsteady incompressible and compressible thin-layer Navier-Stokes equations. The two sets of Navier-Stokes equations are solved using a pseudotime stepping of the implicit flux-difference splitting scheme on a curvilinear grid, which is generated by a transfinite grid generator. The Baldwin and Lomax (1978) algebraic eddy-viscosity model is used to model the turbulent flow. The computational applications cover a 6:1 prolate spheroid at different angles of attack and Reynolds numbers. The results are compared with experimental data. Author

A89-25444#

STUDY OF THE VORTICAL WAKE PATTERNS OF AN OSCILLATING AIRFOIL

M. J. STANEK and M. R. VISBAL (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0554)

The laminar wake structure of an airfoil which pitches about the quarter chord in forced sinusoidal motion is numerical simulated. The unsteady flow is simulated by solving the full two-dimensional compressible Navier-Stokes equations with an implicit approximate factorization algorithm utilizing a moving grid. The numerical results are compared with time-averaged wake velocity profile measurements and experimental flow visualization. For a NACA 0012 airfoil, reasonable qualitative agreement is obtained between computed and experimental results. Better qualitative agreement is obtained for the case with a complex double vortex wake structure with an elliptical airfoil/0-grid combination than with a NACA 0012 airfoil/C-grid combination. The computed airfoil wake structure is quite sensitive to the frequency and amplitude of the oscillation waveform. Author

A89-25446*# North Carolina State Univ., Raleigh.

A ONE EQUATION TURBULENCE MODEL FOR TRANSONIC AIRFOIL FLOWS

R. A. MITCHELTREE, H. A. HASSAN (North Carolina State University, Raleigh), and M. D. SALAS (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by USAF and U.S. Navy. refs
(Contract NCC1-22; NAGW-1022; NAGW-1331)
(AIAA PAPER 89-0557)

A one-equation turbulence model has been developed from available experimental observations on both attached and separated turbulence flows, and numerical results are presented for flows about NACA 0012 and RAE 2822 airfoils. The model is shown to duplicate the accurate results of the Baldwin-Lomax (1978) algebraic model for the case of attached flow. For cases of separated flow, the model is found to predict shock location and strength closer to the experimentally observed values than both the algebraic and the q-omega two-equation models. R.R.

A89-25447*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PREDICTION OF SEPARATED TRANSONIC WING FLOWS WITH A NON-EQUILIBRIUM ALGEBRAIC MODEL

RIDHA ABID, VEER N. VATSA (NASA, Langley Research Center, Hampton, VA), DENNIS A. JOHNSON (NASA, Ames Research Center, Moffett Field, CA), and BRUCE W. WEDAN (Vigyan Research Associates, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0558)

A nonequilibrium algebraic turbulence model, which is based on the turbulence closure scheme of Johnson and King (1985), is proposed to predict separated transonic wing flows. The influence of history effects are modeled by solving a partial differential equation for the maximum total Reynolds shear stress, which is then used to scale the eddy viscosity of an algebraic model. The turbulence model is implemented in a three-dimensional, Reynolds-averaged Navier-Stokes code. Comparisons with experimental data are presented which show clearly that the nonequilibrium type of turbulence model is essential for accurate prediction of transonic separated flows. Author

A89-25448#

COMPARISON OF TWO DIFFERENT NAVIER-STOKES METHODS FOR THE SIMULATION OF 3-D TRANSONIC FLOWS WITH SEPARATION

W. KORDULLA, B. MUELLER, and H. VOLLMERS (DFVLR, Goettingen, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract DFG-RU-334/1-6; DFG-DA-183/1-5)
(AIAA PAPER 89-0559)

Previous numerical simulations of the transonic flow past a hemisphere-cylinder configuration, based on the bidiagonal implicit predictor-corrector finite-volume method of MacCormack, have indicated that the investigated flow fields are unsteady and exhibit a highly granular flow structure. To determine whether these laminar flow results are due to numerical reasons or not, a semiimplicit finite-difference method of Beam-and-Warming type has been employed using the same grids as in the finite-volume approach. The former results are essentially confirmed. Author

A89-25451#

ESSENTIALLY NON-OSCILLATORY SCHEMES FOR THE EULER EQUATIONS AND ITS APPLICATION TO COMPLEX AERODYNAMIC FLOWS

J. Y. YANG (National Taiwan University, Taipei, Republic of China), S. Y. HSU, T. S. CHANG, and C. A. HSU AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Sponsorship: National Science Council of the Republic of China. refs
(Contract NSC-77-0210-D002-03; NSC-77-0210-D002-04)
(AIAA PAPER 89-0562)

Essentially nonoscillatory schemes for the Euler equation in a general coordinate system are considered which are based on both the modified flux and modified eigenvalue approaches. Two-dimensional transonic airfoil flow at various angles of attack and with supersonic inlet flow has been simulated along with a two-dimensional time-dependent shock reflection by an ellipse. Both formulations considered provide clean shock representations. R.R.

A89-25452*# Planning Research Corp., Hampton, VA.

INTEGRAL EQUATION SOLUTION OF THE FULL POTENTIAL EQUATION FOR TRANSONIC FLOWS

LI-CHUAN CHU (Planning Research Corp., Hampton, VA), E. CARSON YATES, JR. (NASA, Langley Research Center, Hampton, VA), and OSAMA A. KANDIL (Old Dominion University, Norfolk, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract NAS1-18000)
(AIAA PAPER 89-0563)

An integral equation method for solving the full potential equation has been developed for arbitrary configurations in two- or three-dimensional transonic flows. This method is capable of capturing shocks using Murman-Cole type of finite difference scheme and is capable of predicting accurate and force-free wake shape as well. A rectangular grid combined with a technique of local grid refinement greatly improved the computational efficiency. Author

A89-25453#

VORTEX GENERATOR JETS - A MEANS FOR PASSIVE AND ACTIVE CONTROL OF BOUNDARY LAYER SEPARATION

JAMES P. JOHNSTON (Stanford University, CA) and MICHIHIRO NISHI (Kyushu Institute of Technology, Tobata, Japan) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. Research supported by USAF. refs
(AIAA PAPER 89-0564)

Stalled regions (zones of detached or separated flow sometimes followed by reattachment) in a turbulent boundary layer may be eliminated by a technique called the vortex-generator-jet (VGJ) method. The method employs spanwise arrays of small, skewed and pitched jets from holes in the surface. Low-speed, air-flow experiments are described which (1) demonstrate that the VGJ method creates longitudinal (streamwise) vortices in the boundary layer downstream of the jet holes, like the vortices behind solid vortex generators, and (2) show that the cross-stream mixing associated with these vortices is effective in reduction and elimination of stalled regions. Author

A89-25454*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

CONTROL OF LAMINAR SEPARATION OVER AIRFOILS BY ACOUSTIC EXCITATION

K. B. M. Q. ZAMAN and D. J. MCKINZIE (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Previously announced in STAR as N89-12552. refs

(AIAA PAPER 89-0565)

The effect of acoustic excitation in reducing laminar separation over two-dimensional airfoils at low angles of attack is investigated experimentally. Airfoils of two different cross sections, each with two different chord lengths, are studied in the chord Reynolds number range of 25,000 is less than R sub c is less than 100,000. While keeping the amplitude of the excitation induced velocity perturbation a constant, it is found that the most effective frequency scales as U (sup 3/2) (sub infinity). The parameter St/R (sup 1/2)(sub c), corresponding to the most effective f sub p for all the cases studied, falls in the range of 0.02 to 0.03, St being the Strouhal number based on the chord. Author

A89-25458#

BOUNDARY LAYER MEASUREMENTS ON AN AIRFOIL AT LOW REYNOLDS NUMBERS IN AN ACCELERATING FLOW FROM A NONZERO BASE VELOCITY

R. H. ELLSWORTH and T. J. MUELLER (Notre Dame, University, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs

(Contract N00014-83-K-0239)

(AIAA PAPER 89-0569)

A quantitative experimental study of the effects on transitional separation bubble characteristics of an accelerating freestream from a nonzero base velocity has confirmed previous oscillating freestream results. It is found that as a result of freestream acceleration, the separation bubble position shifts in the direction opposite to the chordwise direction it would move for a quasi-steady velocity change. The transition location was found to be more responsive to the acceleration than was the separation position. R.R.

A89-25485*# Georgia Inst. of Tech., Atlanta.

EVALUATION OF THREE TURBULENCE MODELS FOR THE PREDICTION OF STEADY AND UNSTEADY AIRLOADS

JIUNN-CHI WU, L. N. SANKAR (Georgia Institute of Technology, Atlanta), and DENNIS L. HUFF (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. Research supported by McDonnell Douglas Helicopter Co. Previously announced in STAR as N89-12555. refs

(Contract NAG3-768)

(AIAA PAPER 89-0609)

Two dimensional quasi-three dimensional Navier-Stokes solvers were used to predict the static and dynamic airload characteristics of airfoils. The following three turbulence models were used: the Baldwin-Lomax algebraic model, the Johnson-King ODE model for maximum turbulent shear stress, and a two equation k-e model with law-of-the-wall boundary conditions. It was found that in attached flow the three models have good agreement with experimental data. In unsteady separated flows, these models give only a fair correlation with experimental data. Author

A89-25492#

COMBINED TANGENTIAL-NORMAL INJECTION INTO A SUPERSONIC FLOW

P. S. KING, R. H. THOMAS, J. A. SCHETZ (Virginia Polytechnic Institute and State University, Blacksburg, VA), and F. S. BILLIG (Johns Hopkins University, Laurel, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs

(AIAA PAPER 89-0622)

A combination of tangential and normal air injection into a Mach 3 airflow was experimentally tested. A rearward facing slot producing tangential injection at a nominal Mach number 1.7 was operated at several different total pressures. An array of transverse tubes of height equal to the slot height and placed just downstream of the slot was operated at two dynamic pressure ratios as well as at Mach 1 and 2.2. Mean flow measurements of static and total pressures were taken up to 20 slot heights downstream from which Mach number, density, velocity and entrainment rates were calculated. Various dimensions of the mixing regions and spreading angles were measured directly from nanoshadowgraphs and schlieren photographs. For some cases heated air was injected through the normal tubes and the total temperature decay was measured downstream. It can be seen from the data as a whole that the mixing rate can be significantly increased by the combined tangential-normal injection design over tangential slot injection alone. Author

A89-25505#

MODELING OF SUBSONIC FLOW THROUGH A COMPACT OFFSET INLET DIFFUSER

RICHARD C. JENKINS and ALBERT L. LOEFFLER, JR. (Grumman Corporate Research Center, Bethpage, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs

(AIAA PAPER 89-0639)

A comparison between computational and experimental results is presented for a study of flow through a compact, highly offset diffuser. The experiment was conducted to evaluate the use of a thin-layer Navier-Stokes code, ARC3D (Pulliam, 1984) to predict the effects of diffuser shape and inlet flow properties on pressure recovery and exit flow quality. It is found that the ARC3D code provides a good representation of the flow in most regions, although the Baldwin-Lomax algebraic turbulence model in the code does not adequately represent the flow in regions of separated flow. Preliminary results from computations made with a one-half equation turbulence model are presented. It is suggested that a more complex turbulence model is needed to properly treat the extensive region of flow separation in compact, offset diffusers. R.B.

A89-25507#

DIRECT SOLUTION OF UNSTEADY TRANSONIC FLOW EQUATIONS IN FREQUENCY DOMAIN

C. E. LAN (Kansas, University, Lawrence) and HORNG-REN HWANG AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 19 p. refs

(AIAA PAPER 89-0641)

A novel method of unsteady transonics based on considerations in the freqency domain is developed for computing the unsteady flow field about oscillating airfoils using the two-dimensional full-potential equation. The unsteady equations can be solved with a steady-flow solver without the assumption of time-linearization. The present formulation for solving unsteady transonic flow equations in the frequency domain is a good alternative to time-domain integration for harmonic motions. K.K.

A89-25514*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

CHARACTERISTICS OF THE GROUND VORTEX FORMED BY A JET MOVING OVER A FIXED GROUND PLANE

G. T. KEMMERLY (NASA, Langley Research Center, Hampton, VA) and V. R. STEWART AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs

(AIAA PAPER 89-0650)

This paper discusses an experimental study conducted in the Langley Vortex Facility to investigate the effects on the ground vortex of the jet passing over a fixed ground board. A jet impacting the ground can form a vortex which may materially affect the aerodynamic characteristics of a STOL airplane operating near the ground. Several studies have been done with a stationary jet exiting near and perpendicular to fixed ground board. The resulting ground effects have been documented in terms of ground vortex and aerodynamic characteristics. The ground boundary layer created in a wind tunnel facility, however is thought to affect the extent of the ground vortex. This paper reports on an investigation utilizing an isolated moving jet to eliminate the ground boundary layer. The results are compared to the existing data base and show a 30 percent decrease in the vortex penetration shown by the stationary jet conditions. Author

A89-25517*# Tennessee Univ., Knoxville.
PROGRESS ON A TAYLOR WEAK STATEMENT FINITE ELEMENT ALGORITHM FOR HIGH-SPEED AERODYNAMIC FLOWS
A. J. BAKER (Tennessee, University, Knoxville) and J. D. FREELS AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. Research supported by the University of Tennessee. refs
(Contract NAS2-12568; F04704-87-C-0100)
(AIAA PAPER 89-0654)
A new finite element numerical Computational Fluid Dynamics (CFD) algorithm has matured to the point of efficiently solving two-dimensional high speed real-gas compressible flow problems in generalized coordinates on modern vector computer systems. The algorithm employs a Taylor Weak Statement classical Galerkin formulation, a variably implicit Newton iteration, and a tensor matrix product factorization of the linear algebra Jacobian under a generalized coordinate transformation. Allowing for a general two-dimensional conservation law system, the algorithm has been exercised on the Euler and laminar forms of the Navier-Stokes equations. Real-gas fluid properties are admitted, and numerical results verify solution accuracy, efficiency, and stability over a range of test problem parameters. Author

A89-25521*# Planning Research Corp., Hampton, VA.
A THREE-DIMENSIONAL UPWIND FINITE ELEMENT POINT IMPLICIT UNSTRUCTURED GRID EULER SOLVER
RAJIV R. THAREJA (Planning Research Corp., Hampton, VA), KEN MORGAN, JAIME PERAIRE, and JOAQUIN PEIRO (Swansea, University College, Wales) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(Contract NAS1-18000; NAGW-478)
(AIAA PAPER 89-0658)
A three-dimensional upwind finite element technique that uses cell-centered quantities and implicit and/or explicit time marching was developed for computing hypersonic inviscid flows using adaptive unstructured grids. This technique was used to predict shock interference on a swept cylinder. An attempt was made to determine the flowfield and, in particular, the pressure augmentation caused by an impinging shock on the swept leading edge of a cowl lip of an engine inlet. K.K.

A89-25530#
SIMPLE TURBULENCE MODELS FOR SUPERSONIC AND HYPERSONIC FLOWS - BODIES AT INCIDENCE AND COMPRESSION CORNERS
SIAMACK A. SHIRAZI and C. RANDALL TRUMAN (New Mexico, University, Albuquerque) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by Sandia National Laboratories. refs
(AIAA PAPER 89-0669)
Parabolized Navier-Stokes predictions of turbulent flows at supersonic and hypersonic speeds past two sphere-cones and a cone-cylinder-flare are used to evaluate simple turbulence models. Modifications to an algebraic turbulence model are proposed to improve predictions for flow on bodies at incidence. Predictions using a simple modification for the length scale and a model based upon Bradshaw's extra-strain-rate hypothesis are compared with measurements of supersonic and hypersonic flows at incidence. The modifications lead to significant improvements in predicted wall shear stress for a supersonic flow at incidence. Author

A89-25532#
ON THE SOLUTION OF NONEQUILIBRIUM HYPERSONIC INVISCID STEADY FLOWS
M. ONOFRI, B. FAVINI (Roma I, Universita, Rome, Italy), and M. VALORANI AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. Research supported by Avions Marcel Dassault Breguet Aviation and CIRA. refs
(AIAA PAPER 89-0671)
The effects of finite-rate chemical reactions on inviscid hypersonic flows are investigated theoretically by means of numerical simulations using a shock-fitting technique. The theoretical basis of the method, which treats the finite-rate reaction as a singular-perturbation problem, is discussed in detail; the formulations for shock waves in nonequilibrium flows and the chemical and gasdynamic operators are derived; and the relaxation strategy for the global model is explained. Typical results demonstrating the efficiency and accuracy of the present method are presented in extensive graphs and briefly characterized. T.K.

A89-25534#
NUMERICAL SOLUTIONS TO THREE-DIMENSIONAL SHOCK WAVE/VORTEX INTERACTION AT HYPERSONIC SPEEDS
GRIFFIN CORPENING (Johns Hopkins University, Laurel, MD) and JOHN D. ANDERSON, JR. (Maryland, University, College Park) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0674)
Euler solutions to three-dimensional shock wave/vortex interactions at Mach numbers of 2.28 and 5.00 are studied. First, a numerical model capable of simulating the flowfield is presented and then, an input vortex is developed which can be fed into the upstream boundary of the computational domain. Areas of flow reversal around the outside of the post-shock vortex were seen at both Mach numbers. K.K.

A89-25602#
DRAGONFLY UNSTEADY AERODYNAMICS - THE ROLE OF THE WING PHASE RELATIONS IN CONTROLLING THE PRODUCED FLOWS
DANIEL SAHARON and MARVIN W. LUTTGES (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. refs
(Contract F49620-84-C-0065; N00014-85-K-0053)
(AIAA PAPER 89-0832)
Visualizations of three-dimensional unsteady separated flow produced by a mechanically driven dragonfly wing kinematics model were collected and analyzed. Tandem wing effects were evaluted by comparison with effects produced by fore and aft wings tested individually. The effects of wing kinematics were studied with an emphasis on changes in the phase relations between fore and aft wings. Vortex structures produced by the mechanical model were quite similar to those elicited from tethered dragonflies in wind tunnel tests. The eight kinematic elements of the model wing beat were short-lived such that each yielded a specific transitional flow structure. Fore and aft wing phase differences produced flow structures that interacted, one with another, in differing ways. Flow interactions were either constructive or destructive and yielded different wing - flow interactions. Constructive flow interactions were evalutaed in terms of integrating and fusing of vortex structures. Destructive flow interactions were evaluated in terms of vortex disruption, splitting and deflecting. The net results of these interactions were to enhance lift and thrust as seen in downwash and downstream flow structures. Author

A89-25603#
MEASUREMENT OF TRANSIENT VORTEX-SURFACE INTERACTION PHENOMENA
S. G. LIOU, N. M. KOMERATH, and H. M. MCMAHON (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract DAAG29-82-K-0084)
(AIAA PAPER 89-0833)
The transient, periodic interaction of a helical vortex with a

circular cylinder is experimentally studied. Close approach of the primary vortex causes stagnation and flow reversal near the surface. Regions of negative vorticity are created under the primary vortex when it is still well above the surface. Later, such a region appears above the vortex and moves rapidly downstream. As the primary structure impacts the surface, its lower part disappears. A secondary structure simultaneously appears downstream. This structure moves rapidly downstream and dissipates. The surface pressure variation corresponds to the structure of the tip vortex until the vortex impinges on the surface. Thereafter, the pressure is dominated by the secondary vortex structure. Simultaneous peaks in velocity and surface pressure are seen, due to the high stagnation pressure in the tip vortex. Vortex deformations and induced velocities do not agree quantitatively with two-dimensional potential theory at the top of the airframe. C.D.

A89-25606#
A SELF-ADAPTIVE COMPUTATIONAL METHOD APPLIED TO TRANSONIC TURBULENT PROJECTILE AERODYNAMICS
W. D. NEWBOLD and M. H. LEE AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0837)

An adaptive grid generation code coupled with an axisymmetric thin-layer Navier-Stokes code has been investigated for self-adaptive computation fo transonic turbulent projectile aerodynamics. The governing equations for an adaptive grid are obtained by minimizing the integral which measures the smoothness, orthogonality, and adaptivity, while the thin-layer Navier-Stokes equations are approximated by a TVD scheme in which turbulence is simulated by the Baldwin-Lomax algebraic eddy viscosity model. Two illustrative flow problems involving Mach 0.96 and 1.20 flow past a secant-ogive-cylinder-boattail projectile with base flow region and at zero angle of attack are considered. C.D.

A89-25611#
FLOW VISUALIZATION INVESTIGATION OF DYNAMIC STALL ON A PITCHING AIRFOIL
K. F. TCHON AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0842)

The dynamic stall on a pitching airfoil is studied using chronophotography techniques. The study was based on a 16-mm film taken at 50 frames/sec during water tunnel flow visualizations using colored dye injections on a NACA 0018 airfoil undergoing damped pitching oscillations about an axis located at 30 percent chord, for a Reynolds number of 10,000 and a reduced frequency of 0.550. Stall occurred during the downstroke of the airfoil, and an almost simultaneous double separation of the boundary layer. Informations regarding the trajectory, convection velocity, growth, effective viscosity, roll-up, and approximate initial circulation of the shed vortices are also evaluated. Author

A89-25615#
ELEVATOR DEFLECTION EFFECTS ON THE ICING PROCESS
RANDALL K. BRITTON (Texas A & M University, College Station) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0846)

A computer code has been developed to calculate the performance degradation due to ice accretion on a NACA 0012 airfoil. The results indicate that the icing process is dependent on elevator deflection and affects the flowfield about the airfoil by adding camber to the horizontal stabilizer system. The results are presented in terms of total collection efficiency and impingement limits as functions of angle of attack and elevator deflection angle. Author

A89-25856
NUMERICAL SIMULATION OF THE TRANSONIC DFVLR-F5 WING EXPERIMENT; PROCEEDINGS OF THE INTERNATIONAL WORKSHOP ON NUMERICAL SIMULATION OF COMPRESSIBLE VISCOUS-FLOW AERODYNAMICS, GOETTINGEN, FEDERAL REPUBLIC OF GERMANY, SEPT. 30-OCT. 2, 1987
WILHELM KORDULLA, ED. (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) Workshop supported by DFVLR. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn (Notes on Numerical Fluid Mechanics. Volume 22), 1988, 314 p. For individual items see A89-25857 to A89-25867.

Papers are presented on the DFVLR-F5 test wing experiment for computational aerodynamics, advances in numerical grid generation, and boundary layer transition and turbulence modeling of three-dimensional flow. Also considered are turbulence modeling for compressible flows, a Navier-Stokes simulation of transonic wing flow fields using a zonal grid approach, and the numerical simulation of viscous transonic flow over a DFVLR-F5 wing. Other topics include three-dimensional viscous flow simulations using an implicit relaxation scheme, and Navier-Stokes calculations for the DFVLR-F5 wing in a wind tunnel using a Runge-Kutta time-stepping scheme. R.R.

A89-25857
DFVLR-F5 TEST WING EXPERIMENT FOR COMPUTATIONAL AERODYNAMICS
H. SOBIECZKY (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany), G. HEFER (DFVLR, Institut fuer experimentelle Stroemungsmechanik, Goettingen, Federal Republic of Germany), and S. TUSCHE (DFVLR, Goettingen, Federal Republic of Germany) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 4-22. refs

This paper describes the design and the experimental investigation of a test wing configuration for the validation of aerodynamic computer codes. Half model technology is used with a controlled splitter plate flow. The main objective of the work was to produce a well defined boundary value problem for the transonic flow past a wing mounted onto a wall, as can be derived from geometrical and measured flow data. Author

A89-25858
DFVLR-F5 TEST WING CONFIGURATION - THE BOUNDARY VALUE PROBLEM
H. SOBIECZKY (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 27-37.

Experimental results for the configuration geometry and control volume of a 20-deg DFVLR-F5 swept wing were obtained, and the boundary conditions on the control surface have been observed. The obtained data can be used to develop numerical analysis codes. The flow boundary conditions are modeled by simple analytical functions. R.R.

A89-25862* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NAVIER-STOKES SIMULATION OF TRANSONIC WING FLOW FIELDS USING A ZONAL GRID APPROACH
NEAL M. CHADERJIAN (NASA, Ames Research Center, Moffett Field, CA) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics,

Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 159-183. Previously announced in STAR as N89-10022. refs

The transonic Navier-Stokes code was used to simulate flow fields about isolated wings for workshop wind-tunnel and free-air cases using the thin-layer Reynolds-averaged Navier-Stokes equations. An implicit finite-difference scheme based on a diagonal version of the Beam-Warming algorithm was used to integrate the governing equations. A zonal grid approach was used to allow efficient grid refinement near the wing surface. The flow field was sensitive to the turbulent transition model, and flow unsteadiness was observed for a wind-tunnel case but not for the corresponding free-air case. The specification of experimental pressure at the wind-tunnel exit plane is the primary reason for the difference of these two numerical solutions. Author

A89-25863
NUMERICAL SIMULATION OF VISCOUS TRANSONIC FLOW OVER THE DFVLR F5 WING
TONY LINDEBERG, ARTHUR RIZZI, and BERNHARD MUELLER (Flygtekniska Forsoksanstalten, Bromma, Sweden) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 184-199. Research supported by the Styrelsen for Teknisk Utveckling. refs

An algebraic code for studying turbulent flow over quadrilateral wings is used to generate three-dimensional meshes for a large-aspect-ratio DFVLR F5 wing. The Reynolds-averaged compressible Navier-Stokes equations are used to model the behavior of the fluid. Results are presented for the cases of the wing in a square wind tunnel and the wing alone. R.R.

A89-25864* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NAVIER-STOKES SIMULATION OF WIND-TUNNEL FLOW USING LU-ADI FACTORIZATION ALGORITHM
SHIGERU OBAYASHI, KOZO FUJII (NASA, Ames Research Center, Moffett Field, CA), and SHARAD GAVALI (Amdahl Corp., Sunnyvale, CA) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 200-225. Previously announced in STAR as N88-17584. refs

The three dimensional Navier-Stokes solution code using the LU-ADI factorization algorithm was employed to simulate the workshop test cases of transonic flow past a wing model in a wind tunnel and in free air. The effect of the tunnel walls is well demonstrated by the present simulations. An Amdahl 1200 supercomputer having 128 Mbytes main memory was used for these computations. Author

A89-25865
THREE-DIMENSIONAL VISCOUS FLOW SIMULATIONS USING AN IMPLICIT RELAXATION SCHEME
M. A. SCHMATZ (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 226-243. refs

A Navier-Stokes solver using characteristic flux extrapolation is used to numerically simulate a DFVLR-F5 test wing in a wind tunnel experiment. The code involves a Godunov-type averaging procedure by means of which the inviscid fluxes are evaluated at the finite-volume faces. Results are presented for transonic flow with an angle of attack of 2 degrees. Problems due to mesh distortion at the wing-body junction and in the wind tunnel corners are discussed. R.R.

A89-25866
SIMULATION OF THE DFVLR-F5 WING EXPERIMENT USING A BLOCK STRUCTURED EXPLICIT NAVIER-STOKES METHOD
D. SCHWAMBORN (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 244-268. refs

A block structured solver for the numerical integration of the time-dependent form of the Navier-Stokes equations is presented. The method, which allows for high flexibility, is based on an explicit finite volume approach. The solver is applied to the flow about the DFVLR-F5 wing at M = .82 and Rex = 10 to the 7th/m at two angles of attack (0 deg, 2 deg). Results are obtained for the wing alone and for the wing in the wind tunnel. A comparison with experiments is made, and the influence of the computational grid is discussed. Author

A89-25867* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NAVIER-STOKES CALCULATIONS FOR DFVLR F5-WING IN WIND TUNNEL USING RUNGE-KUTTA TIME-STEPPING SCHEME
V. N. VATSA (NASA, Langley Research Center, Hampton, VA) and B. W. WEDAN (Vigyan Research Associates, Inc., Hampton, VA) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 269-305. refs

A three-dimensional Navier-Stokes code using an explicit multistage Runge-Kutta type of time-stepping scheme is used for solving the transonic flow past a finite wing mounted inside a wind tunnel. Flow past the same wing in free air was also computed to assess the effect of wind-tunnel walls on such flows. Numerical efficiency is enhanced through vectorization of the computer code. A Cyber 205 computer with 32 million words of internal memory was used for these computations. Author

A89-25929#
A NUMERICAL METHOD FOR UNSTEADY TRANSONIC FLOW ABOUT TAPERED WINGS
JIANBAI ZHANG (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 389-399. refs

A numerical method is presented for predicting steady and unsteady transonic aerodynamic flow about aircraft wing configuration. A special designed coordinate transformation is employed in the method. The numerical procedure solves the unsteady transonic modified three-dimensional small perturbation equation by time-accurate alternating direction, implicit finite difference algorithm. Numerical results are presented for an F-5 fighter wing and compared with experimental data for transonic flight conditions. Author

A89-25930#
APPLICATIONS OF AN EFFICIENT ALGORITHM TO TRANSONIC CONSERVATIVE FULL-POTENTIAL FLOW PAST 3-D WINGS
MINGKE HUANG (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 401-408. In Chinese, with abstract in English. refs

A computer program for analyzing three-dimensional transonic flow past wings has been developed using Holst's algorithm for the finite difference method. A fast conformal mapping technique is utilized to form a two-dimensional O-type grid, which is then used to generate the three-dimensional body-fitted grid. This leads to a great saving of CPU time in grid generation. For transonic flow computation, the same iteration scheme as used in the TWING code is applied. The resulting computer program has been applied not only to thick wings with moderate sweep angle but also to highly swept and tapered thin wings. The difficult case for this method is the computation of delta wings with tip cut. C.D.

A89-25931#

COMPUTATION FOR SUPERSONIC AND TURBULENT SEPARATED FLOW OVER A COMPRESSION CORNER

QIPENG CAO (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 409-415. In Chinese, with abstract in English. refs

A unified levyless transformation and direct/inverse method is used to obtain a numerical solution for supersonic and turbulent separated flow over a compression corner. A direction method is applied with given pressure distributions obtained by the unified supersonic/hypersonic small disturbance theory over a wedge. The turbulent model adopted is the simple algebraic 'eddy viscosity' model. An inverse method is used for the separated flow region in which the displacement-thickness is prescribed with pressure treated as the unknown parameter. The turbulent model adopted is the algebraic relaxation model. The Keller box scheme is used to solve the boundary layer equations. The computation well predicts the separated point, reattachment point, wall pressure, and the skin friction stress distribution. C.D.

A89-25932#

A PREDICTION OF THE STALLING OF THE MULTIELEMENT AIRFOILS

BAOQIN ZHANG and ZHILIANG LU (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 416-425. In Chinese, with abstract in English. refs

A multicomponent airfoil program which computes stall characteristics has been developed. A higher-order singularity panel method is used for the potential flow solution. The vorticity and sources distribution in each panel is assumed linear with respect to the arc length of the panel. A separated wake model is used when the separation occurs at the trailing edges of the elements of the multielement airfoils. The final viscous solution is obtained by representing the boundary layer displacement thickness with an appropriate source distribution and by a viscous-potential iteration technique. The calculated pressure distribution and the lift for angles of attack up to the stall are in good agreement with experimental results. C.D.

A89-25938#

EXPERIMENTAL RESEARCH OF FLOW SEPARATION, HEAT TRANSFER AND ABLATION ON FLAT PLATE-WEDGES IN SUPERSONIC, TURBULENT FLOW

YINDA HAN (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 463-471. In Chinese, with abstract in English. refs

A ground test capability for simulating heating and pressure fields around the control wing of controllable lifting vehicles is developed in order to study ablation phenomena on heatshield surfaces. An experimental method based on an arc heater is introduced, and major results are shown for flow separation, heat transfer, and ablation on a model of a control wing for supersonic, turbulent flow across a flat plate. The results show that with a transverse seam in front of the wing angle, the effects of flow separation are weakened, leading to the minimum wing angle that produces increased flow separation. Because of the effects of flow separation the pressures and heat fluxes increase and the ablation velocities increase significantly in the regions on and around the wing. Correlating formulas are presented. C.D.

A89-25939#

TESTING ON TWO DIMENSIONAL VERTICAL MODELS IN A CONVENTIONAL WIND TUNNEL

YIXIN LIU (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 472-479. In Chinese, with abstract in English. refs

This paper recommends a method of testing two-dimensional vertical models in a conventional wind tunnel. Up to now, up to 10 two-dimensional models have been tested using this method in the CARDC 4 x 3 wind tunnel, including the model of the NASA GA(W)-1 airfoil section, which was tested as a calibration model. The results were compared with data from NASA and good agreement was obtained. The tests were conducted over an angle-of-attack from -10 deg to 24 deg and up to a Reynolds number of 4.69 x 10 to the 6th. Tufts were attached for flow visualization. A head rake of 39 Venturi tubes was used to obtain the drag profile. C.D.

A89-25940#

APPLICATIONS OF AF3 EFFICIENT ITERATION SCHEME TO TRANSONIC NONCONSERVATIVE FULL-POTENTIAL FLOW PAST AIRFOILS

HANJIE LI and MINGKE HUANG (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 480-484. In Chinese, with abstract in English. refs

The finite difference method proposed by Jameson (1975) for computation of transonic, nonconservative full-potential flow past airfoils is improved in convergence speed by the use of Baker's (1988) AF3 efficient iteration scheme. A computer program is developed accordingly. Test examples show that computations on a mesh of 128x32 require only several decade iterations in most cases for convergence and that the results obtained agree very well with those by Jameson's original method. Author

A89-25941#

A NUMERICAL METHOD FOR CALCULATING THE LOW-SPEED AERODYNAMIC CHARACTERISTICS OF THE STRAKE-WING CONFIGURATIONS

YANSUN XIANG (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 485-490. In Chinese, with abstract in English. refs

The equivalent concentrated vortex method is used for strake-wing configuration aerodynamic characteristics calculations. When the so-called mixed flow pattern concept is adopted, flow over a strake-wing is characterized by the leading-edge separated vortex flow of the strake and the attached flow of the basic main wing. Similar treatment for a slender wing can be used for the strake and a conventional vortex lattice method can be used for the basic main wing. Calculations were performed to estimate the aerodynamic characteristics of several strake-wing configurations. The results show good agreement with experimental data. C.D.

A89-25942#

AN INTEGRAL METHOD FOR CALCULATING TURBULENT BOUNDARY LAYER FLOW ON PRACTICAL WINGS

HANLING BAO (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 491-496. In Chinese, with abstract in English. refs

In this paper an entrainment method for 3-D compressible turbulent boundary layer on arbitrary wings is presented. The method can be applied to cases of boundary layer with potential or nonpotential external flow fields. The calculating results of this method for the C-5A aircraft wing are fairly close to that of the implicit finite-difference method using Cebecis algebraic turbulent model. An example of viscosity effect on the wing lift and the aerodynamic focus location in a subsonic Mach number using this method is also presented in the paper. Author

A89-25944#

DERIVATION OF AN INTEGRAL EQUATION FOR LARGE DISTURBING TRANSONIC FLOW AND ITS NUMERICAL METHOD OF UNDERCRITICAL FLOW

WUFAN CHEN (National University of Defence Technology, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 501-505. In Chinese, with abstract in English.

In this paper, a new approximate procedure is presented to simplify the potential equation of large-disturbing transonic flow in two-dimensions. An integral equation corresponding to the potential equation has been mathematically derived in which the conditions of boundaries and shock waves are treated in small-disturbing theorem. Author

A89-25946#

AN EFFECTIVE MODELING METHOD OF UNSTEADY AERODYNAMICS FOR STATE-SPACE AEROELASTIC MODELS

QING CHEN (Beijing University of Aeronautics and Astronautics, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 512-516. In Chinese, with abstract in English. refs

This paper presents an effective method for linearizing Karpel's nonlinear model and combining the advantage of Roger's (1977) approximate method, which can get high accuracy by solving elements of a same coefficient matrix independently. The method simplifies the fitting calculation and improves the accuracy of results. Also it has the property of Karpel's minimum number of argumented states. Numerical results are given for the two-dimensional case and the three-dimensional case. Author

A89-26011

UNSTEADY SEPARATION WAVE IN A SUPERSONIC BOUNDARY LAYER [NESTATSIONARNAIA VOLNA OTRYVA V POGRANICHNOM SLOE PRI SVERKHZVUKOVOM OBTEKANII]

V. I. ZHUK and S. P. POPOV (AN SSSR, Vychislitel'nyi Tsentr, Moscow, USSR) Akademiia Nauk SSSR, Doklady (ISSN 0002-3264), vol. 303, no. 4, 1988, p. 822-824. In Russian. refs

Theoretical results are presented on a number of unsteady inviscid flows characterized by the presence of separation zones with closed streamlines propagating upstream along the boundary layer. A numerical solution is obtained to the Burgers equation with inhomogenous terms. It is shown that a shock wave incident on the boundary layer or steady injection creates favorable conditions for the appearance of broad separation zones propagating upstream. B.J.

A89-26163

ASYMPTOTICS OF STATIONARY SEPARATED FLOW PAST A BODY AT LARGE REYNOLDS NUMBERS [ASIMPTOTIKA STATSIONARNOGO OTRYVNOGO OBTEKANIIA TELA PRI BOL'SHIKH CHISLAKH REINOL'DSA]

S. I. CHERNYSHENKO Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 52, Nov.-Dec. 1988, p. 958-966. In Russian. refs

An asymptotic theory is developed for stationary separated flow past bodies at large Re numbers. It is shown that the length and the width of the separation zone are proportional to Re and the drag coefficient is proportional to 1/Re. On the body scale, the flow tends to a Kirchhoff flow satisfying the Brillouin condition with a velocity at a free flow line of the order of Re exp -1/2. V.L.

A89-26368#

NONEQUILIBRIUM VISCOUS HYPERSONIC FLOWS OVER ABLATING TEFLON SURFACES

BILAL A. BHUTTA, DONG JOO SONG, and CLARK H. LEWIS (VRA, Inc., Blacksburg, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs
(Contract F04704-86-C-0031)
(AIAA PAPER 89-0314)

A three-dimensional nonequilibrium parabolized Navier-Stokes (PNS) scheme was developed which can accurately predict the effects of Teflon ablation into air under hypersonic flight conditions. This PNS scheme, which uses a general curvilinear coordinate system, is inherently stable in the subsonic as well as the supersonic flow regions and, thus, does not require any sublayer approximation. Two test cases are presented for the nonequilibrium flow over a sphere-cone configuration with Teflon ablation at the wall, which demonstrate this new PNS scheme under zero and nonzero angle-of-attack conditions, showing the accuracy, efficiency, and stability of the scheme. I.S.

A89-26369*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

EXPERIMENTAL INVESTIGATION OF TRANSONIC OSCILLATING CASCADE AERODYNAMICS

DANIEL H. BUFFUM (NASA, Lewis Research Center, Cleveland, OH) and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0321)

Fundamental experiments are performed in the NASA Lewis Transonic Oscillating Cascade Facility to investigate the subsonic and transonic aerodynamics of cascaded airfoils executing torsion mode oscillations at realistic values of reduced frequency. In particular, an unsteady aerodynamic influence coefficient technique is developed and utilized. In this technique, only one airfoil in the cascade is oscillated at a time, with the resulting airfoil surface unsteady pressure distribution measured on one dynamically-instrumented reference airfoil. The unsteady aerodynamics of an equivalent cascade with all airfoils oscillating at any specified interblade phase angle are then determined through a vector summation of these data. Author

A89-26371*# PRC Systems Services Co., Hampton, VA.

AN EULER ANALYSIS OF LEADING-EDGE VORTEX FLOWS ON A FOREBODY-STRAKE AT SUPERSONIC SPEEDS

O. J. ROSE (PRC Systems Services, Hampton, VA) and JAMES L. PITTMAN (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 19 p. refs
(AIAA PAPER 89-0343)

The flowfield, surface pressure, and integrated forces and moments for a fighter-type forebody with sharp leading-edge strakes have been obtained by numerical solution of the Euler equations. The method is found to correctly predict the leading-edge vortices and embedded shocks which arise at higher angles of attack. Results are presented for the effects of crossflow grid density, artificial viscosity, angle of attack, streamwise station, and camber on the flow characteristics. R.R.

A89-26373*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

LASER VELOCIMETER MEASUREMENTS OF THE FLOWFIELD GENERATED BY AN ADVANCED COUNTERROTATING PROPELLER

GARY G. PODBOY and MARTIN J. KRUPAR (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 33 p. Previously announced in STAR as N89-13409. refs
(AIAA PAPER 89-0434)

Results are presented of an 0.72 regime, with the advance ratio of each rotor set at 2.80. The measured data indicate only a slight influence of the potential field of each front rotor blade on the flowfield upstream of the rotor. The data measured downstream of the front rotor characterize the tip vortices, vortex sheets and potential field nonuniformities generated by the front rotor. The unsteadiness of the flow in the rotating frame of reference of the aft rotor is also illustrated. Author

A89-26374#

PRELIMINARY RESULTS IN THE DEVELOPMENT OF A METHOD TO CORRECT PROPELLER INFLOW FOR IMPROVED UNSTEADY FORCE CALCULATIONS

T. S. MAUTNER (U.S. Navy, Naval Ocean Systems Center, San

Diego, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 29 p. Research supported by the U.S. Navy. refs
(AIAA PAPER 89-0436)
An existing propeller design method was modified and used to calculate the spatial variation of propeller performance and velocity components for use in determining unsteady forces. The calculations showed only small changes in the magnitude of the various velocity components when compared to typical counterrotating propeller design results, and Fourier analysis of the axial velocity data revealed the introduction of the 6th and 18th harmonics which were previously zero. Sign changes in the Fourier coefficients were obtained, and there was approximate agreement between the (absolute) magnitude of both the harmonic coefficients and unsteady forces obtained using the axial velocity and the measured wake (axial and radial components). However, the unsteady force distributions associated with the calculated axial velocity, which includes propeller effects, showed an increase in magnitude at the inner radii with minimal change in the shape of the radial distributions. Author

A89-26689
LOW SPEED AERODYNAMICS OF CANARD CONFIGURATIONS
G. BANDYOPADHYAY (Indian Institute of Technology, Kharagpur, India) Aeronautical Journal (ISSN 0001-9240), vol. 93, Jan. 1989, p. 22-28. Research supported by the Ministry of Defence of India. refs
Numerical methods treating both attached and separated flow over canard surfaces in incompressible, inviscid conditions have been developed for the prediction of aerodynamic characteristics in aircraft of this configuration, assuming that flow over the main wing surface remains attached. Attention is presently given to a comparison of these numerical results with those of a wind tunnel investigation that yielded pressure distributions as well as overall forces and moments. Good agreement is obtained to approximately 16-deg incidence. O.C.

A89-26946
FINITE ELEMENT SIMULATION OF 3D TURBULENT FREE SHEAR FLOWS
DOMINIQUE PELLETIER and RICARDO CAMAREO (Montreal, Ecole Polytechnique, Montreal, Canada) (FIDAP Users Conference, 1st, Evanston, IL, Sept. 13-15, 1987) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 8, Dec. 1988, p. 1563-1586. refs
This paper reviews past and current efforts in developing a simple but robust turbulence model for free shear flows. Much of this work has been published previously and this paper is a rearrangement aimed at the conference. The model is presented and is interfaced with FIDAP to solve three-dimensional flows and a pusher-prop configuration. The eight-node brick, the penalty formulation and the Broyden method are used to solve the Navier-Stokes equations. The propeller is modeled as an actuator disk and the direct simulation of a given propeller is considered in detail. Good results are obtained for the square jet. For propeller cases, detailed comparison with wind tunnel measurements shows excellent prediction of the velocity and pressure for flows of this complexity. Author

A89-27384
EVOLUTION OF PERTURBATIONS NEAR A SURFACE IN SUPERSONIC FLOW [RAZVITIE VOZMUSHCHENII VBLIZI POVERKHNOSTI, OBTEKAEMOI SVERKHZVUKOVYM POTOKOM]
S. A. GAPONOV and V. I. LYSENKO PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Nov.-Dec. 1988, p. 70-76. In Russian. refs
The stability of a supersonic boundary layer near a surface is investigated analytically. It is found that, for different flow parameters, such as longitudinal velocity, temperature, and pressure, the perturbation growth rates are different and that these relations are strongly dependent on the Mach number. The results are compared with experimental data obtained by using hot-wire anemometers on the surface of models. V.L.

A89-27706#
TURBULENCE MEASUREMENTS IN A RADIAL UPWASH
BARRY GILBERT (Grumman Corporate Research Center, Bethpage, NY) AIAA Journal (ISSN 0001-1452), vol. 27, Jan. 1989, p. 44-51. Previously cited in issue 18, p. 2809, Accession no. A87-42455. refs
(Contract F49620-85-C-0111)

A89-27716#
DIAGONAL IMPLICIT MULTIGRID CALCULATION OF INLET FLOWFIELDS
D. A. CAUGHEY and R. K. IYER (Cornell University, Ithaca, NY) AIAA Journal (ISSN 0001-1452), vol. 27, Jan. 1989, p. 110-112. refs
The Caughey (1988) diagonal implicit multigrid algorithm for solving the Euler equations of two-dimensional transonic flow is presently extended in order to compute the supersonic flow past, and that within, a two-dimensional planar inlet. The inlet studied has a 10-deg ramp and a 20-deg wedge cowl, and is subjected to a Mach 2 freestream velocity; because the farfield flow is supersonic, all flow variables are specified at points on the inflow boundary, while all flow variables are extrapolated from the interior of the domain at points on the outflow boundary. O.C.

A89-27728#
SUPERSONIC, TRANSVERSE JET FROM A ROTATING OGIVE CYLINDER IN A HYPERSONIC FLOW
D. L. MCMASTER, J. S. SHANG (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH), and W. C. GOLBITZ (DNA, Washington, DC) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Jan.-Feb. 1989, p. 24-30. Previously cited in issue 18, p. 2810, Accession no. A87-42459. refs

A89-27742*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF SIDEWALL BOUNDARY LAYER ON A WING IN A WIND TUNNEL
V. N. VATSA (NASA, Langley Research Center, Hampton, VA) and B. W. WEDAN (Vigyan Research Associates, Inc., Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 157-161. Previously cited in issue 07, p. 927, Accession no. A88-22073. refs

A89-27746#
TURBULENCE MODELING IN SEPARATED FLOW BEHIND STRONG SHOCKS
DON W. KINSEY (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) and F. E. EASTEP (Dayton, University, OH) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 185, 186. Previously cited in issue 07, p. 941, Accession no. A88-22531. refs

A89-27748#
INVESTIGATION OF INTERNAL SINGULARITY METHODS FOR MULTIELEMENT AIRFOILS
M. J. SHEU (National Tsing Hua University, Hsinchu, Republic of China) and D. R. CHEN Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 189-192. refs
The present flat-element method, which is based on linear distributions of vorticity and sources along the mean-camber line of the airfoil elements, is noted to constitute a useful approach to the solution of general potential flow problems. The method obviates the leaving of a gap between the leading edge and the element on the mean-camber line that is closest to the leading edge, in order to avoid the instability of the numerical solutions. Good agreement is obtained between flat-element method and curved-element method pressure distributions. O.C.

A89-28074
EULER FLOW SOLUTIONS FOR TRANSONIC SHOCK WAVE-BOUNDARY LAYER INTERACTION
BARRY KOREN (Centrum voor Wiskunde en Informatica, Amsterdam, Netherlands) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 9, Jan. 1989, p. 59-73. Research supported by Stichting voor de Technische Wetenschappen. refs

Steady two-dimensional Euler flow computations have been performed for a wind tunnel section, designed for research on transonic shock wave-boundary layer interaction. For the discretization of the steady Euler equations, an upwind finite volume technique has been applied. The solution method used is collective, symmetric point Gauss-Seidel relaxation, accelerated by nonlinear multigrid. Initial finest grid solutions have been obtained by nested iteration. Automatic grid adaptation has been applied for obtaining sharp shocks. An indication is given of the mathematical quality of four different boundary conditions for the outlet flow. Two transonic flow solutions with shock are presented: a choked and a non-choked flow. Both flow solutions show good shock capturing. A comparison is made with experimental results. Author

A89-28203* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LOW-SPEED VORTICAL FLOW OVER A 5-DEGREE CONE WITH TIP GEOMETRY VARIATIONS
J. CHU, R. M. HALL, and S. O. KJELGAARD (NASA, Langley Research Center, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 9 p. refs
(SAE PAPER 881422)

Experimental results on the surface pressures and sectional side forces on a 5-deg cone were obtained for the cases of three different nose tips. The sectional side force data for both the sharp cone and the blunt nose cone configurations showed a dependence on roll orientation. The blunt nose configurations were found to be effective in reducing the sectional side force for angles of attack up to 25 deg. R.R.

A89-28218* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LDV SURVEYS OVER A FIGHTER MODEL AT MODERATE TO HIGH ANGLES OF ATTACK
WILLIAM L. SELLERS, III, JAMES F. MEYERS (NASA, Langley Research Center, Hampton, VA), and TIMOTHY E. HEPNER (U.S. Army, Aviation Research and Development Command, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 14 p. refs
(SAE PAPER 881448)

The vortex flowfield over an advanced twin-tailed fighter configuration has been studied in a low-speed wind tunnel at two angles of attack using LDV, along with laser light sheet and surface flow visualizations. At 15 deg angles of attack, the vortices generated by the wing leading edge extension (LEX) were found to be unburst over the model and to pass outboard of the vertical tail. At 25 deg angle of attack, the vortices were shown to burst in the vicinity of the wing-LEX intersection and to impact directly on the vertical tails. R.R.

A89-28229* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THEORETICAL INVESTIGATION FOR THE EFFECTS OF SWEEP, LEADING-EDGE GEOMETRY, AND SPANWISE PRESSURE GRADIENTS ON TRANSITION AND WAVE DRAG TRANSONIC, AND SUPERSONIC SPEED WITH EXPERIMENTAL CORRELATIONS
S. H. GORADIA and P. J. BOBBITT (NASA, Langley Research Center, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 26 p. refs
(Contract NAS1-17919)
(SAE PAPER 881484)

A89-28251*# Vigyan Research Associates, Inc., Hampton, VA.
VISCOUS SHOCK-LAYER SOLUTIONS FOR THE LOW-DENSITY HYPERSONIC FLOW PAST LONG SLENDER BODIES
R. N. GUPTA (Vigyan Research Associates, Inc., Hampton, VA), J. N. MOSS, E. V. ZOBY (NASA, Langley Research Center, Hampton, VA), S. N. TIWARI (Old Dominion University, Norfolk, VA), and K. P. LEE AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 16 p. refs
(AIAA PAPER 88-0460)

Results are obtained for the surface pressure, drag, heat-transfer, and skin-friction coefficients for hyperboloids and sphere cones. Body half angles from 5 to 22.5 degrees are considered for various low-density flow conditions. Recently obtained surface-slip and shock-slip equations are employed to account for the low-density effects. The method of solution employed for the viscous shock-layer (VSL) equations is a partially coupled spatial-marching implicit finite-difference technique. The flow cases analyzed include highly cooled long slender bodies in high Mach number flows. The present perfect-gas VSL calculations compare quite well with available experimental data. Results have also been obtained from the steady-state Navier-Stokes (NS) equations by successive approximations. Comparison between the NS and VSL results indicates that VSL equations even with body and shock-slip boundary conditions may not be adequate in the stagnation region at altitudes greater than about 75 km for the cases analyzed here. Author

A89-28341*# Massachusetts Inst. of Tech., Cambridge.
ACTIVE SUPPRESSION OF AERODYNAMIC INSTABILITIES IN TURBOMACHINES
A. H. EPSTEIN, J. E. FFOWCS WILLIAMS, and E. M. GREITZER (MIT, Cambridge, MA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 204-211. Previously cited in issue 22, p. 3219, Accession no. A86-45410. refs
(Contract NSG-3208)

A89-28404*# High Technology Corp., Hampton, VA.
FLOW MEASUREMENT ON THE FUSELAGE OF A BOEING 737 AIRPLANE
A. BERTELRUD (High Technology Corp., Hampton, VA), R. D. WATSON, and C. B. MCGINLEY (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 23 p. refs
(AIAA PAPER 89-0209)

Results are presented on flow measurements on the fuselage of a Boeing 737 aircraft, carried out during flight tests. The instruments used to measure static pressure, local skin friction, boundary layer characteristics, turbulence properties, and pressure fluctuations are described together with the computational methods used. Boundary layer thicknesses were found to be typically 6-8 inches at Reynolds numbers based on the momentum thickness of 60-180,000, depending on flight conditions and location along the fuselage. I.S.

A89-28406*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UNSTEADY EULER CASCADE ANALYSIS
JONG-SHANG LIU (NASA, Lewis Research Center, Cleveland, OH; Textron Lycoming, Stratford, CT) and PETER M. SOCKOL (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0322)

The results of an investigation of the rotor-stator interaction phenomena in turbomachines are presented. Numerical study was carried out by solving the unsteady Euler equations in the blade-to-blade direction for a variety of cascade geometries. The problem of uneven rotor and stator blades is addressed by adopting the tilted time domain technique. Computed solutions are presented and discussed for a NACA 0012 type cascade and the first stage fuel turbopump of the Space Shuttle Main Engine (SSME). Author

A89-28407*# Case Western Reserve Univ., Cleveland, OH.
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF AN OBLIQUE SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTION WITH CONTINUOUS SUCTION
DRISS BENHACHMI, ISAAC GREBER (Case Western Reserve University, Cleveland, OH), and WARREN R. HINGST (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract NAG3-61)
(AIAA PAPER 89-0357)

An numerical and experimental investigation has been conducted into the interaction of an incident oblique shock wave with a turbulent boundary layer, for the cases of a rough plate and a porous plate with suction, at a nominal Mach number of 2.5 and flow deflection angles of 0, 4, 6, and 8 deg. Attention is given to the pitot pressure profiles, wall static pressures, and porous plate local bleed distributions measured for the two plates. Suction is found to increase the strength of the incident shock required to separate the boundary layer; for all shock strengths tested, separation is completely eliminated. O.C.

A89-28413*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL ANALYSIS OF FLOW THROUGH OSCILLATING CASCADE SECTIONS
DENNIS L. HUFF (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 24 p. Previously announced in STAR as N89-14220. refs
(AIAA PAPER 89-0437)

The design of turbomachinery blades requires the prevention of flutter for all operating conditions. However, flow field predictions used for aeroelastic analysis are not well understood for all flow regimes. The present research focuses on numerical solutions of the Euler and Navier-Stokes equations using an ADI procedure to model two-dimensional, transonic flow through oscillating cascades. The model prescribes harmonic pitching motions for the blade sections for both zero and nonzero interblade phase angles. The code introduces the use of a deforming grid technique for convenient specification of the perioidic boundary conditions. Approximate nonreflecting boundary conditons were coded for the inlet and exit boundary conditions. Sample unsteady solutions were performed for an oscillating cascade and compared to experimental data. Also, test cases were run for a flat plate cascade to compare with the unsteady, small-perturbation, subsonic analysis. The predictions for oscillating cascades with nonzero interblade phase angle cases, which were near a resonant condition, differ from the experiment and theory. The zero degree interblade phase angle cases, which were near a resonant condition, differ from the experiment and theory. Studies on reflecting versus nonreflecting inlet and exit boundary conditions show that the treatment of the boundary can have a significant effect on the first harmonic, unsteady pressure distribution for certain flow conditions. Author

A89-28428*# Analytical Services and Materials, Inc., Hampton, VA.
OPTIMIZATION OF NATURAL LAMINAR FLOW AIRFOILS FOR HIGH SECTION LIFT-TO-DRAG RATIOS IN THE LOWER REYNOLDS NUMBER RANGE
WERNER PFENNINGER and CHANDRA S. VEMURU (Analytical Services and Materials, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. refs
(Contract NAS1-18235; NAS1-18599)
(AIAA PAPER 89-0539)

Relatively thin natural-laminar-flow airfoils were arranged optimally for different design lift coefficients in the wing chord Reynolds number ranges of 200,000-600,00 and 0.875 x 10 to the 6th to 2 x 10 to the 6th. The 9.5 percent thick airfoil ASM-LRN-010, the 7.9 percent thick airfoil ASM-LRN-012, the 10.4 percent thick airfoil ASM-LRN-015, and the 8.2 percent thick airfoil ASM-LRN-017 were designed for high lift-to-drag ratios using Drela's design and analysis. K.K.

A89-28434#
THE EFFECTS OF ASPECT RATIO ON THE STALL OF A FINITE WING
ALLEN E. WINKELMANN (Maryland, University, College Park) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. refs
(AIAA PAPER 89-0570)

Results of the first phase of a study of the stall characteristics of high-aspect-ratio plane rectangular wings are presented. The oil flow visualization tests on a wing AR = 9 have indicated the existence of three and then four mushroom-shaped stall cells as the angle of attack has increased toward full stall. The effects of yawing a high-aspect-ratio plane rectangular wing are such that discrete mushroom stall cells do not occur. K.K.

A89-28442#
TRANSONIC STORE SEPARATION USING A THREE-DIMENSIONAL CHIMERA GRID SCHEME
F. CARROLL DOUGHERTY and JYH-HORNG KUAN (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0637)

This paper describes the development of a numerical simulation capability, using finite difference techniques, for flows around aircraft carrying stores. A multiple overset mesh approach, called the chimera scheme, is used in order to avoid the difficulties associated with generating a single global mesh around this complex configuration. In the chimera scheme, the configuration is mapped with a global mesh about the main component (the wing), and minor overset meshes are generated about each additional component (the stores). The minor meshes can be freely moved with respect to the global mesh, so that a time-accurate simulation of a moving store beneath a wing is possible without regridding the configuration. An implicit approximate factorization code for inviscid calculations is used here to solve time-dependent Euler equations to simulate flows about separating stores. It is shown that the time accuracy is adequately maintained, and the automatic bookkeeping routines are capable of tracking the moving grids in three dimensions. S.A.V.

A89-28443*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE FREE-WAKE PREDICTION OF ROTOR HOVER PERFORMANCE USING A VORTEX EMBEDDING METHOD
K. RAMACHANDRAN (Flow Analysis, Inc., Mountain View, CA), C. TUNG, and F. X. CARADONNA (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0638)

A method is developed to predict the rotor hover performance. This method solves the compressible mass conservation equation much like current full potential codes and can therefore predict the transonic flows on a rotor. However, the newly developed approach also allows for the free convection of shed vorticity and permits the computation of the entire hover wake system. The method uses a vortex embedding scheme in potential flow and has been implemented in a computer code, HELIX -I. To predict power we implement a simple boundary layer and two different induced-drag integration schemes. The induced-drag is obtained from surface pressure integration and an energy flux integral. Comparisons between computations and experiment show good agreement for the prediction of power polars, surface pressure distribution, and tip vortex geometry. Author

A89-28444#
F-14 FLOW FIELD SIMULATION
K. Y. SZEMA, S. R. CHAKRAVARTHY, and B. L. BIHARI (Rockwell International Science Center, Thousand Oaks, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p.
(AIAA PAPER 89-0642)

The computer code EMTAC-MZ has been applied to investigate the flow field over a variety of very complex three-dimensional configurations for supersonic flow with large subsonic pockets. In the code, a finite volume, multizone implementation of high accuracy, total variation diminishing formulation is used to solve the unsteady Euler equations. In the supersonic regions of the flow, an 'infinitely large' time step and a space-marching scheme is employed. A finite time step and a relaxation of three-dimensional approximate factorization method is used in subsonic flow regions. The multizone technique allows very complicated configurations to be modeled without geometry modifications, and can easily handle combined yaw and angle of attack cases. The F-14 flow field was investigated at subsonic and high angle of attack conditions by using the EMTAC-MZ code. Numerical results are obtained and are in very good agreement with available experimental data. Author

A89-28453*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN EXPERIMENTAL INVESTIGATION OF MULTI-ELEMENT AIRFOIL ICE ACCRETION AND RESULTING PERFORMANCE DEGRADATION
MARK G. POTAPCZUK (NASA, Lewis Research Center, Cleveland, OH) and BRIAN M. BERKOWITZ (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 39 p. Previously announced in STAR as N89-15084. refs
(AIAA 89-0752)

An investigation of the ice accretion pattern and performance characteristics of a multi-element airfoil was undertaken in the NASA Lewis 6- by 9-Foot Icing Research Tunnel. Several configurations of main airfoil, slat, and flaps were employed to examine the effects of ice accretion and provide further experimental information for code validation purposes. The text matrix consisted of glaze, rime, and mixed icing conditions. Airflow and icing cloud conditions were set to correspond to those typical of the operating environment anticipated for a commercial transport vehicle. Results obtained included ice profile tracings, photographs of the ice accretions, and force balance measurements obtained both during the accretion process and in a past-accretion evaluation over a range of angles of attack. The tracings and photographs indicated significant accretions on the slat leading edge, in gaps between slat or flaps and the main wing, on the flap leading-edge surfaces, and on flap lower surfaces. Force measurements indicate the possibility of severe performance degradation, especially near C sub Lmax, for both light and heavy ice accretion and performance analysis codes presently in use. The LEWICE code was used to evaluate the ice accretion shape developed during one of the rime ice tests. The actual ice shape was then evaluated, using a Navier-Strokes code, for changes in performance characteristics. These predicted results were compared to the measured results and indicate very good agreement. Author

N89-16726# Continuum Dynamics, Inc., Princeton, NJ.
VORTEX DYNAMICS FOR ROTORCRAFT INTERACTIONAL AERODYNAMICS
TODD R. QUACKENBUSH and DONALD B. BLISS (Duke Univ., Durham, NC.) Mar. 1988 65 p Prepared in cooperation with Duke University, Durham, NC
(Contract DAAL03-87-C-0013)
(AD-A200128; ARO-25093.1-EG-SBI) Avail: NTIS HC A04/MF A01 CSCL 01A

Promising results were obtained that indicate that new techniques in the analysis of vortex dynamics could be used as the foundation of a general analysis of rotor/airframe interactions. Prediction of the velocity field downstream of helicopter rotors was addressed first. Using a novel, full-span rotor wake representation constructed of curved vortex elements, accurate qualitative and quantitative predictions of wake velocity data were achieved for rotors in both low- and high-speed forward flight. The flow field predictions illustrated the radical changes that take place in the wake velocity field as speed increases and demonstrated the success of this approach in capturing these variations. New methods for analyzing close interactions between vortices and fixed surfaces were developed. The basis of this new approach is the inclusion of the special treatment of the vortex velocity field for close interactions with paneled surfaces which obviates the need for high local panel density. Model problems were solved featuring vortices in close proximity to flat surfaces and cylinders that amply illustrate the accuracy and efficiency of the new method. GRA

N89-16728# Naval Postgraduate School, Monterey, CA.
AERODYNAMIC PERFORMANCE OF WINGS OF ARBITRARY PLANFORM IN INVISCID, INCOMPRESSIBLE, IRROTATIONAL FLOW M.S. Thesis
CHRIS L. HOLM Sep. 1988 200 p
(AD-A200436) Avail: NTIS HC A09/MF A01 CSCL 01A

This thesis contains discussion, theory and program code for a computational fluid dynamics (CFD) model of a wing of arbitrary planform. The mathematical model assumes incompressible, inviscid, irrotational flow. The program computes forces acting on the wing by modeling the flow with a set of horseshoe vortex elements. It models the flow over an arbitrary wing using two solutions. One solution is the ideal lift, associated with a cambered and twisted wing. The other solution is the additional lift associated with a flat wing. The program computes wing camber and twist using an elliptic loading distribution. The thesis includes the FORTRAN source code, a separable user's manual for the VORTEX program, discussion of the theory applied in the model, and instructions for operating the program. It shows a sample wing planform with tabular and graphic results. Two other CFD models are also discussed, based on circulation and pressure difference, along with some of the problems and solutions in grid generation. Computer programs. Theses. (edc) GRA

N89-16730 ESDU International Ltd., London (England).
ESTIMATION OF DRAG ARISING FROM ASYMMETRY IN THRUST OR AIRFRAME CONFIGURATION
Dec. 1988 40 p
(ESDU-88006; ISBN-0-85679-638-7; ISSN-0141-4054) Avail: ESDU

This data item 88006, an addition to the Sub-series on Aircraft Performance, gives a simple method, based on a correlation of established for a range of propeller and turbo-jet and turbo-fan powered aircraft, for predicting approximately the drag increment in flight with one or more engines inoperative (including the drag of the failed engine(s)). The derivation of the parameters used in that non-dimensional presentation is also considered and methods of estimating asymmetric flight is also considered and methods of estimating some of them are provided together with a list of sources of data for the others. The force and moment equations used to determine equilibrium flight conditions are given for use with either estimated or wind-tunnel aerodynamic data and an example of their application to a transport aeroplane is included. There is also a detailed discussion of alternative ways in which an aircraft may be flown in steady straight flight with thrust or other airframe asymmetries. ESDU

N89-16731 ESDU International Ltd., London (England).
ROLLING MOMENT DERIVATIVE LXI, FOR PLAIN AILERONS AT SUBSONIC SPEEDS
Aug. 1988 18 p Supersedes ESDU Aero C.06.01.01
(ESDU-88013; ISBN-0-85679-645-X; ISSN-0141-397X) Avail: ESDU

This Data Item 88013, an addition to the Sub-series on Aerodynamics, presents a semi-empirical method that improves the traditional approach based on Weissinger's simplified lifting-surface theory which drew parallels with the dihedral contribution to the rolling moment due to sideslip. The method relies on ESDU 74011 to estimate the lift increment due to control deflection (in conjunction with the wing lift-curve slope from ESDU 70011), assumes that it acts at the mid-span of the aileron, and corrects the rolling moment so derived by an empirical factor that allows for the aileron effectiveness. The ranges of wing and control geometry for which the method is validated are given, and it is found to predict the derivative to within 20 percent for values up to -0.15 and to within 0.03 for numerically higher values. ESDU

N89-16732 ESDU International Ltd., London (England).
DERIVATION OF PRIMARY AIR-DATA PARAMETERS FOR HYPERSONIC FLIGHT
Dec. 1988 48 p
(ESDU-88025; ISBN-0-85679-657-3; ISSN-0141-4054) Avail: ESDU

This Data Item 88025, an addition to the Sub-series on Aircraft Performance, gives data and methods of analysis for deriving true airspeed, Mach number, pressure height and ambient air temperature from registered values of total pressure and temperature, and static pressure. The methods apply for Mach numbers between approximately 4 and 10 and for heights up to 65 km (210,000 ft). Such air data are of particular importance where they are used to control an air-breathing propulsion unit. The assuptions and limitations of the methods are clearly stated and explaned, and a worked example illustrates the use of graphs and tables for the properties of equilibrium air behind a normal shock which are then used with the Rankine-Hugoniot relationships to devise the required data. ESDU

N89-16734 ESDU International Ltd., London (England).
YAWING MOMENT COEFFICIENT FOR PLAIN AILERONS AT SUBONIC SPEEDS
Dec. 1988 16 p
(ESDU-88029; ISBN-0-85679-661-1; ISSN-0141-397X) Avail: ESDU

This data item 88029, an addition to the Sub-series on Aerodynamics, predicts the adverse yawing moment accompanying aileron deflection as two components, an induced drag contribution due to the differential setting and a profile drag component. For the first component a semi-empirical correlation procedure is developed while for the second the method of ESDU 87024, which deals with the profile drag due to deflection of plain flaps, is used. The method applies to sealed controls (or controls with small gaps) and allows for differential operation and flap deployment. The experimental data drawn from the literature (with some unpublished wind-tunnel measurements) covered a wide range of wing and aileron geometry which is specified. The method predicted the change of yawing moment coefficient per unit control deflection to within 0.003/rad at zero lift and without deployed flaps. ESDU

N89-16735 ESDU International Ltd., London (England).
BOUNDARIES OF LINEAR CHARACTERISTICS OF CAMBERED AND TWISTED WINGS AT SUBCRITICAL MACH NUMBERS
Nov. 1988 43 p
(ESDU-88030; ISBN-0-85679-662-X; ISSN-0141-397X) Avail: ESDU

This Data Item 88030, an addition to the Sub-series on Aerodynamics, estimates the onset of non-linear aerodynamic characteristics by giving an empirical method for predicting the incidence and corresponding lift coefficient for either initial leading- or trailing-edge separation. The method developed treats the incidence as contributed to by three components: one from a datum plane wing, and one each from the superimposed aerodynamically smooth wings provided that the local effective twist does not exceed 10 degrees and will not apply when the ranges of planform and flow conditions are covered by the method (including aspect ratios from 1.4 to 13 and leading-edge sweeps from zero to 62 degrees). The method applies to any camber line slope, which may vary spanwise, as may the thickness chord ratio, and comparisons are shown between predicted lift coefficient for the onset of separation for both leading- and trailing-edge types which show it is predicted to within 15 percent. Comprehensive practical worked examples illustrate the use of the method, and a calculation summary sheet guides the user step-by-step through the procedure. ESDU

N89-16736 ESDU International Ltd., London (England).
LIFT AND LONGITUDINAL FORCES ON PROPELLER/NACELLE/WING/FLAP SYSTEMS
Dec. 1988 41 p
(ESDU-88031; ISBN-0-85679-663-8; ISSN-0141-397X) Avail: ESDU

This Data Item 88031, an addition to the Sub-series on Aerodynamics, provides a simple semi-empirical method for estimating the free air low-speed values of these forces for an unswept wing/flap system submerged in the slipstream from multiple propellers. It provides for the separate estimation of forces on the propeller and on the nacelle/wing/flap and requires a knowledge of the geometry and of the power-off lift and drag for the nacelle/wing/flap. There is a basic method, developed using simple momentum theory, which applies to flaps continuous across the slipstream, circular section nacelles of diameter equal to that of the spinner, and propellers that do not overlap. Guidance is then provided on the effect of flap cut-out, nacelle size and propeller overlap. The wing may be fitted with any of a wide range of single- or multi-element flaps, provided the flow is fully attached. Estimates are provided over the full range of thrust coefficients (based on slipstream kinetic pressure and propeller disc area) from zero to unity and predictions of the lift and longitudinal force on the nacelle/wing/flap system are within 10 and 15 percent respectively. ESDU

N89-16738# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
INTAKE AERODYNAMICS, VOLUME 1
1988 333 p Lecture series held in Rhode-Saint-Genese, Belgium, 22-26 Feb. 1988
(VKI-LS-1988-04-VOL-1; ISSN-0377-8312; ETN-89-93592) Avail: NTIS HC A15/MF A01

Tactical fighter inlets; inlet-engine compatibility; intake swirl and simplified methods for dynamic pressure distortion assessment; Jaguar/Tornado intake design; intake-airframe integration; intakes for high angle of attack; transonic cowl design; and intake drag were discussed.
ESA

N89-16739# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
INTRODUCTION TO INTAKE AERODYNAMICS
J. SEDDON *In its* Intake Aerodynamics, Volume 1 28 p 1988
Avail: NTIS HC A15/MF A01

Pressure recovery in axial flow engines, with subsonic or supersonic inlets; boundary layers around inlets; inlet drag; and variable geometry inlets are introduced. ESA

N89-16740# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Flight Dynamics Lab.
TACTICAL FIGHTER INLETS
LEWIS E. SURBER and KEITH E. NUMBERS *In* VKI, Intake Aerodynamics, Volume 1 34 p 1988
Avail: NTIS HC A15/MF A01

It is shown that the design of a tactical fighter air intake results from a compromise of performance and stability against complexity and weight, driven by overall aircraft mission requirements. Intake design requires thorough understanding of the various facets of inlet performance and the flow field phenomena which affect them. The basic measures of performance and the primary flow field phenomena which must be controlled are introduced. Design considerations involved in maximizing pressure recovery, minimizing drag, and controlling the flow for improved uniformity and steadiness are discussed. Given the design techniques available and their implementation in current aircraft it is shown that the inlet configuration itself can reveal much about the intended aircraft mission application and the overall system design philosophy.
ESA

N89-16742# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.
INTAKE SWIRL AND SIMPLIFIED METHODS FOR DYNAMIC PRESSURE DISTORTION ASSESSMENT
F. AULEHLA and D. M. SCHMITZ *In* VKI, Intake Aerodynamics, Volume 1 58 p 1988
Avail: NTIS HC A15/MF A01
It is shown that all supersonic intakes of present combat aircraft produce essentially two types of swirl components of varying magnitude, i.e., bulk and twin swirl. Depending on the sensitivity of the engine towards such disturbances serious engine/intake compatibility problems may arise, for example engine surge and fan vibration. The remedial measures to overcome this problem are described and the solution of fenced intakes selected for Tornado is discussed. A similar problem solution for the Airbus A300 is also presented. The relevance of dynamic total pressure distortion as the prime compatibility parameter for engines without inlet guide vanes is questioned and a proposal for an improved intake disturbance simulation in engine bench tests is made. It is suggested that fully dynamic distortion measurements can be replaced by simplified methods at least in the early stage of a project. ESA

N89-16743# British Aerospace Aircraft Group, Preston (England). Military Aircraft Div.
JAGUAR/TORNADO INTAKE DESIGN
D. C. LEYLAND *In* VKI, Intake Aerodynamics, Volume 1 25 p 1988
Avail: NTIS HC A15/MF A01
The assessment of aerodynamic features that led to the chosen intake configurations and particular aspects that had to be taken into account in overall design of the Jaguar and Tornado intakes are summarized. Intake sizing and profiles; pressure recovery; boundary layers; intake control; supersonic characteristics; and vortex-incidence aspects are discussed. ESA

N89-16747# British Aerospace Aircraft Group, Preston (England). Military Aircraft Div.
INTAKE DRAG
D. C. LEYLAND *In* VKI, Intake Aerodynamics, Volume 28 p 1988
Avail: NTIS HC A15/MF A01
Intake drag associated with location and external geometry at full mass flow and that due to reduction in entry flow from the maximum or datum value, the engine throttle dependent term, is discussed. General methods for estimating intake spillage drag are given but there is considerable installation geometry dependence and it is preferable to use test data for a similar configuration. The need for a correct understanding of the origin of propulsion related forces and of the requirements for proper book keeping of thrust and drag terms is emphasized. The use of part models in propulsion installation analysis is reviewed, and it is suggested that distinction needs to be made between the contributions to axial force from potential flow and real flow, only the latter part being strictly drag and contributing to overall aircraft drag. The use of data from part models is indicated, in support of the usual book keeping arrangement for throttle dependent terms to be taken into the engine installation account. ESA

N89-16748# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
INTAKE AERODYNAMICS, VOLUME 2
1988 302 p Lecture series held in Rhode-Saint-Genese, Belgium, 22-26 Feb. 1988
(VKI-LS-1988-04-VOL-2; ISSN-0377-8312; ETN-89-93593) Avail: NTIS HC A14/MF A01
Transport aircraft intake design; missile intakes; wind tunnel air intake test techniques; computational methods for inlet airframe integration; computational fluid dynamics (CFD) application to subsonic inlet airframe integration; and CFD application to supersonic/hypersonic inlet airframe integration were discussed. ESA

N89-16751# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
WIND TUNNEL AIR INTAKE TEST TECHNIQUES
JACKY LEYNAERT *In* VKI, Intake Aerodynamics, Volume 2 30 p 1988
Avail: NTIS HC A14/MF A01
The general concept and validation of wind tunnel intake test setups are reviewed. The main intake test parameters are defined. Test rigs adapted to subsonic transport intakes, and to supersonic or combat aircraft intakes at supersonic Mach number, at transonic, and low speed are discussed. Devices for unsteady flow analysis, and for detailed inner flow probing are mentioned. ESA

N89-16753*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CFD APPLICATION TO SUBSONIC INLET AIRFRAME INTEGRATION
BERNHARD H. ANDERSON *In* VKI, Intake Aerodynamics, Volume 2 59 p 1988
Avail: NTIS HC A14/MF A01
The fluid dynamics of curved diffuser duct flows of military aircraft is discussed. Three-dimensional parabolized Navier-Stokes analysis, and experiment techniques are reviewed. Flow measurements and pressure distributions are shown. Velocity vectors, and the effects of vortex generators are considered. ESA

N89-16754*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CFD APPLICATION TO SUPERSONIC/HYPERSONIC INLET AIRFRAME INTEGRATION
THOMAS J. BENSON *In* VKI, Intake Aerodynamics, Volume 2 62 p 1988
Avail: NTIS HC A14/MF A01
Supersonic external compression inlets are introduced, and the computational fluid dynamics (CFD) codes and tests needed to study flow associated with these inlets are outlined. Normal shock wave turbulent boundary layer interaction is discussed. Boundary layer control is considered. Glancing sidewall shock interaction is treated. The CFD validation of hypersonic inlet configurations is explained. Scramjet inlet modules are shown. ESA

N89-16756# Centre Aeroporte de Toulouse (France).
STUDY OF THE AERODYNAMIC SITUATION ALONG THE C 160 AIRCRAFT IN PARACHUTING CONFIGURATION [ETUDE DE LA SITUATION AERODYNAMIQUE LE LONG DU C 160 EN CONFIGURATION DE PARACHUTAGE]
M. CAROL May 1988 97 p In FRENCH
(DAT-88-06; ETN-89-93610) Avail: NTIS HC A05/MF A01
Wind tunnel tests and flight tests were carried out to characterize the aerodynamic flow along and behind the C 160 aircraft when proceeding to a parachuting operation. The study gives indications to improve the aircraft design and the understanding of parachute behavior after leaving the aircraft. The test results, associated to a theoretical analysis show that the aerodynamical effect on the torsion of a parachute in automatic operation is negligible. ESA

N89-16757# National Aeronautical Lab., Bangalore (India). Fluid Mechanics Div.
NUMERICAL SOLUTION OF FLOW FIELDS AROUND DELTA WINGS USING EULER EQUATIONS METHOD
ANAND KUMAR and A. DAS (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) Jan. 1987 15 p Presented at the International Vortex Flow Symposium on Euler Code Validation, Stockholm, Sweden, 1-3 Oct. 1986
(NAL-TM-FM-8701) Avail: NTIS HC A03/MF A01
Flow over cropped delta wings having a leading edge sweep of 65 deg and an aspect ratio of 1.38 are computed using the DFVLR Euler code. Both sharp and round leading edges are considered. Calculations are performed for angles of incidence of 10, 20 and 24 deg for free-stream Mach number of 0.85, and for

angles of incidence of 2, 10, to 30 deg (5 deg) for free-stream Mach number of 0.4. Influence of grid refinement and surface pressure evaluation on the solution are also studied. Author

N89-16758*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.
AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC CHARACTERISTICS OF SLANTED BASE OGIVE CYLINDERS USING MAGNETIC SUSPENSION TECHNOLOGY Progress Report, 1 Apr. - 30 Sep. 1988
CHARLES W. ALCORN and COLIN BRITCHER Aug. 1988 90 p
(Contract NAG1-716)
(NASA-CR-184624; NAS 1.26:184624) Avail: NTIS HC A05/MF A01 CSCL 01A

An experimental investigation is reported on slanted base ogive cylinders at zero incidence. The Mach number range is 0.05 to 0.3. All flow disturbances associated with wind tunnel supports are eliminated in this investigation by magnetically suspending the wind tunnel models. The sudden and drastic changes in the lift, pitching moment, and drag for a slight change in base slant angle are reported. Flow visualization with liquid crystals and oils is used to observe base flow patterns, which are responsible for the sudden changes in aerodynamic characteristics. Hysteretic effects in base flow pattern changes are present in this investigation and are reported. The effects of a wire support attachment on the zero degree slanted base model is studied. Computational drag and transition location results using VSAERO and SANDRAG are presented and compared with experimental results. Base pressure measurements over the slanted bases are made with an onboard pressure transducer using remote data telemetry. Author

N89-16760# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
REYNOLDS NUMBER EFFECTS IN TRANSONIC FLOW
A. ELSENAAR, T. W. BINION, JR., E. STANEWSKY, and H. C. HORNUNG, ed. (California Inst. of Tech., Pasadena.) Mar. 1989 92 p
(AGARD-AG-303) Avail: NTIS HC A05/MF A01

Reynolds number effects in transonic flow are critically reviewed. A discussion is presented of the viscous effects observed on realistic configurations. The following geometries are considered: Airfoils and high aspect ratio wings typical of transport aircraft, fighter-type low aspect ratio delta wings, two- and three-dimensional bodies characteristic of missiles and combat aircraft fuselages, and afterbodies. Pseudo-Reynolds number effects are identified which may arise, for instance due to the influence of the Reynolds number on the wind tunnel environment and in turn affect the flow about a model. As an introduction, a brief retrospect of the history of Reynolds number effect is presented. Author

N89-16761*# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
DEVELOPMENT OF DIRECT-INVERSE 3-D METHODS FOR APPLIED TRANSONIC AERODYNAMIC WING DESIGN AND ANALYSIS Semiannual Progress Report, 1 Jul. - 31 Dec. 1988
LELAND A. CARLSON Feb. 1989 85 p
(Contract NAG1-619)
(NASA-CR-184788; NAS 1.26:184788; TAMRF-5373-89-01)
Avail: NTIS HC A05/MF A01 CSCL 01A

Progress in the direct-inverse wing design method in curvilinear coordinates has been made. This includes the remedying of a spanwise oscillation problem and the assessment of grid skewness, viscous interaction, and the initial airfoil section on the final design. It was found that, in response to the spanwise oscillation problem that designing at every other spanwise station produced the best results for the cases presented, a smoothly varying grid is especially needed for the accurate design at the wing tip, the boundary layer displacement thicknesses must be included in a successful wing design, the design of high and medium aspect ratio wings is possible with this code, and the final airfoil section designed is fairly independent of the initial section. Author

N89-16847*# Army Aviation Systems Command, Moffett Field, CA.
A CRITICAL ASSESSMENT OF WIND TUNNEL RESULTS FOR THE NACA 0012 AIRFOIL
W. J. MCCROSKEY *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 21 p Jul. 1988 Previously announced as N88-11636
Avail: NTIS HC A22/MF A01 CSCL 01A

A large body of experimental results, obtained in more than 40 wind tunnels on a single, well known two-dimensional configuration, was critically examined and correlated. An assessment of some of the possible sources of error was made for each facility, and data which are suspect were identified. It was found that no single experiment provided a complete set of reliable data, although an investigation stands out as superior in many respects. However, from the aggregate of data the representative properties of the NACA 0012 airfoil can be identified with reasonable confidence over wide range of Mach numbers, Reynolds number, and angles of attack. This synthesized information can now be used to assess and validate existing and future wind tunnel results and to evaluate advanced Computational Fluid Dynamics codes. Author

N89-16849# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
COMPARISON OF THE RESULTS OF TESTS ON A300 AIRCRAFT IN THE RAE 5 METRE AND THE ONERA F1 WIND TUNNELS
C. QUEMARD and P. B. EARNSHAW (Royal Aircraft Establishment, Farnborough, England) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p Jul. 1988
Avail: NTIS HC A22/MF A01

Studies of the A300 Airbus were carried out in the pressurized low speed wind tunnel at RAE and ONERA. Initially comparison of the results from the same model mounted on an identical three strut support, showed discrepancies which in the case of lift coefficient amounted to about 2.5 pct. A systematic comparison was made of the measurement techniques together with the methods used in the reduction of the resulting data. The production of uncorrected aerodynamic coefficients required the measurement of loads by means of underfloor balances and of the reference pressure. Checks were carried out on the balance calibrations confirming their accuracy after which an attempt was made in both facilities to assess and refine the accuracy of the reference pressure measurement. As a result, corrections were applied to the measurements made in both wind tunnels which reduced but did not eliminate the differences between the two sets of results. The data reduction relies on corrections to be applied for tunnel wall interference as well as that from the strut support system. Author

N89-16858# Office National d'Etudes et de Recherches Aerospatiales, Modane (France).
PRECISION IMPROVEMENT OF TRANSPORT AIRCRAFT DRAG MEASUREMENTS [AMELIORATION DE LA PRECISION DE LA MESURE DE LA TRAINEE D'UN AVION DE TRANSPORT]
C. ARMAND and C. PUJOL (Societe Nationale Industrielle Aerospatiale, Toulouse, France) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 14 p Jul. 1988 In FRENCH
Previously announced in IAA as A88-22597
Avail: NTIS HC A22/MF A01

Methods used in the ONERA S1MA and S2MA wind tunnels for attaining the desired absolute precision of 0.0002 in drag measurements of Airbus type transport aircraft are discussed. Factors considered include the quality of the balances, the precision of the incidence measurements, and the effects of friction and extreme temperatures. It is also noted that in order to obtain accurate drag measurements the airfoil geometry and the pressure distribution on the airfoil must be known to a high degree of precision. The results are corrected for the pressure fields in the test section and for the effects of the wall and the sting. E.R.

N89-16869# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
SOME DIFFICULTIES IN THE WIND TUNNEL PREDICTION OF MODERN CIVIL AIRCRAFT BUFFETING: PROPOSED REMEDIES
R. DESTUYNDER, V. SCHMITT, J. BERGER, and R. BARREAU (Societe Nationale Industrielle Aerospatiale, Toulouse, France) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 14 p Jul. 1988 In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

The prediction of transport aircraft buffet response still remains a challenge despite recent progress in understanding of the phenomenon. The prediction is up to now inaccessible to a purely theoretical approach and so is mainly based on wind tunnel investigations. After a review of experimental methods currently used to determine model buffeting and a short description of full scale application techniques, the simulation problems that appear are presented. The next point deals with a number of improvements concerning models and experimental methodology with the final objective to provide more reliable buffeting predictions on large transport aircrafts. Author

N89-17566 Old Dominion Univ., Norfolk, VA.
FULL-POTENTIAL INTEGRAL SOLUTIONS FOR STEADY AND UNSTEADY TRANSONIC AIRFOILS WITH AND WITHOUT EMBEDDED EULER DOMAINS Ph.D. Thesis
HONG HU 1988 173 p
Avail: Univ. Microfilms Order No. DA8813660

The integral equation solution of the full potential equation is presented for steady and unsteady transonic airfoil flow problems. The method is also coupled with an embedded Euler domain solution to treat flows with strong shocks for steady flows. For steady transonic flows, three integral equation schemes are well developed. The three schemes are applied to different airfoils over a wide range of Mach numbers, and the results are in good agreement with the experimental data and other computational results. For unsteady transonic flows, the full-potential equation formulation in the moving frame of reference was used. The steady Integral Equation with Shock Capturing (IE-SC) scheme was extended to treat airfoils undergoing time-dependent motions, and the unsteady IE-SC scheme was thus developed. The resulting unsteady scheme was applied to a NACA 0012 airfoil undergoing a pitching oscillation around the quarter chord length. The numerical results are compared with the results of an implicit approximately-factored Euler scheme. Dissert. Abstr.

N89-17568*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NASA SC(2)-0714 AIRFOIL DATA CORRECTED FOR SIDEWALL BOUNDARY-LAYER EFFECTS IN THE LANGLEY 0.3-METER TRANSONIC CRYOGENIC TUNNEL
RENALDO V. JENKINS Washington, DC Mar. 1989 58 p
(NASA-TP-2890; L-16385; NAS 1.60:2890) Avail: NTIS HC A04/MF A01 CSCL 01A

This report presents the corrected aerodynamic data for A NASA SC(2)-0714 airfoil tested in the Langley 0.3-Meter Transonic Cryogenic Tunnel. This test was another in the series of tests involved in the joint NASA/U.S. industry Advanced Technology Airfoil Tests program. This 14 percent thick critical airfoil was tested at Mach numbers from 0.6 to 0.76 and angles of attack from -2.0 to 6.0 deg. The test Reynolds numbers were 4 million, 6 million, 10 million, 15 million, 30 million, 40 million, and 45 million. Corrections for the effects of the sidewall boundary layer have been made. The uncorrected data were previously published in NASA Technical Memorandum 4044. Author

N89-17569 Texas Univ., Arlington.
AN EXPERIMENTAL INVESTIGATION OF THE PERPENDICULAR VORTEX-AIRFOIL INTERACTION AT TRANSONIC SPEEDS Ph.D. Thesis
IRAJ MASBOOGHI KALKHORAN 1987 178 p
Avail: Univ. Microfilms Order No. DA8812828

Extensive studies were conducted in the UTA High Reynolds Number Transonic Wind Tunnel facility. The tests included a complete calibration of the wind tunnel over a wide range of transonic Mach numbers and at Reynolds numbers representing the normal operating condition of interest to aerospace vehicles. Experimental tests of the compressible trailing vortex system were performed by means of a thorough probing of the viscous core of the vortex system. Detailed flow field measurements and contour plots of the total pressure field in the neighborhood of the vortex core are presented. Thorough tests were conducted to investigate the pressure distribution on a C-141 and a NACA airfoil sections for a range of transonic flow conditions. The results obtained from these experiments indicate a substantial change in the pressure distribution of the downstream airfoil, a spanwise drift of the vortex core after interacting with the airfoil, and a high degree of unsteadiness in the vicinity of the vortex viscous core.
Dissert. Abstr.

N89-17577*# Johnson Aeronautics, Palo Alto, CA.
WAKE MODEL FOR HELICOPTER ROTORS IN HIGH SPEED FLIGHT
WAYNE R. JOHNSON Nov. 1988 305 p
(Contract NAS2-12767)
(NASA-CR-177507; USAVSCOM-TR-88-A-008; NAS 1.26:177507)
Avail: NTIS HC A14/MF A01 CSCL 01A

Two alternative approaches are developed to calculate blade-vortex interaction airloads on helicopter rotors: second order lifting-line theory, and a lifting surface theory correction. The common approach of using a larger vortex core radius to account for lifting-surface effects is quantified. The second order lifting-line theory also improves the modeling of yawed flow and swept tips. Calculated results are compared with wind tunnel measurements of lateral flapping, and with flight test measurements of blade section lift on SA349/2 and H-34 helicopter rotors. The tip vortex core radius required for good correlation with the flight test data is about 20 percent chord, which is within the range of measured viscous core sizes for helicopter rotors. Author

N89-17578*# McDonnell-Douglas Helicopter Co., Mesa, AZ.
APPLICATION OF A COMPREHENSIVE ANALYTICAL MODEL OF ROTOR AERODYNAMICS AND DYNAMICS (CAMRAD) TO THE MCDONNELL DOUGLAS AH-64A HELICOPTER Final Report
CYNTHIA B. CALLAHAN and DUANE E. BASSETT Nov. 1988 62 p
(Contract NASA ORDER A-63622-C)
(NASA-CR-177455; NAS 1.26:177455) Avail: NTIS HC A04/MF A01 CSCL 01A

A model of the AH-64A helicopter was generated in a Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics (CAMRAD) in an effort to validate its analytical capabilities for modeling a current advanced Army helicopter. The initial phase of the effort involved the generation of CAMRAD input files necessary for the complete aerodynamic, structural, and dynamic definition of the production AH-64A helicopter. The input files were checked by making comparisons of CAMRAD full helicopter trim and main rotor blade natural frequency predictions with those of full helicopter trim program, Blade Element Trim (BETRIM), and dynamic analysis code, Dynamic Analysis Research Tool (DART), respectively. The main thrust concerned the application of the AH-64A CAMRAD model thus developed and verified for main rotor blade structural loads predictions and comparison with DART analytical results. The investigation provided insight not only into the usefulness of CAMRAD for the AH-64A performance and dynamics prediction, but also into the limitations of the program for modeling advanced rotor and fuselage systems. The model development effort is discussed, the results of the

CAMRAD correlation studies presented, and some general conclusions are offered on the applicability of CAMRAD for rotor aeroelastic loads prediction for current and future rotorcraft configurations. Author

N89-17579*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TIP AERODYNAMICS AND ACOUSTICS TEST: A REPORT AND DATA SURVEY
JEFFREY L. CROSS and MICHAEL E. WATTS Dec. 1988 463 p
(NASA-RP-1179; A-87128; NAS 1.61:1179) Avail: NTIS HC A20/MF A01 CSCL 01A

In a continuing effort to understand helicopter rotor tip aerodynamics and acoustics, a flight test was conducted by NASA Ames Research Center. The test was performed using the NASA White Cobra and a set of highly instrumented blades. All aspects of the flight test instrumentation and test procedures are explained. Additionally, complete data sets for selected test points are presented and analyzed. Because of the high volume of data acquired, only selected data points are presented. However, access to the entire data set is available to the researcher on request. Author

N89-17580# Tokyo Univ. (Japan). Inst. of Space and Astronautical Science.
A NUMERICAL SIMULATION OF FLOWS ABOUT TWO-DIMENSIONAL BODIES OF PARACHUTE-LIKE CONFIGURATION
TORU SHIMADA Jun. 1988 15 p
(ISAS-629; ISSN-0285-6808) Avail: NTIS HC A03/MF A01

Transient aerodynamic characteristics of the flows around bodies of parachute-like configuration are numerically analyzed from the solution of the Navier-Stokes equations. The computational method is mainly based upon the combination of effective and efficient techniques recently developed in the field of computational fluid mechanics. The results show that the flow behavior around a mouth plays a key role in determining the maximum peak drag acting on the parachute-like body in the starting period from the rest and also a vent is effective in controlling the starting peak of the drag. Author

N89-17582# Naval Surface Weapons Center, Silver Spring, MD.
NOTES ON A THEORETICAL PARACHUTE OPENING FORCE ANALYSIS APPLIED TO A GENERAL TRAJECTORY Final Report, 1987 - 1988
WILLIAM P. LUDTKE 28 May 1988 72 p
(AD-A201050; NSWC-TR-88-6) Avail: NTIS HC A04/MF A01 CSCL 01C

The report presents a method for calculating the inflation reference time and opening shock forces of the solid-cloth family of parachutes when deployed at an arbitrary trajectory angle to the horizontal. The method is extended to other types of parachutes, but it is limited in that the inflation reference times are not calculated as part of the deployment process. Particular inflation times must be provided as input data to the furnished computer program. The variation of opening shock force versus inflation reference time may be surveyed by providing several values or using actual field test data. Examples are used to demonstrate the effects of canopy cloth rate of airflow, altitude, and trajectory deployment angle for constant velocity and constant dynamic pressure altitude profiles. GRA

03

AIR TRANSPORTATION AND SAFETY

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

A89-25545#
ON DESIGN AND PROJECTED USE OF DOPPLER RADAR AND LOW-LEVEL WINDSHEAR ALERT SYSTEMS IN AIRCRAFT TERMINAL OPERATIONS
EDWIN KESSLER (Oklahoma, University, Norman) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0704)

The path of development envisioned by the FAA for a prospective Doppler radar which may be useful in warning against low-altitude windshear near airports is presently questioned, on the grounds that while the system contemplated will yield high-quality operation in the high plains and desert regions of the U.S., windshear-related accidents in such regions are rare. By contrast, the major accidents involving windshear in the Mississippi region and eastward to the Atlantic coast have been associated with heavy precipitation; since precipitation-detection would then control aircraft guidance, windshear-detection capabilities would be redundant. O.C.

A89-25547#
WEATHER ACCIDENT PREVENTION USING THE TOOLS THAT WE HAVE
DENNIS W. NEWTON (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0707)

This paper points out devices and methods which have the potential to increase safety in hazardous weather situations. The methods are available, or could be made available quickly and at reasonable cost. Some instances of effective use of existing tools are cited by way of example. Author

A89-25553*# Continuum Dynamics, Inc., Princeton, NJ.
PROBLEMS IN UNDERSTANDING AIRCRAFT ICING DYNAMICS
ALAN J. BILANIN (Continuum Dynamics, Inc., Princeton, NJ) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by NASA. refs
(AIAA PAPER 89-0735)

A general discussion of the nonthermodynamic mechanisms present during ice accretion on nonrotatig and rotating/flexing aerodynamic surfaces is undertaken. It is shown that competing physical effects do not in general allow a rigorous scaling methodology to be formulated, but suggestions are made which may result in an acceptable approxiamte scaling scheme. A test program is described which may provide data from which these approximate scaling schemes may be validated. Author

A89-25555#
ENROUTE CONVECTIVE TURBULENCE DEVIATION CONSIDERATIONS ON SHORT SEGMENTS
JEFFREY L. DICKINSON (Southwest Airlines Co., Dallas, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p.
(AIAA PAPER 89-0738)

This paper deals with the subject of enroute turbulence and weather avoidance as seen from a line pilot's point of view. The policies, procedures and techniques used enroute at both high and low altitude for weather avoidance or when encountering unsuspected hazardous weather are included. These procedures and techniques are generic to all carriers utilizing high performance, swept wing commercial aircraft. Author

A89-25556#
ENROUTE TURBULENCE AVOIDANCE PROCEDURES
ARCHIE TRAMMELL (AJT, Inc., Trinidad, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 5 p.
(AIAA PAPER 89-0739)

Case studies are analyzed which illustrate the possibilities for weather disturbance avoidance through greater reliance on airliner crews' more perspicacious use of airborne radar data that are already available in contemporary cockpits. The major considerations involved in the anticipation of possible weather problems during flight encompass a dewpoint greater than 50 F, a temperature/dewpoint spread greater than 30 F, and a turbulent weather feature movement that is greater than 10 knots. Attention is given to the possible consequences of these conditions over time. O.C.

A89-25557#
THE EFFECTS OF ENROUTE TURBULENCE REPORTS ON AIR CARRIER FLIGHT OPERATIONS
W. S. DOBBS (American Airlines, Inc., Dallas, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p.
(AIAA PAPER 89-0741)

The science of meteorology has been continually improved through the development of many new tools and techniques. The resultant effects on airline flight planning have aided dramatically in reducing the discomforts and potential hazards of enroute encounters with turbulence. While forecasting the large scale dynamics of the upper air environment is now being done more accurately than ever before, the immensity of this environment allows many small scale anomalies to exist undetected except through firsthand experience. By requiring immediate reports on time, altitude, location and type from those pilots who experience such anomalous turbulence, it may be possible to prevent similar encounters by subsequent flights, and to add to a body of knowledge intended to further improve forecasting. Author

A89-25558#
DO PILOTS LET AIRCRAFT OPERATIONS SCHEDULES INFLUENCE ENROUTE TURBULENCE AVOIDANCE PROCEDURES?
E. B. MCCRARY (SimuFlite Training International, Dallas, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 4 p.
(AIAA PAPER 89-0743)

An account is given of the factors responsible for the degree to which pilots allow scheduling considerations to influence their reactions to the detection of atmospheric turbulence conditions and the selection of appropriate turbulence-avoidance procedures. Attention is given to the fixation on time-schedules that may be brought to commercial airline operations by pilots with extensive experience in military flying. It is noted that insufficient consciousness of the turbulence-avoidance problem may delay necessary political action on behalf of regulatory improvement of procedures. O.C.

A89-25560*# Ohio State Univ., Columbus.
EFFECT OF SIMULATED GLAZE ICE ON A RECTANGULAR WING
M. B. BRAGG and A. KHODADOUST (Ohio State University, Columbus) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by NASA. refs
(AIAA PAPER 89-0750)

Experimental measurements of the effect of simulated glaze ice on a three-dimensional wing are presented. A semispan wing of effective aspect ratio five was mounted from a splitter plate in the OSU subsonic wind tunnel. The model has a straight, untwisted rectangular platform, and uses a NACA 0012 airfoil section. Surface pressures were measured at 5 semispan locations and a total-pressure wake-survey probe was used on the model centerline. The section lift and drag data from the model centerline compared well to earlier two-dimensional data. These data show a large drag and maximum lift penalty due to the simulated glaze ice. Three-dimensional span-load data compare well to computational results. Author

A89-25561*# United Technologies Corp., Windsor Locks, CT.
PROP-FAN AIRFOIL ICING CHARACTERISTICS
J. A. PIKE, H. S. WAINAUSKI, and L. S. BOYD (United Technologies Corp., Windsor Locks, CT) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 32 p. Research supported by NASA. refs
(AIAA PAPER 89-0753)

An icing test program was carried out during the 1986-87 and 1987-88 icing seasons at the Fluidyne Icing Tunnel. The testing consisted of evaluating the icing characteristics and aerodynamic performance characteristics of two thin, two-dimensional airfoil sections. The two airfoils were a NACA Series 16-203 and a Hamilton Standard PF1-304, 3 and 4 percent thickness-to-chord ratio airfoils, respectively. These airfoils are representative of the thin airfoils currently being evaluated for Prop-Fan propulsion systems. The tests were conducted over a wide range of icing conditions, angles-of-attack, and Mach numbers (0.3 to 0.8). Author

A89-25563#
SELECTION OF THE CRITICAL ICING/FLIGHT CASE FOR AN UNPROTECTED AIRFOIL
KENNETH E. YEOMAN (Key Industries Corp., San Antonio, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0757)

A method for determining the critical icing conditions for an aircraft is discussed. The method defines trends caused by variations in the geometry, flight, and icing parameters. It is suggested that the trend method uses less computer time than the method which determines the finite values of collection efficiency. Methods for determining trends in the effects of altitude, temperature, airspeed, and aircraft operation are given. R.B.

A89-25564#
ELECTROMAGNETIC EMISSIONS FROM A MODULAR LOW VOLTAGE EIDI SYSTEM
PETER ZIEVE, BRENT HUFFER, and JAMES NG (Electroimpact, Inc., Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. Research sponsored by FAA. refs
(AIAA PAPER 89-0758)

An important consideration in the certification of Electro-Impulse Deicing (EIDI) systems for aircraft ice protection is electromagnetic interference (EMI). The Low Voltage Electro-Impulse De-Icing system is unique in that the capacitor bank is mounted adjacent to the coil thereby eliminating most of the cables. Electromagnetic emissions from this system would then be primarily from the coil. The performed tests investigate the EMI environment inside and outside of both a composite and an aluminum wing. Measurements of the radiated electric field indicate that emissions from the aluminum wing were well within the standards. Some tests with the composite wing were within standards while others were not. It was found that the composite wing could be brought back into compliance through the addition of thin metallic shielding. Author

A89-25566#
INFRARED TECHNIQUE TO MEASURE THE SKIN TEMPERATURE ON AN ELECTROTHERMAL DE-ICER - COMPARISON WITH NUMERICAL SIMULATIONS
ROBERT C. HENRY and DIDIER P. GUFFOND (ONERA, Chatillon-sous-Bagneux, France) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0760)

Helicopters are developed and certified under icing conditions using models capable of simulating the behavior of electrothermal deicers. An electrothermal deicer has been modeled by the finite difference method. To validate the code, the blade temperatures during the deicing process must be known. As the skin temperature is difficult to measure by sensors, in particular during a deicing sequence, the infrared technique has been used. Deicing code results are compared with measured temperature, and further developments are presented. Author

A89-25567#
DROPLET IMPACTION ON A SUPERSONIC WEDGE - CONSIDERATION OF SIMILITUDE
L. J. FORNEY (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0763)

The theoretical collection efficiency has been determined for water droplets impinging on a two-dimensional supersonic wedge with an attached shock. By defining a moving coordinate system such that the gas is stationary behind the shock and scaling the droplet Stokes number with a shock-to-wedge distance, a similarity parameter has been defined which properly accounts for the effects of freestream Mach number, wedge angle and large droplet Reynolds number. The effective Stokes number, which represents the ratio of the droplet stopping distance in the moving frame to the appropriate shock-to-wedge length, is shown to correlate both the total collection efficiency and local impingement rate. Author

A89-25584#
IMPACT OF SEVERE WEATHER ON AVIATION - AN NWS PERSPECTIVE
CHARLES H. SPRINKLE, JR. (NOAA, National Weather Service, Silver Spring, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0795)

Methods for providing the aviation community with weather information are reviewed, focusing on techniques used by the National Weather Service for weather observation, storm detection, and forecast formulation. Several aviation weather systems are described, including the Automated Surface Observing System, the Next Generation Weather Radar, the Terminal Doppler Weather Radar, thermodynamic and wind atmospheric profilers, the Aircraft to Satellite Data Relay, and the Aeronautical Radio Incorporated Communications Addressing and Reporting System. The use of satellite remote sensing of the atmosphere, surface-based lightning detection systems, the Advanced Weather Interactive Processing System, and the work done at the National Severe Storms Forecast Center are examined. The prospects for future aviation weather dissemination systems are considered. R.B.

A89-25585#
THE EFFECTS OF INCLEMENT WEATHER ON AIRLINE OPERATIONS
JAMES F. SULLIVAN (USAir, Pittsburgh, PA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 4 p.
(AIAA PAPER 89-0797)

The operation of airline dispatch offices is discussed, focusing on the way in which they handle inclement weather conditions. The use of weather information from the FAA, the National Weather Service, and contract sources on flight planning is examined. The effects of several types of inclement weather are considered, including snow, clear air turbulence, wind, and freezing rain. R.B.

A89-25592#
WEATHER DATA DISSEMINATION TO AIRCRAFT
RICHARD H. MCFARLAND and CRAIG B. PARKER (Ohio University, Athens) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0809)

The requirements for the transmission of weather data products from the ground to aircraft by data uplink are determined. It is shown that the Mode S Beacon System (Orlando and Drouilhet, 1982) does not have sufficient data link capability to provide service to all aircraft. An alternative system is proposed which uses hybrid modulation techniques to transmit data on an existing aeronautical VHF voice communication channel. Results are presented from a computer analysis which demonstrates the capability of this hybrid modulation technique. R.B.

A89-26231
ELECTRIC CHARGE ACQUIRED BY AIRPLANES PENETRATING THUNDERSTORMS
J. J. JONES (New Mexico Institute of Mining and Technology, Socorro) IN: International Conference on Atmospheric Electricity, 8th, Uppsala, Sweden, June 13-16, 1988, Proceedings. Uppsala, Sweden, Institute of High Voltage Research, 1988, p. 560-565. refs
(Contract NSF ATM-82-05468; NSF ATM-82-18621; NSF ATM-86-00526)

Three airplanes - a sailplane, a piston-powered sailplane, and a twin turboprop - have been instrumented to measure electric fields inside thunderstorms. A method is presented for determining the net electric charge on the airplanes. For small amounts of charge on the airplane the engine exhaust acts to discharge the airplane, while for larger charges corona emission becomes the predominant mechanism of discharge. In unelectrified clouds the powered airplanes become negatively charged in the presence of liquid cloud water droplets. In thunderstorm electric fields there are at least two charging mechanisms. One involves the liquid water droplets of the cloud and the other shedding of polarization charge in strong fields. For both charging processes the sign of the acquired charge depends on the sign of the electric field component along the direction of flight. Author

A89-27249
PROBLEMS OF ENSURING CIVIL-AIRCRAFT FIRE SAFETY
V. K. LUZHETSKII (Gosudarstvennyi Nauchno-Issledovatel'skii Institut Grazhdanskoi Aviatsii, Moscow, USSR) ICAO Bulletin (ISSN 0018-8778), vol. 43, Oct. 1988, p. 26-29.

Experimental and theoretical research by Soviet scientist to study airborne fire-protection systems is examined. The ways in which fires start and spread are reviewed. The development of fire-warning systems for future aircraft is discussed, including the functional requirements, structure, flight tests, and specific procedures such as landing and smoke removal. In addition, the psychological aspects of a crew's actions during an in-flight fire are considered. R.B.

A89-27739*# Massachusetts Inst. of Tech., Cambridge.
INVESTIGATION OF SURFACE WATER BEHAVIOR DURING GLAZE ICE ACCRETION
R. JOHN HANSMAN, JR. and STEPHEN R. TURNOCK (MIT, Cambridge, MA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 140-147. Research supported by FAA. Previously cited in issue 07, p. 943, Accession no. A88-22079. refs
(Contract NAG3-666; NGL-22-009-640)

A89-28187
RESULTS OF THE AIA/ATA/FAA DYNAMIC SEAT TESTING PROGRAM
JAMES L. WEBSTER, SR., JEAN A. MCGREW, and WILLIAM H. SHOOK (Douglas Aircraft Co., Long Beach, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 7 p.
(SAE PAPER 881375)

Dynamic tests were conducted in 1986 with airline passenger triple-seat assemblies to gain experience in testing methods and to gather data on airline seat performance in the dynamic environment of an emergency landing. The test series investigated acceleration levels, impact velocity, longitudinal and vertical impacts, multiple-row effects, and floor deformation. The test conditions remained below the point of total seat assembly failure so that the performance of the seat assemblies could be evaluated for structural integrity, reaction loads of the seat legs with the floor structure, and the loads experienced by the instrumented dummy occupant. Author

A89-28188
MEASUREMENT OF DYNAMIC REACTIONS IN PASSENGER SEAT LEGS
VAN GOWDY and RICHARD F. CHANDLER (FAA, Civil Aeromedical Institute, Oklahoma City, OK) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 9 p. refs
(SAE PAPER 881376)
A procedure is described for measuring the dynamic forces acting between seats and the floor of an aircraft during an impact. The procedure involves a series of sled tests using strain gages on the seat legs to measure the impact, and the calibration of the strain gage output in terms of forces transmitted to the floor of a rigid test fixture during the test of each seat. The instrumentation, the acquired data, and the analysis of the results of calibration procedure results are presented. I.S.

A89-28189
TRANSPORT AIRPLANE FUSELAGE SECTION LONGITUDINAL IMPACT TEST
RICHARD JOHNSON, STEVE SOLTIS (FAA, Washington, DC), JIM BLAKER, and BARRY WADE (Ohio, Transportation Research Center, East Liberty) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 18 p. refs
(SAE PAPER 881377)
A transport airplane fuselage section with a full complement of cabin seats and anthropomorphic test dummies was longitudinally impact-tested at a condition that approached the ultimate strength of the airframe protective shell structure. Airframe structural responses, seat/floor reaction loads, and the interactive effects of secondary impacts between multiple cabin seat rows were investigated. The scope and conduct of the test are presented together with some preliminary analyses of the test results. Author

A89-28190
DISCUSSION OF TRANSPORT PASSENGER SEAT PERFORMANCE CHARACTERISTICS
S. P. DESJARDINS, MARK R. CANNON, and S. JOSEPH SHANE (Simula, Inc., Phoenix, AZ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 11 p. refs
(SAE PAPER 881378)
The performance requirements for the seats of a transport aircraft are summarized. It is emphasized that, in order to minimize the severity of injury to the passenger while providing sufficient opportunity to egress, the seat must have the following characteristics: (1) it must carry the inertial loads of the occupant and the seat and to limit the floor reaction loads to magnitudes not above the floor strength, (2) must minimize the hazard associated with the secondary impact of the accupants with the seat in front, and (3) must not leave the occupant in a position or orientation that would impede egress. Some of the factors that must be considered in designing such a seat are discussed. I.S.

A89-28191
EFFECTS OF AIRCRAFT SIZE ON CABIN FLOOR DYNAMIC PULSES
CAESAR A. CAIAFA and LAWRENCE M. NERI (FAA, Technical Center, Atlantic City, NJ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 17 p. refs
(SAE PAPER 881379)
The experiments performed during the Federal Aviation Administration sponsored tests on the effect of the aircraft size on cabin-floor dynamic pulses are described. The results of narrow-body- and wide-body-section tests are reviewed, together with the results of a supporting analytical model, and the relationships between the parameters which influence the dynamic response of aircraft structure are defined. The aircraft-size-effect trend curves for the cabin floor dynamic pulses are developed in terms of triangular pulse acceleration magnitude, velocity change, and pulse duration. Data on the effects of aircraft size on the cabin-floor dynamic pulses are presented for several types of aircraft, including the commuter aircraft, general-aviation aircraft, and narrow-body and wide-body transport aircraft. I.S.

A89-28192* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN OVERVIEW OF THE CURRENT NASA PROGRAM ON AIRCRAFT ICING RESEARCH
RICHARD J. RANAUDO, ANDREW L. REEHORST, and MARK G. POTAPCZUK (NASA, Lewis Research Center, Cleveland, OH) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 20 p. refs
(SAE PAPER 881386)
The NASA Lewis Research Center is presently conducting an aircraft icing research program, the major thrust of which is to advance technologies that improve our ability to model the icing phenomenon and its effect on aircraft. The approach employs three interrelated elements: analysis; wind tunnel experiments; and, considerable flight testing in natural icing clouds. This paper presents a brief overview of this program with emphasis on recent accomplishments. Author

A89-28294#
WAYS TO SOLVE CURRENT FLIGHT-SAFETY PROBLEMS [WEGE ZUR LOESUNG DER AKTUELLEN PROBLEME DER FLUGSICHERUNG]
Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 343-362. In German.
The current status of flight-safety systems in the FRG and of European cooperation in this field is surveyed, and policy alternatives for solving outstanding and foreseeable problems are suggested, in a report presented by FRG administration officials to the budget committee of the Bundestag. Topics addressed include the continuing rapid growth of European air traffic volume, the sudden and unpredicted 15-20-percent increase during 1987, the potential impact of EEC integration plans for 1992, the geographically and militarily central position of the FRG, and personnel shortages in the FRG ATC agencies. Consideration is then given to short-term and long-term planning strategies, international negotiations and the role of Eurocontrol, and specific measures for possible inclusion in the 1989 FRG budget. T.K.

A89-28448#
ANALYSIS OF ARROW AIR DC-8-63 ACCIDENT GANDER, NEWFOUNDLAND ON 12 DECEMBER 1985
JAMES K. LUERS and MARK A. DIETENBERGER (Dayton, University, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 23 p. Research sponsored by the Canadian Aviation Safety Board.
(AIAA PAPER 89-0706)
A two-part performance analysis of the Arrow Air DC-8-63 takeoff accident which occurred at Gander, Newfoundland on December 12, 1985 is presented. Takeoff sensitivity analysis was performed using a digital, fixed stick, simulation program to establish the relative performance degradation resulting from several candidate causes. The accident trajectory was reconstructed by solving the airplane equations of motion using flight recorder data as input. Consistent results are achieved by the two approaches. C.D.

A89-28451*# Massachusetts Inst. of Tech., Cambridge.
MODELING OF SURFACE ROUGHNESS EFFECTS ON GLAZE ICE ACCRETION
R. JOHN HANSMAN, JR., KEIKO YAMAGUCHI (MIT, Cambridge, MA), BRIAN BERKOWITZ (Sverdrup Technology, Inc., Middleburg Heights, OH), and M. POTAPCZUK (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(Contract NAG3-666; NGL-22-009-640)
(AIAA 89-0734)
The cause and effects of roughness on accreting glaze ice surfaces were studied with microvideo observations. Distinct zones of surface water behavior were observed, including a smooth wet

zone in the stagnation region with a uniform water film, a rough zone where surface tension effects caused coalescence of surface water into stationary beads, and a zone where roughness elements grow into horn shapes. In addition, a zone where surface water ran back as rivulets and a dry zone where rime feathers formed were observed. The locations and behaviors of these zones are discussed. A simple multizone modification to the glaze ice accretion model is proposed to include spatial variability in surface roughness. Two test cases using the multizone model showed significant improvements for the prediction of glaze ice shapes.
R.B.

A89-28464*# Rice Univ., Houston, TX.
OVERVIEW OF OPTIMAL TRAJECTORIES FOR FLIGHT IN A WINDSHEAR
A. MIELE, T. WANG (Rice University, Houston, TX), W. W. MELVIN (Delta Air Lines, Inc., Atlanta, GA), and H. WANG AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 41 p. Research supported by Boeing Commercial Airplane Co. and Air Line Pilots Association. refs
(Contract NAG1-516)
(AIAA 89-0812)
Optimal flight trajectories for the B-727, B-737, and B-747 aircraft in the presence of wind shear are studied. The takeoff problem and the abort landing problem are considered with reference to flight in a vertical plane. In the former, optimal trajectories are computed by minimizing the peak deviation of the absolute path inclination from a reference value; in the latter, optimal trajectories are computed by minimizing the peak value of the altitude drop. Numerical computations show that, for both the problems under consideration, the optimal trajectories of the three aircraft show the same qualitative behavior. Hence, it appears that the near-optimal guidance schemes developed for the B-727 can be extended to the other two aircraft, albeit with some quantitative modification.
C.D.

A89-28486
KINEMATICS OF U.S. ARMY HELICOPTER CRASHES - 1979-85
DENNIS F. SHANAHAN and MAUREEN O. SHANAHAN (U.S. Armed Forces Institute of Pathology, Washington, DC) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, Feb. 1989, p. 112-121. refs
All records of U.S. Army Class A and B mishaps of four types of helicopters occurring from Oct. 1, 1979, through Sept. 30, 1985, were reviewed for terrain impact kinematic parameters. During this 6-year period, there were 298 mishaps involving 303 aircraft. Approximately 88 percent of these crashes were considered survivable. Mean and 95th percentile vertical velocity changes at the most severe terrain impact were similar for all aircraft types except the UH-60, which experienced significantly higher impact velocities. Overall 95th percentile vertical and horizontal velocity changes at the most severe terrain impact were 11.2 m/s and 25.5 m/s, respectively. Both these values are substantially different from values cited in current design standards. Roll, pitch, and yaw attitudes at impact were similar for all aircraft and agreed with the values in current design standards, except that the distribution of roll angles was considerably wider. The importance of using current kinematic parameters for crashworthiness design standards and crash injury prevention is stressed. Recommendations are made to improve crashworthiness design standards.
Author

N89-16766# Sandia National Labs., Albuquerque, NM. Systems Engineering Div.
AVIATION SECURITY: A SYSTEM'S PERSPECTIVE
JAMES P. MARTIN 1988 35 p Presented at the 5th FAA International Civil Aviation Security Conference, Washington, DC, 24 Oct. 1988
(Contract DE-AC04-76DP-00789)
(DE89-002020; SAND-88-2629C; CONF-8810219-1) Avail: NTIS HC A03/MF A01
For many years the aviation industry and airports operated with security methods and equipment common to most other large industrial complexes. At that time, the security systems primarily provided asset and property protection. However, soon after the first aircraft hijacking the focus of security shifted to emphasize the security requirements necessary for protecting the traveling public and the one feature of the aviation industry that makes it unique---the airplane. The airplane and its operation offered attractive opportunities for the homesick refugee, the mentally unstable person and the terrorist wanting to make a political statement. The airport and its aircraft were the prime targets requiring enhanced security against this escalated threat. In response, the FAA, airport operators and air carriers began to develop plans for increasing security and assigning responsibilities for implementation.
DOE

N89-16768# National Transportation Safety Board, Washington, DC.
AIRCRAFT ACCIDENT/INCIDENT SUMMARY REPORT, TRAVIS AIR FORCE BASE, CALIFORNIA, 8 APRIL 1987
31 Dec. 1988 16 p
(PB88-910414; NTSB-AAR-88-03-SUM) Avail: NTIS HC A03/MF A01 CSCL 01C
This report is a summary of an aircraft accident investigated by the National Transportation Safety Board. The accident location and date is Travis Air Force Base, California, April 8, 1987.
Author

N89-17584*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN OF AUTOMATION TOOLS FOR MANAGEMENT OF DESCENT TRAFFIC
HEINZ ERZBERGER and WILLIAM NEDELL Dec. 1988 35 p
(NASA-TM-101078; A-89058; NAS 1.15:101078) Avail: NTIS HC A03/MF A01 CSCL 01C
The design of an automated air traffic control system based on a hierarchy of advisory tools for controllers is described. Compatibility of the tools with the human controller, a key objective of the design, is achieved by a judicious selection of tasks to be automated and careful attention to the design of the controller system interface. The design comprises three interconnected subsystems referred to as the Traffic Management Advisor, the Descent Advisor, and the Final Approach Spacing Tool. Each of these subsystems provides a collection of tools for specific controller positions and tasks. This paper focuses primarily on the Descent Advisor which provides automation tools for managing descent traffic. The algorithms, automation modes, and graphical interfaces incorporated in the design are described. Information generated by the Descent Advisor tools is integrated into a plan view traffic display consisting of a high-resolution color monitor. Estimated arrival times of aircraft are presented graphically on a time line, which is also used interactively in combination with a mouse input device to select and schedule arrival times. Other graphical markers indicate the location of the fuel-optimum top-of-descent point and the predicted separation distances of aircraft at a designated time-control point. Computer generated advisories provide speed and descent clearances which the controller can issue to aircraft to help them arrive at the feeder gate at the scheduled times or with specified separation distances. Two types of horizontal guidance modes, selectable by the controller, provide markers for managing the horizontal flightpaths of aircraft under various conditions. The entire system consisting of descent advisor algorithm, a library of aircraft performance models, national airspace system data bases, and interactive display software has been implemented on a workstation made by Sun Microsystems, Inc. It is planned to use this configuration in operational evaluations at an en route center.
Author

N89-17585# Tokyo Univ. (Japan). Inst. of Space and Astronautical Science.
DEVELOPMENT OF NEW REDUNDANT FLIGHT SAFETY SYSTEM USING INERTIAL SENSORS
SHIGEKI TSUKAMOTO Oct. 1988 18 p
(ISAS-634; ISSN-0285-6808) Avail: NTIS HC A03/MF A01

A Flight Safety System requires high reliability in its operation because of the crucial duty to decide to destroy a flying vehicle or not, etc., in a state of emergency. A new Flight Safety System, one totally independent of the old one, which depends on radar information, is based on the principle of inertial navigation in calculating a real-time trajectory and impact points on earth by online PCM-telemetry data. This backup system has been applied to practical missions such as Halley and Ginga, with good success. An efficient, redundant system was created by connecting an ordinary personal computer to the line for speedy calculation in order to construct a transfer matrix for a single pole representation of altitude. Author

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

A89-26708#
LABORATORY AND FLIGHT EVALUATION OF THE INTEGRATED INERTIAL SENSOR ASSEMBLY (IISA)
JACK JANKOVITZ (U.S. Navy, Naval Air Development Center, Warminster, PA) and JOHN PERDZOCK (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 126-133.

Two complete sets of the Integrated Inertial Sensor Assembly (IISA) have been built, one set for laboratory evaluation and the other for flight test evaluation. The flight test evaluation was performed at Edwards Air Force Base on an F-15 aircraft. The authors provide an overview of the laboratory and flight test evaluations conducted by the Navy and Air Force. It is concluded that the IISA program has shown that it is feasible to use dispersed skewed inertial navigation quality sensors for redundant flight control sensors, navigation, cockpit displays and sensor stabilization. It is further concluded that evaluation has been 100 percent successful and has proven that the IISA concept is viable as a navigation and flight control reference. I.E.

A89-26724
VERDICT - A PLAN FOR GRAVITY COMPENSATION OF INERTIAL NAVIGATION SYSTEMS
MARVIN MAY, JAMES A. LOWREY, III, and MIKIE AIKAWA (U.S. Navy, Naval Air Development Center, Warminster; Rockwell International Corp., Pittsburgh, PA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 280-287.

The effect of gravitational disturbances prior and subsequent to compensation with preprepared maps for advanced tactical fighter application is quantified. The avionics issues associated with implementation of vertical deflection compensation are addressed. It is shown that a unique implementation concept designated the VERDICT (vertical deflection inertial compensation terminal) can provide the required compensation and is adaptable to a wide variety of inertial navigators. The authors document the validation of the VERDICT concept and present an approach to the hardware design of VERDICT. It is concluded that the combination of advanced mass storage and digital processing electronics, and the availability of large gravity databases from satellite altimetry make the VERDICT concept feasible for near-term implementation. I.E.

A89-26725
CORRECTION FOR DEFLECTIONS OF THE VERTICAL AT THE RUNUP SITE
PALMER O. HANSON (Honeywell, Inc., Military Avionics Div., Minneapolis, MN) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 288-296. Research supported by USAF. refs

The effects of unmodeled deflections of the vertical on aircraft inertial navigation system performance are considered. It is argued that, with few exceptions, the work on the area to date has ignored an important aspect, the correlated effects of deflections of the vertical at the runup site interacting with the system's self-alignment algorithm. The author reviews statistical analysis and flight test results, examines the effects of self-alignment on navigation errors, and describes a methodology that applies appropriate corrections during self-alignment and static navigation testing, and removes those corrections during flight. An implementation that substantially reduced the resulting errors for navigation times of one or two Schuler cycles was successfully demonstrated during flight test of the Mini-GEANS (Gimbaled Electrostatic Gyro Aircraft Navigation System). I.E.

A89-26726
PRECISION TRAJECTORY RECONSTRUCTION
WANG TANG and NEWTON JOHNSON (General Dynamics Corp., Convair Div., San Diego, CA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 297-302.

A precision trajectory reconstruction technique based on photoscoring has been developed to evaluate the airborne accuracy performance of guidance and navigation systems. The sensors include a reference inertial navigation system (INS) and a motion picture camera. The camera is mounted in the aircraft at a known position and attitude with respect to the inertial system and is used to photograph marker panels placed at precisely surveyed locations on the gound. The camera includes a time display device which is driven by a clock associated with the inertial data. The image data from the camera are processed with a modern Kalman filter/smoother to estimate the inertial system errors. The trajectory is then reconstructed by correcting the inertial system data with the estimated errors. It is shown using covariance analysis that the precision photoscoring technique can be used to reconstruct the flight trajectory with a position error of 0.4 m under baseline conditions. In addition, flight tests were used to evaluate the accuracy of the photoscoring process. I.E.

A89-26733
AIR TRAFFIC CONTROL AUTOMATION CONCEPTS TO OPTIMIZE FLIGHT MANAGEMENT SYSTEM UTILIZATION
SATISH C. MOHLEJI (Mitre Corp., McLean, VA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 341-346. refs
(Contract DOT-FA01-84-C-00001)

The author defines the requirements and design philosophy for developing ground-based automation planning and control advisory concepts to best serve the aircraft with FMS (flight management system) capabilities. Analytical results are presented, based on comparison of operational data with the user-preferred trajectories to identify flying-time variabilities in various segments of arriving flights. En route descents, terminal maneuvering areas, and the final approaches are considered to determine the impact of aircraft and environmental factors on flying times essential for traffic planning. Simple time-estimation algorithms based on FMS-defined speed schedules and prevailing winds are presented for estimating flying times during en route descents. Automation planning and control concepts are developed which utilize flexible route structures and a speed-control strategy to permit the aircraft maximum use of FMS and onboard avionics in all operating conditions. I.E.

A89-26734
THE REALIZATION OF MICROWAVE LANDING SYSTEM BENEFITS
AGAM N. SINHA (Mitre Corp., McLean, VA) IN: PLANS '88 -

IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 347-352. refs
(Contract DOT-FA01-84-C-00001)

The operational benefits derived from the use of MLS (microwave landing system) attributes are classified in five general categories: (1) use of curved/segmented approaches, (2) use of back azimuth guidance, (3) use of higher glide slopes/reduced siting problems, (4) relief of frequency congestion, and (5) other benefits (e.g., reliability and maintainability). Each of these categories is discussed, with specific examples. The requirements necessary to achieve the benefits are described. I.E.

A89-26735
CAUSAL PROBABILITY MODEL FOR TRANSOCEANIC TRACK SEPARATIONS WITH APPLICATIONS TO AUTOMATIC DEPENDENT SURVEILLANCE
JAMES H. ROME and VENKATARAMA KRISHNAN (Lowell, University, MA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 353-365. Research supported by DOT. refs

With the advent of automatic dependent surveillance (ADS), a detailed model of aircraft crosstrack deviations is required to determine the impact of ADS. The authors present a suitable probability model which is amenable to extrapolation. Normal navigation, degradation, pilot blunders, and failures are characterized by Gaussian density functions with associated standard deviations defined by the physics of the event. The overall model is a weighted sum of these Gaussian error probabilities. Overlap and encroachment probabilities are derived, and the impact of ADS on this model determined. It is shown that, by using the simplest form of ADS, the separation standards can be reduced and in addition, by transmitting a figure of merit (FOM) providing information on failures and degradations, the separation standards can be further reduced. The results suggest an improvement by a factor of two over current separation standards. I.E.

A89-26740
A KALMAN FILTER FOR AN INTEGRATED DOPPLER/GPS NAVIGATION SYSTEM
ALAN M. SCHNEIDER (California, University, La Jolla) and JAMES L. MAIDA (Teledyne Ryan Electronics, San Diego, CA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 408-415.

A Kalman filter has been designed to integrate a Doppler radar navigation system with a GPS (Global Positioning System) system. The filter uses eight states for flights over land, and ten over water. Simulation data shows navigation errors of 1 m or less on each axis under good operating conditions. The performance is equivalent in position error to the standard standalone GPS filter in straight and level flight, and superior in maneuvering flight under dynamic conditions. The filter implementation was also designed to provide additional improvement in the performance of a Doppler navigation system. The results demonstrate that this capability was achieved. I.E.

A89-26741
THE HONEYWELL/DND HELICOPTER INTEGRATED NAVIGATION SYSTEM (HINS)
G. WEST-VUKOVICH, J. ZYWIEL, B. SCHERZINGER (Honeywell, Ltd., Advanced Technology Centre, Markham, Canada), H. RUSSELL, and S. BURKE (DND, Ottawa, Canada) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 416-425.

HINS, a prototype of a high-performance, fault tolerant navigation system is currently being developed for Canada's antisubmarine warfare helicopter. HINS consists of three primary navigation subsystems (an F3 INS (inertial navigation system), a five channel P-code GPS (Global Positioning System), and a Doppler velocity sensor) and three secondary sensors (a strapdown magnetometer, a vertical gyro, and an air data system). The system is designed to blend the complementary strengths of component sensors, and to provide graceful degradation of performance in the event of failure or slow deterioration of these sensors. During normal operation, the Doppler and secondary sensors are calibrated to enhance performance during degraded mode operation. A multilevel failure detection and isolation scheme monitors sensor health and identifies faulty system components. I.E.

A89-28183
THE EMERGENCE OF SATELLITE COMMUNICATION FOR COMMERCIAL AIRCRAFT
GEORGE A. COBLEY (Rockwell International Corp., Avionics Group, Cedar Rapids, IA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 9 p. refs
(SAE PAPER 881370)

A view of the emerging aeronautical use of geosynchronous relay satellites is presented. This brings to commercial aircraft the first new communications system in over forty years. The new system will provide reliable long range communications to support the needs of airlines, flight crews, air traffic control, and passengers. The various implementations will be explored along with their parameters and operating characteristics. The potential for spectrum saturation will also be examined. Author

A89-28292#
THE INTEGRATION OF EUROPEAN FLIGHT-SAFETY SYSTEMS [ZUR INTEGRATION EUROPAEISCHER FLUGSICHERUNGSSYSTEME]
HANSJUERGEN VON VILLIEZ (Eurocontrol, Maastricht, Netherlands) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 317-329. In German.

Ongoing efforts to increase the efficiency of European ATC services by improving international coordination and cooperation are reviewed, with a focus on technological aspects of an experimental project being undertaken by the FRG, the Benelux countries, and the European agency Eurocontrol. The problems posed by continually increasing air traffic are discussed; the radar network for the experimental system and the scheme devised to exchange radar data are described; and a number of typical control screens and messages are displayed. Also stressed is the need for more and better-qualified ATC personnel. T.K.

A89-28293#
LIRAS - A PROPOSAL FOR AN AIRPORT TRAFFIC SAFETY SYSTEM [LIRAS - EIN VORSCHLAG FUER EIN FLUGPLATZ-VERKEHRS-SICHERUNGS-SYSTEM]
WOLFGANG KOERNER (AEG AG, Ulm, Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 331-342. In German.

The design concept and operation of LIRAS, a linear radar system for monitoring aircraft and service-vehicle traffic on airport runways, are discussed and illustrated with extensive drawings, diagrams, and photographs. Consideration is given to the AVES-type (60-GHz CW) surveillance radar sensors and their placement, the 80-GHz FM/CW vehicle-separation radars, takeoff-runway security procedures, the ground-traffic control center and its computer systems, and vehicle identification methods. T.K.

A89-28296#
GPS ANTENNAS FOR CIVIL AVIATION [GPS-ANTENNEN FUER DIE ZIVILE LUFTFAHRT]
H. FUELBER (Deutsche Lufthansa, Hamburg, Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 421-430. In German.

The design and performance of Navstar-GPS receivers for use in civil transport aircraft are discussed, with a focus on antennas. Topics addressed include the hybrid system proposed for the B737, B747, B757, and B767 aircraft; stand-alone GPS receivers; mechanical criteria for antenna designs; and nominal performance requirements. The requirements call for gains of over -1, -2.5,

-4.5, and -7.5 dBiC at elevation angles over 15, over 10, over 5, and zero degrees, respectively. Diagrams, drawings, and flow charts are provided. T.K.

A89-28297#
GPS ANTENNA PROBLEMS FOR MILITARY AIRCRAFT [PROBLEMATIK DER GPS-ANTENNEN AN MILITAERISCHEN FLUGZEUGEN]
NORBERT BRIESSMANN (Wehrtechnische Dienststelle fuer Luftfahrzeuge, Manching, Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 431-433. In German.

The design and performance requirements imposed on GPS antennas for military aircraft use are discussed. Consideration is given to aircraft dynamics, simultaneous reception of two frequencies, and available antenna locations. It is concluded that a military GPS antenna should (1) obtain zero points with more than 25 dB of damping, even under dynamic conditions and while receiving up to five interference signals; (2) track zero points with at least 300 deg/sec about each rotation axis; (3) track even when interference amplitude varies rapidly; (4) perform beam steering toward the satellite; and (5) have small physical surface area and thickness. T.K.

A89-28298#
AN ANTENNA FOR THE GPS INSTALLATION AT DFVLR [ANTENNE FUER DIE GPS-ANLAGE DER DFVLR]
S. HODABBAR (DFVLR, Oberpfaffenhofen, Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 442-447. In German.

The design concept, realization, and performance of the GPS receiver antenna installed at DFVLR Oberpfaffenhofen are presented in extensive drawings and diagrams and briefly characterized. The antenna comprises a disk of diameter 2/3 lambda, six conducting rods, a double-Archimedean-spiral radiator of diameter 2 lambda, and a resonance cavity. The maximal antenna-pattern expansion obtainable with this configuration is half-width 140 deg, with right circular polarization, low reflection and spurious radiation, horizontal radiation level -6 dB below maximum, and gain 0 dB. For a typical satellite passage, reception begins as the satellite is about 18 deg above one horizon and continues until it is 25 deg above the other horizon. T.K.

A89-28299#
A GPS RECEIVER ANTENNA WITH INTEGRATED DOWN-MIXER [EINE GPS-EMPFANGSANTENNE MIT INTEGRIERTEM ABWAERTSMISCHER]
KLAUS LOHSE (FUBA, Hans Kolbe und Co., Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 29, no. 3, 1988, p. 448-454. In German.

The design and performance of a prototype GPS receiver unit comprising antenna, preamplifier, mixer, and IF section are described and illustrated with diagrams and graphs. The antenna is a conical double logarithmic spiral, and the preamplifier is equipped with a band-pass filter especially designed to eliminate interference from a nearby Inmarsat antenna. The prototype receiver has been successfully tested in stationary installations and in land vehicles, ships, and aircraft; a significantly more compact version with a planar antenna is under development. T.K.

N89-17586 Bundesanstalt fuer Flugsicherung, Frankfurt am Main (Germany, F.R.).
ACTIVITIES REPORT IN AIR TRAFFIC CONTROL Annual Report, 1987 [JAHRESBERICHT 1987]
Jul. 1988 52 p In GERMAN
(ETN-89-93513) Avail: Fachinformationszentrum Karlsruhe, 7514 Eggenstein-Leopoldshafen 2, Federal Republic of Germany

Measures taken to improve to safety and regularity of air traffic in West Germany are outlined. Navigation and radiotelephone techniques; information transmission techniques; radar techniques, information techniques; and maintenance of data processing systems are discussed. ESA

N89-17587# Sandia National Labs., Albuquerque, NM.
ADVANCED FIGHTER TECHNOLOGY INTEGRATION/SANDIA INERTIAL TERRAIN-AIDED NAVIGATION (AFTI/SITAN) Final Report
J. RICK FELLERHOFF Nov. 1988 250 p
(Contract DE-AC04-76DP-00789)
(DE89-004000; SAND-88-1325) Avail: NTIS HC A07/MF A01

Sandia Inertial Terrain-Aided Navigation (SITAN) provides continuous position fixes to an Inertial Navigation System (INS) by real-time comparison of radar altimeter ground clearance measurements with stored digital terrain elevation data (DTED). This is accomplished by using an extended Kalman filter algorithm to estimate the errors in the reference trajectory provided by an INS. In this report, Sandia National Laboratories documents the results of a reimbursable effort funded by the Air Force Wright Aeronautical Laboratories (AFWAL) Avionics Laboratory to flight test SITAN as implemented onboard the Advanced Fighter Technology Integration (AFTI)F-16. DOE

N89-17588# Naval Postgraduate School, Monterey, CA.
AN EVALUATION OF AUTOMATING CARRIER AIR TRAFFIC CONTROL CENTER (CATCC) STATUS BOARDS UTILIZING VOICE RECOGNITION INPUT M.S. Thesis
ROBERT D. JENSEN and JOHN J. SPEGELE Jun. 1988 177 p
(AD-A200626) Avail: NTIS HC A09/MF A01 CSCL 25D

Conducting safe flight operations from aircraft carriers requires accurate and timely dissemination of aircraft status information from the Carrier Air Traffic Control Center (CATCC). Presently, the information is manually displayed on status boards throughout the ship by a network of sailors communicating via sound-powered microphones. A prototype, connected speech-based system, developed by the Naval Ocean Systems Command (NOSC), was evaluated. Specific evaluation criteria were the hardware, software and the man-machine interface. The use of connected speech as an input modality across varying noise and syntactic conditions was experimentally tested. The result of this research was the proposal of guidelines for designing connected speech syntaxes and specific recommendations for future prototype development efforts. GRA

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A89-24919
NUMERICAL AND EXPERIMENTAL STUDY OF THE CRASH BEHAVIOR OF HELICOPTERS AND FIXED-WING AIRCRAFT [ETUDE NUMERIQUE ET EXPERIMENTALE DU COMPORTEMENT AU CRASH DES HELICOPTERES ET DES AVIONS]
F. DUPRIEZ, P. GEOFFROY, J.-L. PETITNIOT, and T. VOHY (ONERA, Lille, France) (NATO, AGARD, Meeting on Aircraft Structural Crash Worthiness, Luxembourg, May 2-5, 1988) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 133, 1988, p. 54-72. In French. refs

The crash behavior of helicopters and fixed-wing aircraft has been studied numerically by the FEM and experimentally using representative models. Experimental results obtained with a falling autorating helicopter model have been compared with full-scale testing results. An experimental study of the landing of a light aircraft on soft ground is discussed. Elastoplastic bending results and data on the crushing of metallic structures have been applied to the numerical study of a commercial aircraft substructure. R.R.

A89-25009#
SCISSOR WING - AN ALTERNATIVE TO VARIABLE SWEEP
KAMRAN ROKHSAZ and BRUCE P. SELBERG (Missouri-Rolla, University, Rolla) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0013)

A scissor wing geometry is introduced as an alternative to variable sweep and oblique wing designs. It is shown that this configuration offers certain enhancements to the stability and control of the aircraft, in additon to aerodynamic advantages. It is shown that a scissor wing configuration can maintain a constant static margin throughout its flight Mach numbers. The dependence of the motion of the aircraft neutral point on the sweep angle is shown as a function of the chord and span ratios. It is also demonstrated that with the use of wing mounted elevons, additional pitch and attitude control can be obtained over a range of sweep angles. Author

A89-25041#
LATERAL OSCILLATIONS OF STING-MOUNTED MODELS AT HIGH ALPHA
L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0047)

An analysis is performed showing that, in a static test of a model of a high performance aircraft or missile, lateral oscillations can occur, resulting in static, time-average measurements of the asymmetric loads that are close to zero. In contrast, the loads needed for analysis of full scale aircraft or missile maneuvers are the maximum possible instantaneous asymmetric loads. In contrast to the *in-plane oscillations* due to sting plunging, corrections for the lateral oscillations cannot be made. The only remedy is to perform the subscale test with a support system that can provide coning and/or rolling motions, as in the case of a rotary rig. Author

A89-25081#
CFD IN DESIGN - AN AIRFRAME PERSPECTIVE
MARK I. GOLDHAMMER and PAUL E. RUBBERT (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0092)

CFD has provided a dramatic change in the techniques used for the aerodynamic design of airframes. This paper discusses the impact CFD has had at Boeing on aerodynamic design, testing, and evaluation of commercial aircraft. The evolution of CFD methods, from mathematical formulations to practical engineering tools, is also discussed. Examples of recent CFD implementation at Boeing are shown. The impact of CFD on testing is analyzed. Finally, the future direction of CFD research is discussed. Author

A89-25106*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A PATCHED-GRID ALGORITHM FOR COMPLEX CONFIGURATIONS DIRECTED TOWARDS THE F-18 AIRCRAFT
JAMES L. THOMAS, ROBERT P. WESTON, JAMES M. LUCKRING (NASA, Langley Research Center, Hampton, VA), ROBERT W. WALTERS, TAEKYU REU (Virginia Polytechnic Institute and State University, Blacksburg), and FARHAD GHAFFARI (Vigyan Research Associates, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 18 p. refs
(Contract NAG1-866; NAS1-17919)
(AIAA PAPER 89-0121)

A patched-grid algorithm for the analysis of complex configurations with an implicit, upwind-biased Navier-Stokes solver is presented. Results from both a spatial-flux and a time-flux conservation approach to patching across zonal boundaries are presented. A generalized coordinate transformation with a biquadratic geometric element is used at the zonal interface in order to treat highly stretched viscous grids and arbitrarily-shaped zonal boundaries. Applications are made to the F-18 forebody-strake configuration at subsonic, high-alpha conditions. Computed surface flow patterns compare well with ground-based and flight-test results; the large effect of Reynolds number on the forebody flowfield is shown. Author

A89-25158#
THERMAL-ENERGY MANAGEMENT FOR AIR BREATHING HYPER-VELOCITY VEHICLES
L. J. COULTER, R. W. BASS (United Technologies Research Center, East Hartford, CT), and R. C. ERNST (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0183)

Air-breathing hyper-velocity vehicles require integration of all systems to a greater than any previous aircraft. The thermal-energy management system, relatively simple in existing aircraft, will have to tolerate high heat loads, high heat fluxes and high temperatures and at the same time utilize the fuel as the heat sink for all vehicle waste heat. A methodology is presented which examines the tradeoffs necessary to define a thermal-energy management system which acts in concert with the propulsion system to provide a thermally balanced vehicle for the entire mission. The methodology permits consideration of both external and internal heat loads as welll as thermal interface systems. The impact on engine thrust due to non-ideal fuel preheat is discussed as are the remedies available to the designer to modify the thermal-energy management system to ensure a thermally balanced vehicle. Finally, a six step procedure is given which summarizes the key elements of the methodology. Author

A89-25221*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TRANAIR AND EULER COMPUTATIONS OF A GENERIC FIGHTER INCLUDING COMPARISONS WITH EXPERIMENTAL DATA
AGA M. GOODSELL, MICHAEL D. MADSON, and JOHN E. MELTON (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 26 p. refs
(AIAA PAPER 89-0263)

The TranAir full-potential code and the FLO57 Euler code were used to calculate transonic flow solutions over two configurations of a generic fighter model. The results were computed at Mach numbers of 0.60 and 0.80 for angles of attack between 0 and 12 deg for TranAir and between 4 and 20 deg for FLO57. Due to the fact that TranAir solves the full-potential equations for transonic flow, TranAir is only accurate to about alpha = 8 deg, at which point the experimental results show the formation of a vortex at the leading edge. Euler results show good agreement with experimental results until vortex breakdown occurs in the solutions. K.K.

A89-25236*# Lockheed Missiles and Space Co., Huntsville, AL.
COMPUTATION OF TURBULENT INCOMPRESSIBLE WING-BODY JUNCTION FLOW
R. W. BURKE (Lockheed Missiles and Space Co., Inc., Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract NAS8-37359)
(AIAA PAPER 89-0279)

A three-dimensional incompressible Reynolds-averaged Navier-Stokes solver is presently used in conjunction with a mixing-length turbulence model to characterize the flow around a wing that is mounted on a flat plate, in a wind tunnel, as well as the flow around a support strut within a turnaround duct. Good agreement is found between predicted and observed values of flat-plate static pressure, horseshoe vortex system size, and mean flow velocities in the case of the wing; the case of the strut in a duct is noted to exhibit many of the same overall flow features as the wing/plate. O.C.

A89-25320#
RECOVERABLE TEST VEHICLE, AN INNOVATIVE APPROACH TO A LOW COST COMPOSITE AIRFRAME FOR AEROSPACE APPLICATION
THOMAS W. SKELLY (Aerocet, Inc., Arlington, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0378)
The Recoverable Test Vehicle (RTV), which is being procured by the US Naval Weapons Center, is a low cost re-useable alternative to expensive flight test platforms that have historically been used for development of weapons delivery systems. An innovative approach using commercially available composite materials was developed to meet the requirements for vehicle ruggedness, re-useability and low cost. Although used for years in commercial products and noncritical aerospace applications, the RTV represents the first successful use of these materials as primary structure for a high speed flight test vehicle. This paper presents an overview of the RTV structural design which capitalizes on these composite materials. Also presented in this paper is an innovative approach to fabricating the RTV wing, fin and elevons. Author

A89-25429*# Purdue Univ., West Lafayette, IN.
PROPELLER/WING INTERACTION
DAVID P. WITKOWSKI, ROBERT T. JOHNSTON, and JOHN P. SULLIVAN (Purdue University, West Lafayette, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract NSG-3134)
(AIAA PAPER 89-0535)
The present experimental investigation of the steady-state and unsteady-state effects due to the interaction between a tractor propeller's wake and a wing employs, in the steady case, wind tunnel measurements at low subsonic speed; results are obtained which demonstrate wing performance response to variations in configuration geometry. Other steady-state results involve the propeller-hub lift and side-force due to the wing's influence on the propeller. The unsteady effects of interaction were studied through flow visualization of propeller-tip vortex distortion over a wing, again using a tractor-propeller configuration. O.C.

A89-25449#
A TRANSONIC COMPUTATIONAL METHOD FOR AN AFT-MOUNTED NACELLE/PYLON CONFIGURATION WITH PROPELLER POWER EFFECT
L. T. CHEN, K. C. YU, and T. Q. DANG (Douglas Aircraft Co., Aerodynamics Research and Technology Group, Long Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0560)
A computation method for determining transonic flows about an aft-fuselage mounted capped-nacelle/pylon configuration with and without propeller power is presented. A hybrid conformal-mapping/transfinite-interpolation scheme is used to generate body conforming grid systems, and a multigrid line-relaxation scheme is used to solve the potential flowfield. Special attention is given to the importance of the fuselage boundary-layer effect on the pylon pressure distribution. Results compare well to available test data and to the solutions of a panel method. R.R.

A89-25506#
FEASIBILITY STUDY ON THE DESIGN OF A LAMINAR FLOW NACELLE
R. RADESPIEL, K. H. HORSTMANN, and G. REDEKER (DFVLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0640)
This paper describes the design of a laminar flow nacelle. By means of natural laminar flow, e.g., nacelle contouring, laminar boundary layers on the nacelle surface can be maintained up to 60 percent of the nacelle length at cruise flight conditions. As well at take-off and landing conditions the inlet flow and the outside flow is free of flow separation. The overall drag coefficient of an aircraft equipped with two laminar flow nacelles is estimated to be reduced at cruise flight by Delta c(D) of about 0.0011. Author

A89-25509*# West Virginia Univ., Morgantown.
COMPUTATIONAL DESIGN OF LOW ASPECT RATIO WING-WINGLETS FOR TRANSONIC WIND-TUNNEL TESTING
JOHN M. KUHLMAN and CHRISTOPHER K. BROWN (West Virginia University, Morgantown) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Previously announced in STAR as N88-24630. refs
(Contract NAG1-625)
(AIAA PAPER 89-0644)
A computational design has been performed for three different low aspect ratio wing planforms fitted with nonplanar winglets; one of the three planforms has been selected to be constructed as a wind tunnel model for testing in the NASA LaRC 7 x 10 High Speed Wind Tunnel. A design point of M = 0.8, CL approx = 0.3 was selected, for wings of aspect ratio equal to 2.2, and leading edge sweep angles of 45 and 50 deg. Winglet length is 15 percent of the wing semispan, with a cant angle of 15 deg, and a leading edge sweep of 50 deg. Winglet total area equals 2.25 percent of the wing reference area. This report summarizes the design process and the predicted transonic performance for each configuration. Author

A89-25565*# Toledo Univ., OH.
THERMAL ANALYSIS OF ENGINE INLET ANTI-ICING SYSTEMS
THEO G. KEITH, JR., KENNETH J. DE WITT (Toledo, University, OH), JAMES K. NATHMAN (Analytical Methods, Inc., Redmond, WA), DONALD A. DIETRICH (General Electric Co., Cincinnati, OH), and KAMEL M. AL-KHALIL AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research sponsored by the General Electric Co. and NASA. refs
(AIAA PAPER 89-0759)
A hot air anti-icing system of a gas turbine engine inlet is analyzed numerically. A three-dimensional potential flow code, which accounts for compressibility effects, is used to determine the flowfield in and around the inlet. A particle trajectory code is developed using a local linearization technique. The trajectory code is used to calculate local water impingement rates. Energy balances are performed on both the surface runback water and the metallic skin to determine their temperature distributions. A variety of test cases are considered in order to validate the various numerical components of the process as well as to demonstrate the procedure. Author

A89-25571*#
DISTRIBUTED ICE ACCRETION SENSOR FOR SMART AIRCRAFT STRUCTURES
J. J. GERARDI and G. A. HICKMAN (Innovative Dynamics, Ithaca, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract NAS3-25200)
(AIAA PAPER 89-0772)
A distributed ice accretion sensor is presented, based on the concept of smart structures. Ice accretion is determined using spectral techniques to process signals from piezoelectric sensors integral to the airfoil skin. Frequency shifts in the leading edge structural skin modes are correlated to ice thickness. It is suggested that this method may be used to detect ice over large areas with minimal hardware. Results are presented from preliminary tests to measure simulated ice growth. R.B.

A89-25572#
DEVELOPMENTS IN EXPULSIVE SEPARATION ICE PROTECTION BLANKETS
JOSHUA GOLDBERG and BENJAMIN LARDIERE, JR. (Data Products New England Aerospace, Wallingford, CT) AIAA,

Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0774)

The paper discusses two specific improvements to the expulsive blankets described in NASA's original patent. Quantitative discussion which suggests criteria for efficient expulsive blanket design are given. Wind tunnel and laboratory data are provided to substantiate the criteria given. A few speculations based on limited current data are offered on the mechanism of ice shedding in efficient blankets. Author

A89-25605#
THE EFFECTS OF AFT-LOADED AIRFOILS ON AIRCRAFT TRIM DRAG
ROBERT ENDE AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0836)

The effects of aft-loaded airfoils on aircraft trim drag were studied for a High-Altitude, Long-Endurance (HALE) vehicle. A family of high-lift airfoil drag polars with varying pitching moments were designed, and a computer program was developed to calculate the lift distribution between the wing and tail and the trim drag and total drag for a typical HALE configuration at various altitudes and velocities, allowing for changes in airfoil properties and static margin. It was found that aft-loading trim drag and total drag for the dash condition did not vary significantly over the range of pitching moment coefficients from -0.15 to -0.22, and actually reached minimum values at some point in that range, depending on static margin. Aft-loading also improved maximum dash speed. C.D.

A89-26950#
AIRCRAFT LANDING GEAR DESIGN: PRINCIPLES AND PRACTICES
NORMAN S. CURREY (Lockheed Aeronautical Systems Co., Marietta, GA) Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, 383 p. refs

The present guide to design practices in the field of aircraft landing gears considers the entire range of historical experience for all sizes and types of military and commercial aircraft. After discussing the design process and the various performance requirements that must be met by the different elements and functions of typical landing gears, Attention is given to the detailed design of shock absorbers, tires, braking and skid-control practices, and the kinematics of landing gears. Also discussed are steering systems, detailed mechanical design, weight estimation methods, airfield surface and dimension considerations, and unorthodox landing gear designs and their comparative performance. O.C.

A89-27613* Sparta, Inc., Laguna Hills, CA.
THE DEVELOPMENT OF AN AUTOMATED FLIGHT TEST MANAGEMENT SYSTEM FOR FLIGHT TEST PLANNING AND MONITORING
MARLE D. HEWETT, DAVID M. TARTT (Sparta, Inc., Laguna Hills, CA), EUGENE L. DUKE, ROBERT F. ANTONIEWICZ (NASA, Flight Research Center, Edwards, CA), RANDAL W. BRUMBAUGH (PRC Kentron, Inc., Edwards, CA) et al. IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 324-333. refs

The development of an automated flight test management system (ATMS) as a component of a rapid-prototyping flight research facility for AI-based flight systems concepts is described. The rapid-prototyping facility includes real-time high-fidelity simulators, numeric and symbolic processors, and high-performance research aircraft modified to accept commands for a ground-based remotely augmented vehicle facility. The flight system configuration of the ATMS includes three computers: the TI explorer LX and two GOULD SEL 32/27s. K.K.

A89-27695*# Georgia Inst. of Tech., Atlanta.
ANALYSIS OF STRUCTURES WITH ROTATING, FLEXIBLE SUBSTRUCTURES APPLIED TO ROTORCRAFT AEROELASTICITY
DEWEY H. HODGES (Gerorgia Institute of Technology, Atlanta), A. STEWART HOPKINS, and DONALD L. KUNZ (NASA, Ames Research Center, Moffett Field, CA) (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 2B, p. 955-965) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 192-200. Research supported by Georgia Institute of Technology. Previously cited in issue 14, p. 2106, Accession no. A87-33748. refs

A89-27735#
WING ROCK GENERATED BY FOREBODY VORTICES
L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 110-116. Previously cited in issue 08, p. 1048, Accession no. A87-22523. refs
(Contract F33615-87-C-3607)

A89-27738*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UNSTEADY TRANSONIC ALGORITHM IMPROVEMENTS FOR REALISTIC AIRCRAFT APPLICATIONS
JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 131-139. Previously cited in issue 07, p. 946, Accession no. A88-22075. refs

A89-27740*# Pennsylvania State Univ., University Park.
DESIGN AND EXPERIMENTAL RESULTS FOR A HIGH-ALTITUDE, LONG-ENDURANCE AIRFOIL
MARK D. MAUGHMER (Pennsylvania State University, University Park) and DAN M. SOMERS (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 148-153. Previously cited in issue 21, p. 3347, Accession no. A87-49105. refs

A89-27747#
SOME IMPLICATIONS OF WARPING RESTRAINT ON THE BEHAVIOR OF COMPOSITE ANISOTROPIC BEAMS
GABRIEL A. OYIBO (Polytechnic University, Farmingdale, NY) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 664-671) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 187-189. Previously cited in issue 18, p. 2611, Accession no. A86-38947. refs
(Contract F49620-85-C-0090; F49620-87-C-0046)

A89-27808
IMPROVED RELIABILITY AND MAINTAINABILITY FOR FIGHTER AIRCRAFT ENVIRONMENTAL CONTROL SYSTEMS
RICHARD R. DIECKMANN (McDonnell Aircraft Co., Saint Louis, MO) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. Research sponsored by USAF. refs
(SAE PAPER 880999)

Environmental Control System (ECS) features to improve reliability and to reduce maintenance of fighter aircraft are presented. The features are intended to overcome supportability problems of current fighter aircraft ECS, and to reduce supportability requirements for ECS designs in future aircraft. They have the potential to achieve very significant reductions in failure rates, maintenance, and logistics support for fighter aircraft ECS. Two features offer the highest reliability and maintainability improvements. These are use of digital ECS controls integrated with an aircraft maintenance management system, and the use of more rugged bleed air components to reduce maintenance and logistic support. If these and other improvements are installed, ECS downtime can be reduced by 79 percent from that of the best in current fighter aircraft. Author

A89-27809
A DYNAMIC MODEL FOR VAPOR-CYCLE COOLING SYSTEMS
JOHN F. DEFENBAUGH, WILLIAM S. HEGLUND, and ALBERT L. MARKUNAS (Sundstrand Corp., Sundstrand Advanced Technology Group, Rockford, IL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 881001)

A dynamic simulation model has been developed for a vapor-cycle cooling system designed for aircraft environmental control applications. The dynamic models will reduce the risks associated with development and the costs associated with control development on the test stand. The heat exchanger is modeled using multiple-, lumped-parameter, fixed-length elements based on coupled thermal and mass storage effects, and flow equations that incorporate the effects of thermal expansion and contraction. The system requires the modeling of a two-phase binary refrigerant mixture heat exchange process using nonazeotropic refrigerants. The mathematical model for each heat exchange system component is implemented in a FORTRAN subroutine using pressure and enthalpy as the independent thermodynamic variables. The simulation is developed with modular components with causality defined to minimize connection states and, thus, execution time. S.A.V.

A89-27925
DESIGN OF AN ALL BORON/EPOXY DOUBLER REINFORCEMENT FOR THE F-111C WING PIVOT FITTING - STRUCTURAL ASPECTS
L. MOLENT, R. J. CALLINAN, and R. JONES (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) Composite Structures (ISSN 0263-8223), vol. 11, no. 1, 1989, p. 57-83. refs

This paper presents an overview of the structural aspects of the design and development of a local reinforcement designed to lower the stresses in a region of the F-111C wing pivot fitting which is prone to cracking. The stress analysis, representative specimen testing, thermal analysis and aspects of the full-scale static testing of this design are summarized. Author

A89-28176* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FORE-AND-AFT STIFFNESS AND DAMPING CHARACTERISTICS OF 30 X 11.5-14.5, TYPE VIII, BIAS-PLY AND RADIAL-BELTED AIRCRAFT TIRES
MERCEDES C. LOPEZ, PAMELA A. DAVIS, ROBERT B. YEATON (NASA, Langley Research Center, Hampton, VA), and WILLIAM A. VOGLER (PRC Systems Services, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 8 p. refs
(SAE PAPER 881357)

Measurements of footprint geometrical properties and fore and aft stiffness and damping characteristics were obtained on 30 x 11.5-14.5 bias-ply and radial-belted aircraft tires. Significant differences in stiffness and damping characteristics were found between the two design types. The results show that footprint aspect ratio effects may interfere with the improved hydroplaning potential associated with the radial-belted tire operating at higher inflation pressures. R.R.

A89-28177* Michigan Univ., Ann Arbor.
PROPERTIES OF AIRCRAFT TIRE MATERIALS
RICHARD N. DODGE and SAMUEL K. CLARK (Michigan, University, Ann Arbor) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 8 p.
(Contract NSG-1607)
(SAE PAPER 881358)

A summary is presented of measured elastomeric composite response suitable for linear structural and thermoelastic analysis in aircraft tires. Both real and loss properties are presented for a variety of operating conditions including the effects of temperature and frequency. Suitable micro-mechanics models are used for predictions of these properties for other material combinations and the applicability of laminate theory is discussed relative to measured values. Author

A89-28178
COMPARATIVE TESTS OF AIRCRAFT RADIAL AND BIAS PLY TIRES
STEPHEN N. BOBO (DOT, Transportation Systems Center, Cambridge, MA), RICHARD A. JOHNSON (FAA, Technical Center, Atlantic City, NJ), and PAUL C. DURUP (Lockheed Corp., Burbank, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p.
(SAE PAPER 881359)

Laboratory dynamometer tests are being conducted to assess the difference in performance between radial and bias ply tires, both new and retreaded, of various sizes and manufacturers. Tire properties that affect the operation and safety of landing gear systems such as temperature performance, cornering power, dynamic loaded radius and wheel stresses are being compared. The tests are described along with some initial findings. Author

A89-28194
PERFORMANCE TESTING OF AN ELECTRICALLY ACTUATED AIRCRAFT BRAKING SYSTEM
DOUGLAS D. MOSELEY (Loral Corp., Loral Aircraft Braking Systems Div., Akron, OH) and THOMAS J. CARTER (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 34 p.
(SAE PAPER 881399)

The concept of utilizing an electrically actuated aircraft braking system could result is greater fire safety, the elimination of centralized hydraulics, and compatibility with an all-electric aircraft. Using the Air Force A-10 as a test bed, the first fully functional electric brake was laboratory tested, qualified, and installed on an aircraft for testing. On-aircraft testing was curtailed due to a dynamic instability between the brake and landing gear. An extensive laboratory dynamometer test program was substituted. The prototype electric brake demonstrated performance nearly equivalent to the production hydraulic brake with a potential for more accurate torque control. Author

A89-28206* Lockheed Aeronautical Systems Co., Burbank, CA.
CONCEPTUAL DESIGN OF A STOVL FIGHTER/ATTACK AIRCRAFT
Y. T. CHIN (Lockheed Aeronautical Systems Co., Burbank, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p. Research sponsored by NASA. refs
(SAE PAPER 881431)

STOVL aircraft offer unique basing and operational advantages to improve the capabilities of military forces in future warfare. To develop a STOVL fighter design with supersonic capability requires the integration of an advanced propulsion system into the airframe design. A promising propulsion system for supersonic STOVL application is the relatively new Hybrid Fan Vectored Thrust (HFVT) concept. This advanced tandem fan concept incorporates a dual-cycle engine with front and rear fully vectorable nozzles of the three-poster type, to provide the required performance. In this paper, the HFVT STOVL design integration approaches for a conceptual fighter/attack aircraft, as well as some features of the resulting design, will be presented. Author

A89-28207
CONSIDERATIONS OF CONTROL AUTHORITY REQUIREMENTS IN STOVL PROPULSION SYSTEM SIZING
H. P. LEE, Y. T. CHIN, and G. L. HERSTINE (Lockheed Aeronautical Systems Co., Burbank, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 8 p.
(SAE PAPER 881432)

The total control authority available to pilots of STOVL aircraft during very low speed and hovering flight must be sufficient to trim the aircraft, maneuver in all axes, suppress such external disturbances as winds and gusts, and counter such environmental changes as hot exhaust gas reingestion and suckdown. In addition, it must be possible to compensate for asymmetric weapons loading and furnish automatic stability augmentation when required. The effects of these requirements on the sizing of the reaction control system and the propulsion system will be illustrated for the case of a single-seat/single-engine STOVL military aircraft configuration with 42,000 lb TOGW. O.C.

A89-28208
THE CURRENT STATUS OF THE FLIGHT TEST OF THE ASKA
NORIAKI OKADA, KAZUYA MASUI, HIROYUKI YAMATO (National Aerospace Laboratory, Gifu, Japan), MASAMICHI KURIYAMA, and YOSHINARI TOBINAGA (Kawasaki Heavy Industries, Ltd., Kagamigahara, Japan) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 17 p. refs
(SAE PAPER 881433)

The design and current status of ASKA, a four-engine experimental STOL aircraft being developed by the Japanese National Aerospace Laboratory on the basis of the upper-surface blowing concept, are discussed. Data from flight tests on the landing performance are presented in extensive tables and graphs, and drawings and photographs are provided. Particular attention is given to airspeed and angle-of-attack measurements, lift/drag performance and powered-lift characteristics, the pitching moment of the powered-lift aircraft, the tail-load measurement system, and ground effects. T.K.

A89-28252#
SPANLOAD OPTIMIZATION FOR STRENGTH DESIGNED LIFTING SURFACES
ANTHONY P. CRAIG and J. DOUGLAS MCLEAN (Boeing Commercial Airplanes, Seattle, WA) AIAA, Applied Aerodynamics Conference, 6th, Williamsburg, VA, June 6-8, 1988. 8 p. refs
(AIAA PAPER 88-2512)

A computer program has been developed that optimizes spanloads with structural weight taken into account. The program optimizes the twist distribution to minimize a combination of wing drag and weight. The wing drag is based on a Trefftz plane induced drag analysis and on an empirical profile drag estimation. The wing weight is based on a simple beam model where weight is based on bending strength design for a critical condition spanload. The program can be used to analyze multiple non-planer lifting surface configurations with realistic constraints such as trim and material limitations. Author

A89-28255
TOPICS OF AIRCRAFT THERMAL MANAGEMENT
JERRY E. BEAM (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 1-8. refs
(SAE PAPER 881381)

Aircraft thermal management issues are reviewed in order to determine areas necessary for additional research. Particular topics discussed include the philosophy of traditional thermal control systems, the avionics cooling problem, and the application of heat pipes to aircraft systems. Avionics cooling includes a summary of current spacecraft cooling that is applicable. Analysis includes results for free convective cooling, forced convective cooling, and nucleate boiling heat transfer for low gravity applications as well as artificial gravity generation. Heat pipe applications are discussed with particular emphasis on the effects of high acceleration and nonuniform heat loads. Author

A89-28256
THE ALL ELECTRIC AIRPLANE REVISITED
MICHAEL J. CRONIN (Lockheed Aeronautical Systems Co., Burbank, CA) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 9-26. refs
(SAE PAPER 881407)

A development status evaluation is conducted for all-electric military and commercial aircraft power systems in which high-pressure hydraulics are entirely supplanted by electromechanical devices. A significant persistent difficulty is the unwillingness of designers to develop the increased-voltage/frequency electrical power supplies that are critical to an all-electric system's optimization. Once electrical generators are directly integrated into advanced powerplants, as advocated by AFWAL, all power will be easily suppliable electrically. O.C.

A89-28269
X-29A SUBSYSTEMS INTEGRATION - AN EXAMPLE FOR FUTURE AIRCRAFT
EDWARD COLLINS (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 131-147. refs
(SAE PAPER 881504)

An account is given of the method and results of the effort by the X-29A experimental aircraft's designers to integrate five subsystems: these were, respectively, hydraulics, electrical power, emergency power, accessory drive, and environmental controls. Laboratory tests were conducted prior to aircraft installation. Attention is given to the selection rationale used to arrive at the specific off-the-shelf subsystem components employed, the formulation of testing environment requirements, and the configuration of the completed integrated system. O.C.

A89-28350
THE CONTRIBUTION OF PLANFORM AREA TO THE PERFORMANCE OF THE BERP ROTOR
F. J. PERRY (Westland Helicopters, Ltd., Yeovil, England) American Helicopter Society, Journal (ISSN 0002-8711), vol. 34, Jan. 1989, p. 64, 65; Author's Closure, p. 66.

The aerodynamic characteristics of the British Experimental Rotor Programme (BERP) helicopter rotor blade are discussed on the basis of flight test data. Comparisons between the BERP blade and a related tapered blade are presented graphically and briefly characterized. It is shown that the blade planform shape plays a more significant role than the blade profile in the ability of the BERP rotor to sustain high angles of attack prior to stall. The need for a weighted solidity parameter to separate incidence and planform effects in analyzing blade performance is indicated. T.K.

A89-28456#
ELECTRO-IMPULSE DE-ICING SYSTEMS - ISSUES AND CONCERNS FOR CERTIFICATION
CHARLES O. MASTERS (FAA Technical Center, Atlantic City, NJ) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA 89-0761)

This paper discusses issues and concerns associated with the design, implementation and utilization of an electroimpulse deicing (EIDI) system, as related to aviation safety standards. The guidance/criteria currently being formulated by the FAA for verification of EIDI system performance adequacy and, ultimately, a demonstration of compliance are examined. Also, both the normal voltage and low voltage EIDI ice protection systems for composite and metal airframes are discussed. Author

N89-16741# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Flight Dynamics Lab.
INLET-ENGINE COMPATIBILITY
LEWIS E. SURBER and CLAY FUJIMARA *In* VKI, Intake Aerodynamics, Volume 1 32 p 1988
Avail: NTIS HC A15/MF A01

Inlet-engine compatibility is reviewed to show how inlet spatial flow distortion relates to the compatibility problem in turbine-engine powered supersonic fighter aicraft. It is shown that flow distortion is actually experienced as off-design flow incidence by compressor airfoils, but may be characterized and treated as flow field total pressure distortion in the development process. Axial compressor engines respond to time-variant spatial distortion up to the range of the blade passing frequency. Therefore, any accurate compatibility analysis must deal with dynamic distortion. Information is presented to show that accurate distortion parameter values and pressure distortion maps can be produced for low and moderate inlet turbulence levels with as few as eight turbulence measurements. Advanced fighter inlets with compact offset diffusers may experience turbulence levels in the 5 plus percent range where probe-to-probe signal coherence violates the basic premise of statistical analysis. In cases where highly accurate compatibility assessments are required for high turbulence inlet flows, deterministic methods are employed. ESA

N89-16744# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Flight Dynamics Lab.
INTAKE-AIRFRAME INTEGRATION
LEWIS E. SURBER *In* VKI, Intake Aerodynamics, Volume 1 66 p 1988
Avail: NTIS HC A15/MF A01

Intake-airframe integration of tactical aircraft is reviewed. It is shown that the stream flow approaching a side-mounted inlet is substantially distorted by the presence of the fuselage in maneuvering flight. This flow distortion has a generally adverse effect on inlet total pressure recovery and inlet-engine compatibility. Supersonic maneuvering flight can lead to substantial performance degradation in a side-mounted leeward 2-D inlet due to flow separation at the inboard sideplate. Performance degradation in side-mounted half-axisymmetric inlets in supersonic maneuvers results from flow separation in the upper portion of the throat followed by choking of the rest of the throat. Flow field studies show dramatic potential performance advantages for shielding supersonic maneuvering inlets. Fuselage-shielding, however, is the only technique which retains all the advantages for 2-D inlets when alpha/Beta combinations were explored. Half-axisymmetric inlets show substantial performance advantages over 2-D inlets in supersonic wing-shielded flow fields when considering the entire maneuver envelope. Experiments demonstrate limited tailoting of top-mounted inlet flow fields through careful design of wing leading-edge strakes which control the vortex pattern over an aircraft's upper surface. Such designs may be able to facilitate an acceptable inlet environment for limited maneuver conditions. ESA

N89-16745# British Aerospace Aircraft Group, Preston (England). Military Aircraft Div.
INTAKES FOR HIGH ANGLE OF ATTACK
D. C. LEYLAND *In* VKI, Intake Aerodynamics, Volume 1 26 p 1988
Avail: NTIS HC A15/MF A01

Intake design and location for combat aircraft are reviewed. Experience of operation at moderate angles-of-attack was obtained from testing of models of existing aircraft, to the extent of showing what features and characteristics require investigation. Shielding to provide preturning of entry flow is desirable and the chin location chosen for EAP and EFA proves very effective. Research studies, however, included other locations to determine what can be expected and accepted. The chin intake is not always the best overall configuration choice; it constrains fuselage stores carriage in smaller aircraft and is likely to be unacceptable in STOVL aircraft because of hot gas reingestion. Results from research testing, mostly on fuselage integrated intakes, are given to show what flow changes take place with increasing angle-of-attack and what configuration choices can be made to give acceptable characteristics. ESA

N89-16746# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
TRANSONIC COWL DESIGN
J. SEDDON *In its* Intake Aerodynamics, Volume 1 23 p 1988
Avail: NTIS HC A15/MF A01

Transonic cowl design is discussed in the context of external drag of engine nacelles on high-subsonic transport aircraft. The principal concern arises because at high subsonic speeds the airflow over the intake cowl, and in other regions of an overall podded installation, becomes locally supersonic, giving rise to shock waves and possible boundary layer separation. Both these features can lead to substantial increases in aircraft drag. Drag below the critical Mach number (where flow locally reaches sonic speed) and subcritical cowl design are treated. Supercritical cowl design and installation drag are discussed. ESA

N89-16749# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
TRANSPORT AIRCRAFT INTAKE DESIGN
JACKY LEYNAERT *In* VKI, Intake Aerodynamics, Volume 2 28 p 1988
Avail: NTIS HC A14/MF A01

Subsonic air intake, Mach 2+ transport aircraft intake, and Mach 3 are considered. Hypersonic cruise intakes are mentioned. The problem of supersonic intake adaptation to the intermediate flight Mach number range is reviewed. Future multicycle engine design is discussed. ESA

N89-16773 Cranfield Inst. of Tech., Bedford (England).
THE DESIGN, CONSTRUCTION AND TEST OF A POSTBUCKLED, CARBON FIBRE REINFORCED PLASTIC WING BOX Ph.D. Thesis
W. G. BROOKS 1987 290 p
Avail: Univ. Microfilms Order No. BRDX82023

Methods of analysis have been evaluated including: (1) non-linear finite element analysis for the prediction of panel postbuckling; (2) a simpler technique based on an effective width method (forming the core of a design program, OPTIMIST, it predicts buckling loads, postbuckled reduced stiffness and overall column failure of co-cured hat stiffened panels; and (3) the use of the effective width method allied to a large scale, linear finite element analysis. The work includes the development of a new method of construction for composite box structures. The wing skin, stiffeners and rib flanges are co-cured together. Integral slotted joint features are formed in each part. The structure is then adhesively bonded together. A full description of the manufacture of the wing box is included. Dissert. Abstr.

N89-16774# Texas A&M Univ., College Station. Dept. of Mechanical Engineering.
NONLINEAR DYNAMIC RESPONSES OF COMPOSITE ROTOR BLADES Final Technical Report, 1 Dec. 1985 - Jun. 1988
JOHN J. ENGBLOM and OZDEN O. OCHOA Aug. 1988 72 p
(Contract F49620-86-K-0003)
(AD-A200145; ME-5375-88; AFOSR-88-1018TR) Avail: NTIS HC A04/MF A01 CSCL 01C

Summarized are research activities related to Nonlinear Dynamic Response of Composite Rotor Blades. Fundamental to the analysis is the development of a continuum formulation that can accurately account for the effects of interlaminar shear and interlaminar normal stress variation through-the-thickness of a laminate. Technical highlights of the research efforts to date are presented for each of the proposed tasks; namely, Nonlinear Displacement Formulation for Composite Media, Incorporate Damage Mechanisms into Dynamic Response Formulation and Correlation of Formulated Response Model with Experimental data. GRA

N89-16775# Analytical Methods, Inc., Redmond, WA.
DEVELOPMENT OF A PANEL METHOD FOR MODELING CONFIGURATIONS WITH UNSTEADY COMPONENT MOTIONS, PHASE 1 Final Report, 1 Jul. 1987 - 31 Jan. 1988
DAVID R. CLARK and BRIAN MASKEW 15 Apr. 1988 35 p
(Contract DAAL03-87-C-0011)
(AD-A200255; AMI-8801; ARO-25090.1-EG-SBI) Avail: NTIS HC A03/MF A01 CSCL 01C

This report reviews the background to the calculation of unsteady rotor and fuselage loads and presents results from an analysis of a typical helicopter configuration made using a panel method operated in a time-stepping mode. The method models the fuselage and blades using surface singularities and the shed and trailing wakes with doublet lattice sheets. Unsteady local pressures and component forces are presented and the ability of the analysis to determine dynamic phenomena such as fuselage/blade-passage events and blade/vortex interactions is demonstrated. GRA

N89-16778 Maryland Univ., College Park.
AEROELASTIC OPTIMIZATION OF A HELICOPTER ROTOR Ph.D. Thesis
JOON WON LIM 1988 232 p
Avail: Univ. Microfilms Order No. DA8818424

Structural optimization of a hingeless rotor is investigated to reduce oscillatory hub loads while maintaining aeroelastic stability in forward flight. Design variables include spanwise distribution of nonstructural mass, chordwise location of blade center of gravity and blade bending stiffnesses. The objective function is expressed as a function of one or more components of oscillatory hub loads with suitable weighting functions. For inequality constaints, the aeroelastic stability of the blade in forward flight is selected to keep the blade aeroelastically stable. An aeroelastic analysis of rotors, based on a finite element method in space and time, is linked with optimization algorithms to perform optimization of rotor blades. The vehicle trim and blade steady response are calculated iteratively as one coupled solution using a modified Newton method. Eigenvalues corresponding to different blade modes are calculated using Floquet transition matrix theory. For the optimization process, a new methodology, direct analytical approach for calculation of sensitivity derivatives of blade response, hub loads and eigenvalues with respect to design variable is proposed. Dissert. Abstr.

N89-17278# Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).
DAMAGE TOLERANCE BEHAVIOR OF FIBER REINFORCED COMPOSITE AIRFRAMES [ZUM SCHADENSTOLERANZVERHALTEN VON LUFTFAHRZEUGKONSTRUKTIONEN AUS FASERVERBUNDWERKSTOFFEN]
J. J. GERHARZ and H. HUTH *In its* Papers of the 5th LBF Colloquium p 93-110 1988 In GERMAN
Avail: NTIS HC A12/MF A01

The evaluation of the damage tolerance of fiber-reinforced composite aircraft constructions was investigated. An example shows which studies are needed to determine the effects of critical damage on the required properties and to determine how this damage is tolerated by the constructions. The smaller the impactor radius and the thinner the laminate, the lower the energy at which the impact damage is visible. Even at high impact energies, damage on nonhardened constructions is not visible. The importance and effect of damage depend on the impact location. The decrease of pressure strength of laminate plates depends on the relative damage size. The laminate structure in hardened laminates can affect the impact damage. ESA

N89-17589 Cranfield Inst. of Tech., Bedford (England).
ANALYTICAL WING WEIGHT PREDICTION/ESTIMATION USING COMPUTER BASED DESIGN TECHNIQUES Ph.D. Thesis
N. A. D. MURPHY 1987 312 p
Avail: Univ. Microfilms Order BRDX82210

Every pilot knows that the size and position of masses in an aircraft has a fundamental effect on its performance. It comes as a surprise to learn that the methods used for predicting aircraft weights today were developed in the forties and there have only been half hearted attempts at making use of the digital computer. The usual methods are empirical and rely on experience gained from past projects. Things have changed and these methods are potentially inaccurate when applied by the inexperienced engineer to new aircraft based on radical concepts. Sixty percent of an airplane's program cost is determined at the initial stages of design and the structure of an aircraft accounts for up to 55 pct of the cost of a 200 aircraft program. Compare this with the 3 pct share that the initial design stage itself costs. Clearly the problem is that a small error can be very costly or even catastrophic. Dissert. Abstr.

N89-17590 Cranfield Inst. of Tech., Bedford (England).
DESIGN SYNTHESIS FOR CANARD-DELTA COMBAT AIRCRAFT, VOLUMES 1 AND 2 Ph.D. Thesis
V. C. SERGHIDES 1987 554 p
Avail: Univ. Microfilms Order No. BRDX82026

The development of a computerized Design Synthesis is presented for canard-delta combat aircraft. The background to the work and the objectives and limitations are examined. The design of a baseline canard-delta combat aircraft is then described together with all the assumptions and decisions which led to its final configurations. The philosophy behind the progressive evolution of the aircraft geometry and packaging modules from the baseline configuration is explained in detail. The development of detailed modules for the estimation of the aircraft aerodynamics and performance is then presented. A full description of the investigations into the effects of canard-delta interference on the aircraft aerodynamics is also included. The mathematical content of the aircraft geometry, packaging, aerodynamics and performance modules is presented separately in the appendices in greater detail. The development and architecture of the Design Synthesis and graphics programs are finally presented and the program operation is described with the aid of flow charts. A comprehensive user manual and a design example are also provided. Dissert. Abstr.

N89-17591# Rockwell International Corp., Los Angeles, CA.
SUPERPLASTIC FORMED ALUMINUM-LITHIUM AIRCRAFT STRUCTURE Interim Report, 30 Apr. 1987 - 30 Apr. 1988
GARDNER R. MARTIN, CLAIRE ANTON, DEAN KLIVANS, M. A. RAMSEY, P. S. MCAULIFFE, J. C. GEORGE, M. K. GUESS, H. R. PEARSON, C. C. BAMPTON, R. A. GRIMM (Edison Welding Inst., Columbus, OH.) et al. Oct. 1988 133 p Prepared in cooperation with Washington State Univ., Pullman
(Contract F33615-87-C-3223)
(AD-A200245; NA-88-1347L; AFWAL-TR-88-3080) Avail: NTIS HC A07/MF A01 CSCL 01C

This program selects, designs, fabricates, and evaluates SPF Al-Li airframe parts using advanced joining technology; it also screens and evaluates SPF Al-Li alloys for application to candidate parts. Factors used in part selection include supportability, technical risk, and required development. A design trade study modifies and improves the advanced SPF Al-Li candidate parts by implementing efficient design concepts and advanced joining methods. Design and joining methods are evaluated using material from the same lots used for material evaluation. Demonstration parts and the required tooling are fabricated using criteria generated from producibility evaluations. Finally, the demonstration parts are subjected to verification testing as prescribed in the test plan. GRA

N89-17593*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLIGHT MEASURED DOWNWASH OF THE QSRA
JOSEPH C. EPPEL, DENNIS W. RIDDLE, and VICTOR C. STEVENS Dec. 1988 13 p
(NASA-TM-101050; A-88307; NAS 1.15:101050) Avail: NTIS HC A03/MF A01 CSCL 01C

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

N89-17594# Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.
MPC-75 FEEDER CIVIL AIRCRAFT
MING KE 1 Nov. 1988 6 p Transl. into ENGLISH from Guoji Hangkong (Peoples Repubic of China), no. 12(298), 1987 p 5
(AD-A200907; FTD-ID(RS)T-0857-88) Avail: NTIS HC A02/MF A01 CSCL 01C

The project model and partial prototype of the MPC-75 feeder civil aircraft, which was jointly developed and manufactured by the China Aviation Technology Import-Export Company and the MBB Company of the Federal Republic of Germany, was placed at the center of MBB Company exhibition platform in this year's Aviation Exhibit, and it drew a huge crowd. The MPC-75 is a class feeder civil aircraft with 75 to 90 seats, Based upon an extensive market investigation and analysis conducted by the two companies, this aircraft was selected to be the model to fill the open market for feeder civil aircraft with over 60 seats but under 100 seats. GRA

N89-17595# Defense Science Board, Washington, DC.
REPORT OF THE DEFENSE SCIENCE BOARD TASK FORCE ON THE NATIONAL AEROSPACE PLANE (NASP) Final Report
Sep. 1988 90 p
(AD-A201124) Avail: NTIS HC A05/MF A01 CSCL 01C

The NASP started in 1984 as a program to explore hypersonic air breathing propulsion. It transitioned during 1985 to a program with the dual goals of demonstrating single stage to orbit and hypersonic cruise with the same vehicle. DSB Task Force conclusions include: (1) The NASP program goals are valid. The NASP technologies will make significant contributions to our national military and space capabilities and our civilian economy as we enter the 21st century. (2) The NASP is truly an X-Vehicle. Expectations of short term operational utility should not be raised. (3) Technical uncertainties in all critical disciplines must be narrowed before detailed design is initiated. Uncertainties are too large to estimate with any degree of accuracy the cost, schedule or performance which can be achieved in Phase 3. (4) Readjust the program funding priorities to favor the Technology Maturation effort, while retaining sufficient effort in definition airframe and propulsion configuration to provide focus for the technology work. (5) An experimental program of this type should be event driven, not schedule driven. Demonstration of quantitative technical milestones in all critical disciplines should pace the program. GRA

N89-17691# Saab-Scania, Linkoping (Sweden).
AN ANALYSIS METHOD FOR BOLTED JOINTS IN PRIMARY COMPOSITE AIRCRAFT STRUCTURE
INGVAR ERIKSSON *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 19 p Mar. 1988 Prepared in cooperation with Royal Inst. of Tech., Stockholm (Sweden).
Avail: NTIS HC A14/MF A01

The analysis of bolted joints in composite structure requires, like structural analysis in general, methods for determining the stress distributions and relevant failure criteria. The stress analysis procedure discussed here starts by addressing the joints as an integrated part of the overall structure. The stresses in the vicinity of the hole boundary are obtained through a series of finite element analyses, which starts with an overall load distribution analysis and ends with a two-dimensional detailed contact stress analysis of the most highly stressed region in the joint. Strength is predicted for two basic failure modes occurring in a joint, net-tension and bearing failure. The failure hypotheses for these failure modes are described. Both the stress analysis and failure hypotheses are performed and established, respectively under certain idealizations. The conditions in a real joint in an aircraft may differ from these idealizations. Hence, further work is required and is also proposed here. The analysis procedure described here is based on today's powerful computer facilities and offer great advantages compared with more empirical procedures. The procedure is presently used at Saab Aircraft Division. Author

N89-17693# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Technology Programs.
TYPICAL JOINTS IN A WING STRUCTURE
DIETER ROSE, MANFRED ROTHER, and HELMUT SCHELLING (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart, Germany, F.R.) *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 14 p Mar. 1988
Avail: NTIS HC A14/MF A01

For the development of the Alpha-Jet carbon fiber reinforced plastic (CFRP) wing, typical connections between different components were examined both theoretically and experimentally. Environmental conditions - component humidity and temperature were considered mainly within the experimental work which was performed by the DFVLR-Stuttgart. Covered here are typical joints such as: (1) single-shear connection between skins and spars with low load transfer; (2) joints between skins and ribs due to interior tank pressure; and (3) multibolt joint between the CFRP skins and the fuselage attachment fittings with reference to bolt strength distribution and bearing stresses. Author

N89-18380*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
V/STOL AIRCRAFT AND THE PROBLEM OF JET-INDUCED SUCKDOWN
CHERIANNE CARLISLE *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 9-20 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 01C

The suckdown condition encountered when jet propelled, Vertical/Short Takeoff and Landing aircraft hover near the ground is described. A discussion of this ground effect problem and how it is being investigated is followed by a more detailed description of one of the methods researchers are using to investigate the basic mechanisms that influence the suckdown condition. Specific parameters that are taken into account include the height of the jet above the ground, jet exit conditions, and model geometry. Data from a current investigation is presented along with some conclusions from other recent investigations in order to relate the significance of some of the parameters influencing suckdown. Suggestions are made for additional testing methods which might be useful to researchers investigating the mechanisms involved in jet induced suckdown. Author

N89-18387*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE NATIONAL AERO-SPACE PLANE
BRUCE MENDEZ *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 49-53 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 01C

The National Aerospace Plane is an extremely versatile and adaptable aircraft. It can be developed into an Orient Express that would dramatically improve trade with countries in Asia and elsewhere: a commuter transport to ferry men and materials to space, an advanced tactical fighter or bomber, and an unparalleled high altitude spy-plane to observe troubled spots all over the globe. Utilizing the technology developed by this pilot program, it will be possible to quickly and easily get to low Earth orbit, go halfway around the world in a fraction of the time it previously took, and lead the world in the development of advanced technology to improve our lives and the lives of many others. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A89-27247
RESEARCH PRESSED TO IMPROVE FLIGHT INFORMATION CONTRIBUTION TO AIRCRAFT ACCIDENT INVESTIGATIONS
I. E. MASHKIVSKII (State Commission for the Supervision of Flight Safety, USSR) ICAO Bulletin (ISSN 0018-8778), vol. 43, Oct. 1988, p. 20-22.

Research by Soviet scientists to develop improved methods for recording and using flight information for accident investigations is reviewed. The technical features of the airborne flight parameter recorders used in the Soviet Union are examined. Also, the ground systems used to process and analyze flight information are considered. The development of a general-purpose conversational simulation system for studying flight dynamics in accident investigations is discussed. The operation of the system is described, including the analysis and secondary processing of information, the evaluation of flight dynamics, and information display. R.B.

A89-27624* Tennessee Univ., Tullahoma.
AUTOMATIC ACQUISITION OF DOMAIN AND PROCEDURAL KNOWLEDGE
H. J. FERBER and M. ALI (Tennessee, University, Tullahoma) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 2. Tullahoma, TN, University of Tennessee, 1988, p. 762-771. refs
(Contract NAG1-513; NGT-43-001-807)

The design concept and performance of AKAS, an automated knowledge-acquisition system for the development of expert systems, are discussed. AKAS was developed using the FLES knowledge base for the electrical system of the B-737 aircraft and employs a 'learn by being told' strategy. The system comprises four basic modules, a system administration module, a natural-language concept-comprehension module, a knowledge-classification/extraction module, and a knowledge-incorporation module; details of the module architectures are explored. T.K.

A89-27664*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MINIATURE PCM COMPATIBLE WIDEBAND SPECTRAL ANALYZER FOR HYPERSONIC FLIGHT RESEARCH
JOHN K. DIAMOND (NASA, Langley Research Center, Hampton, VA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 277-286.

The design concept and prototype performance of a 10-400-kHz wideband spectral analyzer being developed at NASA Langley as part of the Hypersonic Flight Instrumentation Research Experiment are described and illustrated with diagrams and graphs. The analyzer is intended to compress the bandwidth of data from up to 20 hot-film anemometers, so that the analog PSD waveform from each sensor can be encoded for serial PCM telemetry. Components include an analog multiplier, digital waveform generator, sine-wave VCO, digital VCO, analog low-pass filter, switched-capacitor filter, and rms-dc detector. The prototype demonstrated 1-percent accuracy (referred to a 5-V full-scale output) for sweep rates up to 3/sec over the 10-400-kHz spectrum. T.K.

A89-27668*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
THE DESIGN AND USE OF A TEMPERATURE-COMPENSATED HOT-FILM ANEMOMETER SYSTEM FOR BOUNDARY-LAYER FLOW TRANSITION DETECTION ON SUPERSONIC AIRCRAFT
HARRY R. CHILES (NASA, Flight Research Center, Edwards, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 347-358.

A89-27670
SOFTWARE CONTROL OF A HIGH SPEED, MODULAR SIGNAL CONDITIONER AND PCM ENCODER SYSTEM
WILLIAM F. TROVER (Teledyne Controls, Los Angeles, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 369-380.

The increasing channel capacity and complexity of flight test data acquisition systems have made the problems of physical distribution of the system throughout the test aircraft and determining the system configuration a very time-consuming and costly portion of the flight test process. The solution to the installation problem is to have a highly modular system that can be configured as either a distributed system with remote multiplexing and a PCM central controller, or with the same multiplexed hardware as a stand-alone or master/slave system (where the functional power and complexity afforded by the PCM central controller are not required). The solution to the configuration control problem is to have a 'hands-off' data-acquisition system with all variables of the signal conditioning and PCM encoding functions under software control. Author

A89-28184
AVIONICS DISPLAY SYSTEMS
A. J. DANDEKAR (Rockwell International Corp., Cedar Rapids, IA) and L. E. FARHNER (Boeing Commercial Airplanes, Seattle, WA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p.
(SAE PAPER 881371)

Electronic displays using multicolor cathode ray tube (CRT) technology were introduced to Air Transport cockpits in 1979 when Boeing and Airbus Industries selected CRTs for display of primary flight data, engine information and systems information in new generation aircraft. The introduction of CRTs to the flight deck has been very successful with display capability and symbology undergoing continuous improvement. The evolution of these display systems is reviewed with a look at the flat panel displays of tomorrow. Author

A89-28186
AN AVIONICS DIAGNOSTICS SYSTEM FOR REGIONAL AIRLINES AND BUSINESS AIRCRAFT APPLIED IN THE BEECH STARSHIP 1
DONALD K. GRIMM and PAUL D. HEYSSE (Rockwell International Corp., Avionics Group, Cedar Rapids, IA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 15 p.
(SAE PAPER 881374)

As avionics systems become more integrated, fault isolation becomes more costly and time consuming. The development of the Collins Concept 4 avionics architecture includes a unique central avionics diagnostics function as an integral part of the avionics structure to identify failed LRUs in the aircraft for quick flight line replacement. Repeat squawks are greatly reduced. The central diagnostics processor uses system-wide avionics data in a flexible, table-driven processing algorithm to pinpoint LRU failures. The application in the Beech Starship 1 is described. Author

A89-28199
AIRCRAFT AUTOMATION WITH AN ELECTRONIC LIBRARY SYSTEM
EARL MINCER (Honeywell, Inc., Sperry Commercial Flight Systems Group, Phoenix, AZ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 6 p.
(SAE PAPER 881415)

An electronic library system is being developed for use in commercial aircraft. This system will supplement and eventually replace the conventional paper manuals with electronically stored data. Using advanced technologies of optical disk data storage, high resolution displays, and sophisticated software, the system will provide a high degree of cockpit automation and added functionality for many avionics applications. This paper describes some proposed features of the system as well as the technology used to implement it. Author

A89-28200
USE OF COLOR DISPLAYS IN THE A320 COCKPIT
ROBERT J. WITWER and JAMES C. STAEHLE (Honeywell Inc., Sperry Commercial Flight Systems Group, Phoenix, AZ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 9 p.
(SAE PAPER 881416)

The Airbus A320 is the first commercial aircraft to provide a color display unit as the primary interface between the flight crew and the flight management system. In order to obtain maximum information about the flight management data being displayed, specific rules concerning color usage apply. This enables a more manageable operation thus reducing flight crew workload. Author

A89-28201
SENSOR CONSIDERATION IN THE DESIGN OF A WINDSHEAR DETECTION AND GUIDANCE SYSTEM
TERRY ZWEIFEL (Honeywell, Inc., Sperry Commercial Flight Systems Group, Phoenix, AZ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 7 p.
(SAE PAPER 881417)

The sensor requirements for a windshear detection and guidance system and the impact of sensor inaccuracies on detection and flight guidance are examined. Inertial parameters for windshear detection and guidance algorithms are discussed, including longitudinal acceleration, normal acceleration, and pitch angle. Consideration is also given to air mass parameters such as true air-speed and angle-of-attack. Methods for compensating for sensor errors are analyzed, including increasing the detection threshold to allow for sensor errors and developing algorithms to account for errors to minimize their effect. R.B.

A89-28213
MECHANIZATION, DESIGN AND METHODOLOGICAL LESSONS LEARNED FROM A DYNAMIC COCKPIT MOCK-UP EVALUATION
KIM M. MAZUR, RICHARD W. MOSS (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH), and GREGORY J. BARBATO (Midwest Systems Research, Inc., Dayton, OH) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p.
(SAE PAPER 881438)

By applying existing and evolving design methodolgy, cockpits of tactical aircraft can be designed, based on the the crew system concept. The USAF Crew Systems Development Branch undertook the Tactical Aircraft Cockpit Study (TACS) to establish a firm understanding of the vehicle's mission and the accompanying crew station design issues. The TACS design was mechanized in a dynamic mock-up. Air-to-air and air-to-ground situation formats were considered. The methodology issues dealt with the procedures used during testing of the crew station design, as well the processs involved in the design development. Much more useful evaluations were obtained with full-scale dynamic mock-ups than with nondynamic mock-ups - a finding attributed to subjective factors affecting the test personnel. A.A.F.

A89-28214
COMPUTER-GENERATED MAP DISPLAY FOR THE PILOT/VEHICLE INTERFACE
STEVEN P. ROGERS and V. ALAN SPIKER (Anacapa Sciences, Inc., Santa Barbara, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 16 p. refs
(SAE PAPER 881440)

The computer-generated map display system offers a host of powerful new capabilities. Among these are opportunities to greatly improve the pilot/vehicle interface in tactical aircraft cockpits through integration and clarification of spatial/geographic data. This report describes the results of a survey conducted to evaluate and prioritize formats for integrated digital map displays. Sixteen of the formats judged most valuable by 38 experienced pilots are presented and described, along with the specific survey findings. Author

A89-28224
RECONFIGURABLE COCKPIT DEVELOPMENT
PAUL PENCIKOWSKI (Northrop Corp., Aircraft Div., Hawthorne, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 6 p.
(SAE PAPER 881472)

The Reconfigurable Cockpit (RCP), a cockpit-design software and hardware system, is described and illustrated with drawings and diagrams. The RCP can rapidly generate cockpit layouts and display formats. The user manipulates the high-fidelity graphics representation of multiple avionics devices through virtual touch and voice systems. The RCP is a stand-alone system and utilizes two computers, two terminals, and a physical cockpit. A two-dimensional graphics editor is interfaced to a real-world simulation supporting both the head-down displays of the cockpit and the three-dimensional external world scene. A.A.F.

N89-16785# German Air Force Air Armament Directorate, Cologne (Germany, F.R.).
ON BOARD LIFE MONITORING SYSTEM TORNADO (OLMOS)
J. H. KUNZ and U. SCHULZ (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 6 p Oct. 1988
Avail: NTIS HC A20/MF A01

The development of the onboard life monitoring system (OLMOS) of the GE Tornado proved, that on-board monitoring is possible, and the received data can be used in the logistic system. The Tornado OLMOS is a system which serves engine, structure, and functional equipment. The level of integration is high, but due to the structured software approach the system can be handled. The software was developed by four companies, and in the using phase the same companies are sharing the SW maintenance. High integrated systems definitely do need a very close management on both sides, the government and the industry. The OLMOS proves that even commercial and proprietary aspects can be worked out. Author

N89-16786# Royal Air Force, London (England).
INFORMATION MANAGEMENT SYSTEMS FOR ON-BOARD MONITORING SYSTEMS
P. J. JENKINS *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p Oct. 1988
Avail: NTIS HC A20/MF A01

With the advent of microprocessors is a phase which has heralded a host of advances in aircraft mounted equipment. It promises to yield rich dividends for the hard pressed maintenance engineer by providing detailed information on equipment performance to enable defects to be accurately and rapidly diagnosed. Latest develpments in the propulsion field show the potential of being able to anticipate certain types of defects and thus achieve true on-condition maintenance in these cases. The aim is to highlight the vitally important role played by maintenance information management systems in storing, analyzing, and displaying the data captured by on-board monitoring systems and to make recommendations for a code of practice for the successful implementation of such systems. Author

N89-16788# Rockwell International Corp., Lakewood, CA.
B-1B CITS ENGINE MONITORING
B. LAINE and K. DERBYSHIRE *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p Oct. 1988
Avail: NTIS HC A20/MF A01

The Central Integrated Test Systems (CITS) is a real-time tests system which continually monitors the performance of the 34 principal systems, onboard the B-1B aircraft, including the four General Electric F101 turbofan engines. The CITS consists of an

onboard computer, four data acquisition units, a data conversion unit, a printer, a magnetic tape recorder, and a control and display panel. Approximately 19,000 parameters are available for recording and display purposes. The engine diagnostic algorithm was designed in close coordination with General Electric. Information obtained from early test cell runs was utilized in the original logic design. Many modifications were made as a result of flight test experience, but the overall test sequence has remained unchanged. The engine diagnostic software utilizes approximately 100 parameters per engine. The test logic is exercised four time per second and a fault is declared is a failure condition occurs for six consecutive passes. Every effort is made to ensure that a single failure will result in only one fault code out of 154 possible codes per engine. The B-1B engine diagnostic program is the most advanced flying test algorithm. Its inherent complexities are due to calculations of test limits based on aircraft flight mode, environmental conditions, and engine control schedules. These limits are then compared to actual engine readings, and if established limits are exceeded, a fault code is annunciated.
Author

N89-16789# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
ENGINE LIFE CONSUMPTION MONITORING PROGRAM FOR RB199 INTEGRATED IN THE ON-BOARD LIFE MONITORING SYSTEM
J. BROEDE *In* AGARD, Engine Condition Monitoring: Technology and Experience 11 p Oct. 1988
Avail: NTIS HC A20/MF A01

The On-board Life Monitoring System (OLMOS) of the GE Tornado consists of on-board equipment (data acquisition unit, DAU) where the majority of the data processing is carried out, and of ground equipment (OLMOS Ground Station, OGS, connected to the Central Logistic Support System, BMS) where the majority of the data management tasks are carried out. The Engine Life Consumption Monitoring Program (ELCMP) is part of OLMOS. Its main task is LCF life consumption calculation, which consists of data acquisition and data checking, calculation of temperatures and stresses, as well as damage assessment. A general view of the calculation path within ELCMP is given, and the hardware structure of the system is presented. Some advantages of individual and complete engine monitoring are pointed out. Author

N89-16793# Air France, Paris. Direction du Materiel.
THE CFM 56-5 ON THE A-320 AT AIR FRANCE [LE CFM 56-5 SUR A320 A AIR FRANCE]
P. CHETAIL *In* AGARD, Engine Condition Monitoring: Technology and Experience 19 p Oct. 1988 In FRENCH
Avail: NTIS HC A20/MF A01

A brief history of engine monitoring strategies used by Air France is presented and the systems limitations encountered in service are discussed. The engine monitoring system to be used for the A-320 aircraft is described. The use of the AIRCOM system, the automatic alert function, and the use of the GEM (Ground based Engine Monitoring) program for data analysis are discussed.
M.G.

N89-16795# Pratt and Whitney Aircraft, West Palm Beach, FL.
F100-PW-220 ENGINE MONITORING SYSTEM
DENNIS A. MYERS and G. WILLIAM HOGG *In* AGARD, Engine Condition Monitoring: Technology and Experience 9 p Oct. 1988
Avail: NTIS HC A20/MF A01

The development and operational experience is reviewed of the F100-PW-220 Engine Monitoring System currently in service with the U.S.A.F. and other national defense air forces utilizing the F100-PW-220 engine and its derivatives. The F100-PW-220 Engine Monitoring System (EMS) is an advanced logistics support tools in production for the Pratt and Whitney F100 family of gas turbine engines. The introduction of the PW-220 EMS represents over 10 yrs of diagnostic system and maintenance technology development using aerospace electronic component design and digital engine control system implementation. The PW-220 EMS is a comprehensive engine support system that is fully integrated with in-flight aircraft operating systems, as well as, ground based maintenance and logistics systems. Author

N89-16797# Rolls-Royce Ltd., Bristol (England). Engine Data Systems.
MILITARY ENGINE CONDITION MONITORING SYSTEMS: THE UK EXPERIENCE
C. M. OCONNOR *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p Oct. 1988
Avail: NTIS HC A20/MF A01

The monitoring of engine usage is probably as old as the gas turbine engine itself. However, it was not until the mid-seventies that the concept of engine monitoring became viable following the appearance and general availability of digital electronics, including the minicomputer. Since, the proliferation of engine condition monitoring has resulted in the development of many different systems and it is now customary for defense organizations to include it among their requirements for new military aircraft. The functional requirements for engine condition monitoring are usually defined in general terms, except for the life usage monitoring of major rotating components, these being the discs and the turbines. The level of importance afforded to the monitoring of these components is attributable to safety and economic factors. Engine condition monitoring in the UK military has been built on the foundations of usage monitoring. It is interesting that except for vibration and oil system monitoring, the engine parameters required for usage monitoring can provide enough data for many other condition monitoring functions. This idea is further expanded and detailed. Author

N89-16798# General Electric Co., Cincinnati, OH. Monitoring Systems Engineering.
MILITARY ENGINE MONITORING STATUS AT GE AIRCRAFT ENGINES, CINCINNATI, OHIO
R. J. E. DYSON and M. J. ASHBY *In* AGARD, Engine Condition Monitoring: Technology and Experience 11 p Oct. 1988
Avail: NTIS HC A20/MF A01

The design and development of GE Aircraft engines of recent military engine monitoring systems is described. In particular, the systems for the F101-GE-102 engine in the B-1B aircraft and the F110-GE-100 engine in the F-16C/D are used as examples. Since both of these systems have recently been introduced into service, this experience is discussed together with operational status. These present systems are compared with future evolutionary trends which are affected by the development of miniaturized, rugged electronics and by the desire to minimize the unique hardware and software required for engine monitoring. A discussion of interfaces, both airborne to the flight crew, and, through support equipment and ground analysis programs, to the ground crew, is included.
Author

N89-16799# General Electric Co., Cincinnati, OH. Monitoring Systems Engineering.
COMMERCIAL ENGINE MONITORING STATUS AT GE AIRCRAFT ENGINES, CINCINNATI, OHIO
R. J. E. DYSON and J. E. PAAS *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p Oct. 1988
Avail: NTIS HC A20/MF A01

The design, introduction and development of expanded commercial engine monitoring systems by GE Aircraft Engine is described. The history of present systems is outlined, starting from the introduction of the CF6-80A3 engine for the A310 aircraft of the Propulsion Multiplexer (PMUX) which has led to similar systems on the CF6-80C2 engine. The impact of the full authority digital control on future systems is also discussed. The introduction and application of the Ground-based Engine Monitoring (GEM) software developed by GE in conjunction with several airline users is recounted. The original software development occurred in parallel with the expanded sensor complement and digitization of data. A description of the functions of a typical ground software program is provided together with proposed improvements and future directions. Author

N89-16801# Bureau Veritas, Paris (France).

TREND MONITORING OF A TURBOPROP ENGINE AT LOW AND MEAN POWER [TREND-MONITORING DES TURBO-PROPULSEUR DE PETITE ET MOYENNE PUISSANCE]

PHILIPPE VAQUEZ *In* AGARD, Engine Condition Monitoring: Technology and Experience 9 p Oct. 1988 In FRENCH

Avail: NTIS HC A20/MF A01

Trend monitoring relates to the observation, between two maintenance periods, of changes in certain parameters that represent the physical state of an engine. The experiences of French engineers with the use of this method are discussed. Specifically, the application of trend monitoring to the Pratt and Whitney PT6 A and PW 120, and the General Electric CT 7 turboprop engines is discussed. The engines were mounted on various single and twin engine aircraft. Author

N89-16811# Hochschule der Bundeswehr, Hamburg (Germany, F.R.).

GAS PATH MODELLING, DIAGNOSIS AND SENSOR FAULT DETECTION

R. LUNDERSTAEDT and K. FIEDLER *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p Oct. 1988

Avail: NTIS HC A20/MF A01

The gas path analysis (GPA) becomes more and more an important method for the diagnosis of jet engines. Here, a fundamental way of finding the mathematical engine model is shown, especially with regard to the adaptation of the coefficients of the system matrix to the gradients of the characteristic curves of the turbomachines. The theoretical fundamentals are applied to a two-shaft jet engine. In order to test the method some faults in the engine are simulated. All faults are detected very accurately and the method shows by this its efficiency. For practical use of the method, the faults of the measuring device (sensors) are to be taken into consideration. Therefore filter algorithms are outlined to diminish the stochastic parts of these faults. For the systematic parts (offsets), a special and new theory is developed for compensation. For both, simulation results are given based on actual test stand data. Author

N89-16812# Technische Univ., Munich (Germany, F.R.). Inst. fuer Luft-und Raumfahrt/Flugantriebe.

SYSTEM-THEORETICAL METHOD FOR DYNAMIC ON-CONDITION MONITORING OF GAS TURBINES

F. HOERL, G. KAPPLER, and H. RICK *In* AGARD, Engine Condition Monitoring: Technology and Experience 17 p Oct. 1988

Avail: NTIS HC A20/MF A01

In order to ensure reliability and safety of such complex technical systems as aero-engines, model-related diagnostic techniques must be applied. The basis for this is a linear, time-invariant, dynamic engine state space model derived from system analysis. Due to the model order and the associated difficulties, order reduction procedures are used. The diagnostic parameters to be taken into account are integrated into a dynamic disturbance model. This disturbance model and the reduced engine model form the extended dynamic engine state space model. A detailed investigation of the dynamic system for observability and disturbability is essential. Because of measuring/process noise and other system disturbances, dynamic state estimation methods are applied in the diagnosis, whereby the synthesis of such observer systems is a crucial point. The usefulness of the dynamic monitoring method is demonstrated on the example of the helicopter engine using computed simulations. A sensitivity analysis allows the accuracy of the diagnostic results to be estimated. Author

N89-16817# Stewart Hughes Ltd., Southhampton (England). Centre for Advanced Technology.

GAS PATH CONDITION MONITORING USING ELECTROSTATIC TECHNIQUES

CELIA FISHER *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p Oct. 1988 Sponsored by Ministry of Defence Procurement Executive, London, United Kingdom

Avail: NTIS HC A20/MF A01

The concept of condition monitoring using electrostatics offers the opportunity to monitor gas path faults as they occur. It is based on the assumption that gas path distresses, such as blade rubs and combustor burns, cause the production of minute particles of debris, which carry electrostatic charge, and can be monitored on suitable sensors mounted in the engine. The engine has a normal level of charge, which produces a background signal. The debris produced by distresses causes a change in the signal which can be monitored using suitable signal processing techniques. Described here is the research work which was necessary to provide an understanding of the mechanisms involved. This forms the basis of the technique which is described, with examples of the application of the systems to various engines. Author

N89-16819# Rolls-Royce Ltd., Derby (England).

COMPASS (TRADEMARK): A GENERALIZED GROUND-BASED MONITORING SYSTEM

M. J. PROVOST *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p Oct. 1988

Avail: NTIS HC A20/MF A01

Condition monitoring has developed from simple hand recording and analysis of cockpit instrumentation to the use of electronic systems selecting and recording a multitude of measurements for transmission to ground-based computer systems, which store and analyze data from an entire fleet. COMPASS (Condition Monitoring and Performance Analysis Software System) is a ground-based computer system, currently being developed by Rolls-Royce plc for application on the Rolls-Royce RB211 and Tay and International Aero Engines (IAE) V2500 turbofans. After discussing the benefits of monitoring system, COMPASS, its sources of data and its analytical functions, including details of new techniques developed to improve the usefulness of the analysis that is done are described. Also shown is how COMPASS is designed in two parts: - analytical functions specific to a given application and general host routines, providing all the housekeeping functions required in any monitoring system, including smoothing and trending, alert generation, fleet averaging, compression, data management and data plotting. The use of the general host routines could be extended to cover any operation. The approach Rolls-Royce plc is adopting to enable the COMPASS host to be made available for widespread application is discussed. Author

N89-16820*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PILOTED-SIMULATION EVALUATION OF ESCAPE GUIDANCE FOR MICROBURST WIND SHEAR ENCOUNTERS M.S. Thesis - George Washington Univ.

DAVID A. HINTON Washington, DC Mar. 1989 57 p Sponsored in part by FAA, Washington, DC

(NASA-TP-2886; L-16498; NAS 1.60:2886; DOT/FAA/DS-89/06)

Avail: NTIS HC A04/MF A01 CSCL 01D

Numerous air carrier accidents and incidents result from encounters with the atmospheric wind shear associated with microburst phenomena, in some cases resulting in heavy loss of life. An important issue in current wind shear research is how to best manage aircraft performance during an inadvertent wind shear encounter. The goals of this study were to: (1) develop techniques and guidance for maximizing an aircraft's ability to recover from microburst encounters following takeoff, (2) develop an understanding of how theoretical predictions of wind shear recovery performance might be achieved in actual use, and (3) gain insight into the piloting factors associated with recovery from microburst encounters. Three recovery strategies were implemented and tested in piloted simulation. Results show that a recovery strategy based on flying a flight path angle schedule produces improved performance over constant pitch attitude or acceleration-based recovery techniques. The best recovery technique was initially counterintuitive to the pilots who participated in the study. Evidence

was found to indicate that the techniques required for flight through the turbulent vortex of a microburst may differ from the techniques being developed using classical, nonturbulent microburst models.
Author

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A89-24916
RELATION BETWEEN DIFFUSOR LOSSES AND THE INLET FLOW CONDITIONS OF TURBOJET COMBUSTORS [RELATION ENTRE LES PERTES DANS LES DIFFUSEURS ET LES CONDITIONS D'ENTREE DE L'ECOULEMENT A L'ENTREE DE LA CHAMBRE DE COMBUSTION POUR DES TURBOREACTEURS]
ARMIN KLEIN L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 133, 1988, p. 22-31. In French. refs

Experimental results on the correlation between diffusor losses and the inlet flow conditions of turbojet combustors were obtained, using cascades of compressor blades upstream of the diffusor to simulate the inlet flow field. The measurements show that distortions in the radial direction affect diffusor losses much more than heterogeneities in the azimuthal direction. It is demonstrated that the inlet radial blockage factor is a reliable measurement of turbojet performance. R.R.

A89-24917
COMBINED PROPULSION FOR HYPERSONIC AND SPACE VEHICLES [LA PROPULSION COMBINEE POUR VEHICULES HYPERSONIQUES ET SPATIAUX]
J. CALMON (AAAF, Paris; ONERA, Chatillon-sous-Bagneux, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 133, 1988, p. 32-46. In French. refs

Various configurations of combined propulsion for hypersonic and space flight are evaluated with respect to such factors as specific impulse and specific thrust. Special attention is given to the turboramjet, and it is noted that from takeoff up to Mach 4 flight, both the turborocket and the ramjet chambers are in operation, while between Mach 4 and 7, only the ramjet engine is in operation. Air intake, combustion, flame stabilization, and ignition characteristics of scramjets are also discussed. R.R.

A89-24989*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NNEPEQ - CHEMICAL EQUILIBRIUM VERSION OF THE NAVY/NASA ENGINE PROGRAM
L. H. FISHBACH (NASA, Lewis Research Center, Cleveland, OH) and S. GORDON (Sanford Gordon and Associates, Cleveland, OH) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 111, Jan. 1989, p. 114-116. Previously announced in STAR as N88-21161.
(ASME PAPER 88-GT-314)

The Navy NASA Engine Program, NNEP, currently is in use at a large number of government agencies, commercial companies and universities. This computer code has been used extensively to calculate the design and off-design (matched) performance of a broad range of turbine engines, ranging from subsonic turboprops to variable cycle engines for supersonic transports. Recently, there has been increased interest in applications for which NNEP was not capable of simulating, namely, high Mach applications, alternate fuels including cryogenics, and cycles such as the gas generator air-turbo-rocker (ATR). In addition, there is interest in cycles employing ejectors such as for military fighters. New engine component models had to be created for incorporation into NNEP, and it was found necessary to include chemical dissociation effects of high temperature gases. The incorporation of these extended capabilities into NNEP is discussed and some of the effects of these changes are illustrated. Author

A89-25004#
IMPROVED METHODS OF CHARACTERIZING EJECTOR PUMPING PERFORMANCE
JOE DER, JR. (Northrop Corp., Pico Rivera, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0008)

The present method for the characterization of ejector-pumping performance data performs continuously from zero-flow to high primary nozzle pressure ratio conditions. Choked and unchoked secondary ejector flow regions are distinguished; in the former, ejector pumping characteristics are simplified because the corrected secondary-to-primary weight flow ratio is a function solely of secondary-to-primary pressure ratio for a given ejector area ratio. Attention is also given to a new spacing-ratio definition, which characterizes ejector mixing length in terms of the height of the secondary flow gap rather than the nozzle diameter, is based on the detailed flow mechanics of entrainment due to the development of a free mixing layer. O.C.

A89-25005*# Old Dominion Univ., Norfolk, VA.
ADAPTIVE COMPUTATIONS OF MULTISPECIES MIXING BETWEEN SCRAMJET NOZZLE FLOWS AND HYPERSONIC FREESTREAM
OKTAY BAYSA, WALTER C. ENGELUND, MOHAMED E. ELESHAKY (Old Dominion University, Norfolk, VA), and JAMES L. PITTMAN (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NAG1-811)
(AIAA PAPER 89-0009)

The objective of this paper is to compute the expansion of a supersonic flow through an internal-external nozzle and its viscous mixing with the hypersonic flow of air. The supersonic jet may be that of a multispecies gas other than air. Calculations are performed for one case where both flows are those of air, and another case where a mixture of freon-12 and argon is discharged supersonically to mix with the hypersonic airflow. Comparisons are made between these two cases with respect to gas compositions, and fixed versus flow-adaptive grids. All the computational results are compared successfully with the wind-tunnel tests results. Author

A89-25006*# United Technologies Research Center, East Hartford, CT.
PERFORMANCE POTENTIAL OF AIR TURBO-RAMJET EMPLOYING SUPERSONIC THROUGH-FLOW FAN
C. E. KEPLER (United Technologies Research Center, East Hartford, CT) and G. A. CHAMPAGNE (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(Contract NAS3-24843)
(AIAA PAPER 89-0010)

A study was conducted to assess the performance potential of a supersonic through-flow fan in an advanced engine designed to power a Mach-5 cruise vehicle. It included a preliminary evaluation of fan performance requirements and the desirability of supersonic versus subsonic combustion, the design and performance of supersonic fans, and the conceptual design of a single-pass air-turbo-rocket/ramjet engine for a Mach 5 cruise vehicle. The study results showed that such an engine could provide high thrust over the entire speed range from sea-level takeoff to Mach 5 cruise, especially over the transonic speed range, and high fuel specific impulse at the Mach 5 cruise condition, with the fan windmilling. Author

A89-25092#
FLOWFIELD MODIFICATIONS OF COMBUSTION RATES IN UNSTABLE RAMJETS
D. M. REUTER, U. G. HEGDE, and B. T. ZINN (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th,

Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract N00014-84-K-0470)
(AIAA PAPER 89-0105)

This paper describes interactions between unsteady combustion and vorticity in the flame region of an unstable laboratory ramjet burner. The steady and unsteady components of the velocity field are obtained using a conditional sampling laser-Doppler velocimetry (LDW) technique. The vorticity field is then derived from the measured velocity field. It is shown that combustion instability in the ramjet burner is accompanied by unsteady vortex shedding at the flame holding region. The vortex shedding occurs at the frequency of instability and it periodically distorts the flame front causing a cyclic variation of the flame area. A second important effect of the unsteady vortex shedding is an oscillatory variation of the flame speed. These effects result in a strong unsteady heat release rate capable of driving the longitudinal instabilities in the system. Author

A89-25218#
TURBULENT MIXING IN SUPERSONIC COMBUSTION SYSTEMS
J. SWITHENBANK, I. W. EAMES, S. B. CHIN, B. C. R. EWAN, Z. Y. YANG (Sheffield, University, England) et al. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0260)

Fundamental principles of turbulence generation, dissipation and mixing-limited combustion were applied to the scramjet with particular attention given to the combustor. It is shown that the overall engine performance may be compromised in order to achieve adequate mixing and good combustion efficiency in an acceptable combustor length. Cycle optimization studies show that the highest performance, in terms of fuel specific impulse, is obtained at a combustion efficiency of about 80 percent at M = 10. K.K.

A89-25491#
AN EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF ISOTHERMAL SWIRLING FLOW IN AN AXISYMMETRIC DUMP COMBUSTOR
S. C. FAVALORO (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia), A. S. NEJAD, S. A. AHMED, T. J. MILLER (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH), and S. P. VANKA (Argonne National Laboratory, IL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0620)

Experimental and theoretical studies of nonreacting swirling flow have been performed in a model of an axisymmetric dump combustor. A two-component laser Doppler velocimeter was used to obtain measurements of the three velocity components and a number of fundamental turbulence quantities in two series of tests with minimum disturbance to the combustor flow field. The results showed the significant effects of swirl, both with and without vortex breakdown, on the mean and turbulent flow fields. The experimental results were used to check the performance of a recently developed computer program which used the k-epsilon closure model. Comparison of the numerical and experimental results showed the inadequacy of the k-epsilon turbulence model in representing the complex structure of confined swirling flows. Author

A89-25493#
LOW FREQUENCY PRESSURE OSCILLATIONS IN A MODEL RAMJET COMBUSTOR - THE NATURE OF FREQUENCY SELECTION
K. YU, A. TROUVE, R. KEANINI, L. BAUWENS (California, University, Berkeley), and J. W. DAILY (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 21 p. refs
(Contract N00014-84-K-0372)
(AIAA PAPER 89-0623)

Low frequency pressure oscillations have been studied in a model ramjet dump combustor facility. The facility has a variable geometry test section with full optical access. Pressure and velocity measurements are made at various locations in the inlet duct and combustor. Global C2 and CH radical emission intensities in the combustor are measured to determine the phase relation between heat release rate and pressure in the combustor. Holding the equivalence ratio fixed, the combustor geometry and inlet velocity are varied to determine the effect of mean fluid residence time on frequency of the oscillation. Phase locked schlieren visualization results will be shown which allow tracking of the flame front during an entire pressure cycle. The experimental results are interpreted with the aid of acoustic and residence time analyses. The results indicate that the frequency is controlled by the acoustics in the inlet duct and the vortex convection inside the combustor. The amplitude of oscillation is determined by the nature of the perturbed flow entering and leaving the combustor and there is evidence for a chaotic type of variation in amplitude. Author

A89-25494#
EVIDENCE OF A STRANGE ATTRACTOR IN RAMJET COMBUSTION
RUSSELL G. KEANINI, KENNETH YU (California, University, Berkeley), and JOHN W. DAILY (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract N00014-84-K-0372)
(AIAA PAPER 89-0624)

Preliminary evidence suggests that the random pressure fluctuations which occur during acoustically coupled unstable combustion inside a laboratory ramjet combustor describe a strange attractor. Power spectra, phase portraits, and Poincare sections are all indicative of a strange attractor. The fractal dimension of the attractor is estimated to be in the range of 1.5 to 3.8. The apparent attractor appears to have other properties associated with strange attractors, most notably, exponentially diverging phase trajectories and the tendency to transmute to other structures as a critical parameter is varied. This appears to be the first reported instance of chaotic dynamics occurring in a combustion process. Author

A89-25533#
SCRAMJET ANALYSIS WITH CHEMICAL REACTION USING THREE-DIMENSIONAL APPROXIMATE FACTORIZATION
J. C. WAI and D. SOMMERFIELD (Boeing Advanced Systems, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0672)

The design of a scramjet propulsion system for a hypersonic vehicle is a challenging engineering problem. A thin-layer Navier-Stokes computer program has been developed to study the associated viscous and chemically reacting flow fields. A significant computing speed improvement in the finite rate chemistry analysis was achieved relative to other methods by using an existing proven flow solver technology. The new code solves the gas dynamic and species conservation equations in a fully coupled manner using the diagonalization of the approximate factorization algorithm. The flows of two generic lobed fuel injectors with hydrogen-air combustion were investigated to explore scramjet lobed injector design. Author

A89-27694#
SUBCRITICAL SWIRLING FLOWS IN CONVERGENT, ANNULAR NOZZLES
K. KNOWLES (Royal Military College of Science, Shrivenham, England) and P. W. CARPENTER (Exeter, University, England) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 184-191. refs

A quasicylindrical theory is developed for subcritical, inviscid, swirling flows in annular nozzles and extended to include nonuniform stagnation conditions. A small perturbation theory is also developed and shown to give remarkably good agreement, even for high swirl levels. The effects on mass flow rate, impulse function, and thrust of different swirl velocity profiles are investigated for a typical turbofan geometry, with nonswirling core nozzle flow, at differing nozzle pressure ratios. Specific thrust is found to decrease with swirl. The rate of decay depends on the swirl velocity profile, and the relative effects of different swirl profiles depend on the basis of comparison. Author

A89-28202
PROP-FAN STRUCTURAL RESULTS FROM PTA TESTS
P. C. BROWN and J. E. TURNBERG (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p. refs
(SAE PAPER 881418)

The Propfan Test Assessment program has used a testbed aircraft wing-mounted 9-ft diameter rotor, driven by a gas turbine engine, to both demonstrate this technology and obtain baseline-defining structural data useful in the understanding of larger propfans. Blade dynamic strain measurements have been made over a range of ground-operation and flight-operation conditions; these encompass the effects of various nacelle tilt angles. The trends in blade dynamic response with aircraft operating condition that emerge are compared to propfan forced-response predictions. O.C.

A89-28228* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RESULTS FROM NASA LANGLEY EXPERIMENTAL STUDIES OF MULTIAXIS THRUST VECTORING NOZZLES
BOBBY L. BERRIER (NASA, Langley Research Center, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 18 p. refs
(SAE PAPER 881481)

Multiaxis thrust-vectoring nozzles can furnish substantial combat performance gains for military aircraft; in pursuit of these gains, NASA-Langley has conducted an extensive experimental research program encompassing both static and freestream performance evaluations for numerous multiaxis thrust-vectoring nozzle concepts using air-powered simulation models. An evaluation is presently made of a selection of these experimental results. Two-dimensional and axisymmetric convergent-divergent configurations and hybrid configurations, with and without postexit vanes, have been studied. O.C.

A89-28254
AEROSPACE POWER SYSTEMS TECHNOLOGY; PROCEEDINGS OF THE AEROSPACE TECHNOLOGY CONFERENCE AND EXPOSITION, ANAHEIM, CA, OCT. 3-6, 1988
Conference and Exposition sponsored by SAE. Warrendale, PA, Society of Automotive Engineers, Inc. (SAE SP-758), 1988, 151 p. For individual items see A89-28255 to A89-28269.
(SAE SP-758)

The present conference on aircraft auxilliary power systems discusses aircraft thermal management, highly reliable DC power sources for avionic subsystems, a cascaded doubly-fed variable-speed/constant-frequency generator, the evolution of battery systems employed by USAF aircraft, electrical power system architectures for future aerospace vehicles, and high-reliability aircraft generators. Also discussed are the benefits of digital control and management system integration in secondary power systems, pneumatic link secondary power systems for military aircraft, the combination of emergency power with an APU, X-29A subsystems integration, and the T-100 multipurpose small power unit. O.C.

A89-28257
A HIGHLY RELIABLE DC POWER SOURCE FOR AVIONIC SUBSYSTEMS
MARIO R. RINALDI (Sundstrand Corp., Sundstrand Advanced Technology Group, Rockford, IL) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 27-31.
(SAE PAPER 881408)

A highly reliable alternative source for aircraft + 28 V dc power is presented. This alternative uses a permanent magnet generator and an electronic converter/regulator (C/R). The power system includes such features as independence from the main power system, high power quality with terminal or remote point of regulation, light weight, and constant power availability from engine idle to maximum rpm. Included is a brief system description, a review of steady state and transient performance, and a conclusion with a perspective on future expectations. Author

A89-28258
EXPERIMENTAL CASCADED DOUBLY FED VARIABLE SPEED CONSTANT FREQUENCY GENERATOR SYSTEM
MIGUEL A. MALDONADO and STEVEN M. IDEN (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 33-39.
(SAE PAPER 881409)

Brushless variable-speed constant frequency (VSCF) electric power generation may be obtained using cascaded, symmetrically-wound machines. The feasibility of using these machines as the basis for a stand-alone aircraft generator system was investigated. The concept is attractive as the system operates without hydraulics and employs a solid-state power converter which operates at a fraction of the system output power and frequency. These factors combine to offer a system of relatively low complexity, with the potential for high-reliability operation. This paper will discuss the operation of the cascaded doubly-fed VSCF generator system and microprocessor control unit. Author

A89-28259
PARALLEL OPERATION OF VSCF ELECTRICAL POWER GENERATORS
D. E. BAKER and E. R. HONIGFORD (Westinghouse Electric Corp., Lima, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 41-50.
(SAE PAPER 881410)

While variable-speed/constant-frequency (VSCF) electrical power generation systems have in the past been restricted to aircraft not requiring the parallel operation of multiple channels, novel multiengine aircraft applications entail the continuous parallel operation of installed channels to furnish superior system reliability and equal loading of the generators. In VSCF systems, synchronous operation with precise angle control between channels is furnished during either parallel or split operational modes; the autoparalleling of channels therefore results in very small amplitude transients and virtually no frequency or phase-angle transients on the bus. O.C.

A89-28260
OVERVIEW ON THE EVOLUTION OF AIRCRAFT BATTERY SYSTEMS USED IN AIR FORCE AIRCRAFT
RICHARD A. FLAKE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 51-53.
(SAE PAPER 881411)

Efficient USAF operations require maintenance-free aircraft batteries; potential cost-savings of the order of millions of dollars/year have been projected for maintenance-free battery systems. Attention is given to the current development status and maintenance consequences of Ni-Cd batteries and sealed lead-acid batteries, as well as the the prospects foreseen for their improvement from a maintenance-requirement viewpoint. In 1986, AFWAL initiated the development of a sealed Ni-Cd battery/charger/microprocessor-controlled unit with built-in test capability which can fly aboard aircraft for 3 years (1500 flight hours) before scheduled maintenance. O.C.

A89-28262
UNBALANCED AND NONLINEAR LOADS IN AIRCRAFT ELECTRICAL SYSTEMS
BERNARD A. RAAD (Sundstrand Corp., Sundstrand Advanced Technology Group, Rockford, IL) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 63-68. refs
(SAE PAPER 881413)

Analytical and empirical data are presently brought to bear on the problematic effects of unbalanced and nonlinear loads on three-phase synchronous generator-driven aircraft electrical power system behavior. The effects extend to voltage imbalances, phase-angle displacements, line-induced harmonics, voltage spikes, waveform distortion, and coronas. The present treatment recommends the institution of filtering, load-induced distortion-limiting specifications, and novel voltage regulator designs. O.C.

A89-28263
HIGH RELIABILITY AIRCRAFT GENERATOR SYSTEM
STEVEN M. IDEN and ANGELA MORRIS (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 69-74.
(SAE PAPER 881414)

The resonant-link power system presently considered as an approach to the generation of constant-voltage power by a variable-speed/constant-frequency apparatus. A permanent-magnet genertor is used in conjunction with a resonant-link solid state power converter. The use of the resonant-link allows a bidirectional power flow for engine-start capability, and permits power semiconductor devices to be switched during the high-frequency link zero-crossings; this reduces device stresses and thereby improves reliability. A 40-kVA technology demonstrator resonant link device is under development. O.C.

A89-28264
SECONDARY POWER - BENEFITS OF DIGITAL CONTROL AND VEHICLE MANAGEMENT SYSTEM INTEGRATION
JAMES M. BENSON (McDonnell Aircraft Co., Saint Louis, MO) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 75-81.
(SAE PAPER 881498)

Seconary power by definition is any power other than main propulsive power. Integrated digital control of the secondary power system will play an important role in the overall enhancement of advanced fighter aircraft. This paper will address the design and development philosophy of an integrated, digitally-controlled and monitored secondary power system. Subsystem design requirements and critical technologies needed for implementation and integration with a Vehicle Management System (VMS) will be identified. A design approach and road map will be presented on the procedure to target such a system for a fully integrated application such as a VMS. Author

A89-28265
PNEUMATIC LINK SECONDARY POWER SYSTEMS FOR MILITARY AIRCRAFT
COLIN RODGERS (Sundstrand Corp., Sundstrand Turbomach Div., San Diego, CA) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 83-98. refs
(SAE PAPER 881499)

Recent requirements for in-flight engine cross-bleed starts in twin-engined military aircraft at the higher Mach numbers have compelled increases of bleed internal duct temperatures to 1200 F. Attention is presently given to the consequences of the direct use of higher APU bleed air pressure ratios, or the alternative use of 'bleed-and-burn' power-augmentation, for the power density of pneumatic-link startup systems. It is found that bleed pressure ratios as high as 6.0 can furnish a more that 10-percent savings in power/volume ratio, depending on APU location; the use of power augmentation is found able to furnish a more-than 25-percent weight/volume reduction, but may conflict with increasing avionics ground cooling capacity demands. O.C.

A89-28266
EMERGENCY POWER COMBINED WITH AUXILIARY POWER UNIT
DONALD B. STEWART, JR. (Allied-Signal Aerospace Co., Garrett Auxiliary Power Div., Phoenix, AZ) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 99-113.
(SAE PAPER 881500)

A testing program has demonstrated the feasibility and advantages of combining emergency power unit (EPU) and auxiliary power unit (APU) in a single powerpack, designated the Multifunction Integrated Power Unit, for fighter aircraft. Weight, volume, and cost are thereby reduced due to the obviation of a gearbox and separate control systems. The lower parts count also reduces maintenance, logistics support, and spares requirements. An APU by itself would not supply the requisite fast power initiation, especially at extreme altitudes. The EPU employed uses conventional jet fuel to simplify operational and maintenance requirements. O.C.

A89-28336#
ACOUSTIC-VORTEX INTERACTIONS AND LOW-FREQUENCY OSCILLATIONS IN AXISYMMETRIC COMBUSTORS
K. KAILASANATH, J. H. GARDNER, J. P. BORIS, and E. S. ORAN (U.S. Navy, Naval Research Laboratory, Washington, DC) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 165-171. Research sponsored by the U.S. Navy. Previously cited in issue 08, p. 1050, Accession no. A87-22454. refs

A89-28337#
MODULAR ANALYSIS OF SCRAMJET FLOWFIELDS
JOSEPH A. SCHETZ (Virginia Polytechnic Institute and State University, Blacksburg), FREDERICK S. BILLIG, and STANLEY FAVIN (Johns Hopkins University, Laurel, MD) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 172-180. Research supported by the U.S. Navy. Previously cited in issue 20, p. 3179, Accession no. A87-45443. refs

A89-28342#
INFLUENCE OF VANE/BLADE SPACING AND INJECTION ON STAGE HEAT-FLUX DISTRIBUTIONS
M. G. DUNN (Calspan Advanced Technology Center, Buffalo, NY) and R. E. CHUPP (Teledyne CAE, Toledo, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 212-220. Research supported by the Teledyne CAE Independent Research and Development Funds. Previously cited in issue 20, p. 3156, Accession no. A87-45295. refs

A89-28403*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARISON OF 3D COMPUTATION AND EXPERIMENT FOR NON-AXISYMMETRIC NOZZLES
H. LAI and E. NELSON (NASA, Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Middleburg Heights, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAS3-24105; NAS3-25266)
(AIAA PAPER 89-0007)

Three-dimensional solutions of a single expansion ramp nozzle are computed with the existing PARC computer code by solving the full Navier-Stokes equations. The computations are performed to simulate the non-axisymmetric nozzle flowfield in both the internal/external expansion regions and the exhaust plume in a quiescent ambient environment. Two different configurations of the nozzle at a pressure ratio NPR = 10 are examined. Numerical results of laminar flows are presented, and the wall pressure distributions are compared with the experimental data. Author

A89-28462*# Purdue Univ., West Lafayette, IN.
EFFECT OF HEAVY RAIN ON AVIATION ENGINES
S. N. B. MURTHY (Purdue University, West Lafayette, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. refs
(Contract NAG3-481; DOT-FA03-83-A-00328)
(AIAA 89-0799)

High bypass ratio gas turbine engines may ingest water and hail during flight in an environment of thunderstorms, and the performance and the operation-handling characteristics of the engine and its control become affected often substantially and critically. It is, therefore, of interest to establish predictive schemes for determining changes in performance of components and the total system. The current status of development of such predictive schemes is discussed along with illustrative examples. The needs for additional research are discussed, that are essential for improving: (1) the predictive schemes and (2) the methods of simulating in-rain flight conditions on ground. Author

N89-16782# Naval Air Systems Command, Washington, DC.
AN OVERVIEW OF US NAVY ENGINE MONITORING SYSTEM PROGRAMS AND USER EXPERIENCE
ANDREW J. HESS *In* AGARD, Engine Condition Monitoring: Technology and Experience 16 p Oct. 1988
Avail: NTIS HC A20/MF A01

The Naval Air System Command (NAVAIR) has made a commitment to require inflight engine monitoring capabilities and Engine Monitoring Systems (EMS) on all new aircraft and engine programs. The current EMS requirement and system design concepts are the end result of over 15 years of developing system capabilities and justifying system benefits. These requirements and system design concepts are based on the lessons learned from the F/A-18 and A-7E Inflight Engine Condition Monitoring System (IECMS) program. The highly successful A-7E IECMS is the cornerstone on which all Navy EMS are based today. NAVAIR has revised the general engine specifications to contain detailed requirements for a comprehensive EMS. These requirements were included for flight safety, maintenance, engineering management, and operational support benefits. These specification requirements were used on all new aircraft/engine programs (e.g., F-14A+, F-14D, A-6F, AV-8B, E-2C re-engine, and V-22). When justifiable, EMS is also being considered for retrofit on several older aircraft/engine applications. An overview is given of the U.S. Navy EMS program status. Established EMS functional capabilities and requirements are discussed and detailed specification items are reviewed. Current EMS projects are examined with respect to system description, program status and individual peculiarities. Finally, conclusions are given on EMS projected benefits, user experience, lessons learned, and future directions of this technology. Author

N89-16783# Royal Air Force, London (England).
ENGINE USAGE CONDITION AND MAINTENANCE MANAGEMENT SYSTEMS IN THE UK ARMED FORCES
W. D. M. FLETCHER and N. A. BAIRSTO *In* AGARD, Engine Condition Monitoring: Technology and Experience 5 p Oct. 1988
Avail: NTIS HC A20/MF A01

The cost effectiveness of engine condition monitoring is often questioned. The Royal Air Force (RAF) has considerable experience in engine condition monitoring based on a series of trials. Recently aircraft were introduced with comprehensive monitoring systems. Previous condition usage monitoring trials are outlined together with the reasons for changing from scheduled based maintenance to condition based maintenance. The cost effectiveness of various methods is revealed and the difficulty of justifying the retrofit of equipment fleetwide is discussed. Finally, some of the current activities in the RAF on condition monitoring are presented. Author

N89-16784# National Defence Headquarters, Ottawa (Ontario). Directorate of Transport and Helicopter Engineering and Maintenance.
CANADIAN FORCES AIRCRAFT CONDITION/HEALTH MONITORING: POLICY, PLANS AND EXPERIENCE
CHRISTOPHER SCHOFIELD, ROSS LAGRANDEUR, FRANCOIS DUBE, THOMAS HARRIS, ROBERT W. CUE, and ALAIN LEBLANC *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p Oct. 1988
Avail: NTIS HC A20/MF A01

Current Canadian Forces (CF) policy with respect to aircraft Engine Condition/Health Monitoring (ECM/EHM) is highlighted. In doing so, a summary of CF aircraft types and the ECM/EHM techniques applied to each is presented. The CF's experience to date with the development and application of ECM/EHM is reviewed. This includes an examination of the effectiveness of the CF Spectrometric Oil Analysis Program and the use of magnetic particle detectors and manual performance trending. Present plans for further development and implementation of policy; methodologies and techniques; and for the integration of these into an effective ECM/EHM capability that will pay benefits both in terms of life cycle costs and operational availability, are presented. Author

N89-16787# GasTOPS Ltd., Ottawa (Ontario).
CF-18 ENGINE PERFORMANCE MONITORING
D. E. MUIR, D. M. RUDNITSKI, and ROBERT W. CUE (National Defence Headquarters, Ottawa, Ontario) *In* AGARD, Engine Condition Monitoring: Technology and Experience 20 p Oct. 1988
Avail: NTIS HC A20/MF A01

The Canadian Forces (CF) have adopted a conditional maintenance concept for the engines of the CF-18 fighter aircraft. In support of this concept, advanced engine performance monitoring procedures are being developed to track the general performance level of each engine and identify problematic engine components. The procedures are based on takeoff ground roll data recorded by the aircraft In-Flight Engine Condition Monitoring System and steady-state data obtained from automated Engine Test Facilities. The development and field evaluation of these procedures is described. A discussion of future development work and related research activities is also included. Author

N89-16790# Ministry of Defence, London (England). Directorate of Engines.
RECENT UK TRIALS IN ENGINE HEALTH MONITORING: FEEDBACK AND FEEDFORWARD
M. J. SAPSARD *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p Oct. 1988
Avail: NTIS HC A20/MF A01

Engine health monitoring effectiveness had to be quantified prior to large scale commitment by the UK Services. Some of the activities undertaken in Air Staff Target 603 are described. A program was set up to assess that effectiveness. Also described are some of the incidental lessons learned from this and other related health monitoring exercises. Author

N89-16796# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
SERVICE LIFE CALCULATOR FOR THE M53 TURBOFAN ENGINE [LE CALCULATEUR DE POTENTIEL SUR LE REACTEUR M53]
CLAUDE SPRUNG *In* AGARD, Engine Condition Monitoring: Technology and Experience 15 p Oct. 1988 In FRENCH
Avail: NTIS HC A20/MF A01

The functional requirements for a service life calculator are defined and the flight and ground equipment comprising such a system are described. A system utilization philosophy is defined and preliminary results from studies considering the application of service life calculators are presented. Author

N89-16800# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
THE ADVANTAGE OF A THRUST RATING CONCEPT USED ON THE RB199 ENGINE
P. THEIMER *In* AGARD, Engine Condition Monitoring: Technology and Experience 15 p Oct. 1988
Avail: NTIS HC A20/MF A01

The control system of the RB199 engine was designed for a rating, using the HP-turbine inlet temperature as a limiter. The engine has now been in service for 7 years and still uses the original concept throughout all fleets in the UK, Italy and Germany, although new digital engine control units are being introduced which will allow considerable improvements. For some fleets a thrust rating concept based on the original control system design has been installed recently. The concept is described and the procedure explained. A comparison is made between the existing full thrust concept at the maximum cleared HP turbine temperature and the applied thrust rating concept. Besides the basic behavior of seal gaps, the influence of thrust rating in view of the life usage of life-limited parts as well as in the change of the maintenance material costs is explained. The assumptions for the comparison with their background are described. Finally, a refined thrust rating concept is introduced. Author

N89-16802# Aeronautical Research Labs., Melbourne (Australia).
GAS PATH ANALYSIS AND ENGINE PERFORMANCE MONITORING IN A CHINOOK HELICOPTER
D. E. GLENNY *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p Oct. 1988
Avail: NTIS HC A20/MF A01

Periodic and consistent assessment of engine performance in military heicopters is essential if in-service operating margins are not to be eroded by harsh environmental conditions. Manually initiated GO-NO-GO pre-flight checks (HIT, etc.) or ad-hoc in-flight performance checks rarely provide sufficiently reliable data for maintenance or diagnostic purposes. In contrast, performance assessment methods based on gas path analysis principles and engine/aircraft data, automatically recorded during flight, offer a potentially attractive alternative. ARL has investigated a number of these alternatives, and has carried out an in-service trial on a Boeing CH47C Chinook helicopter operated by the RAAF. In the trial existing aircraft/engine instrumentation was complemented by specially designed probes located at module interfaces while the data was recorded on an ARL designed acquisition system. The performance-fault algorithms used in the analyses were configured for a range of engine operating speeds. Results for the trial are presented in terms of deviations from pre-established baseline conditions. Statistical analyses using linear regression fits and Kalman filtering techniques have been investigated to minimize the effects of data uncertainty. The applicability of the procedures, including thermodynamic analyses and equipment are discussed in terms of fleetwide adoption of the Chinook. Author

N89-16803# National Research Council of Canada, Ottawa (Ontario).
THE EFFECTS OF A COMPRESSOR REBUILD ON GAS TURBINE ENGINE PERFORMANCE
J. D. MACLEOD and J. C. G. LAFLAMME (Canadian Forces Base, Baden-Soellingen, Germany, F.R.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p Oct. 1988
Avail: NTIS HC A20/MF A01

The Canadian Department of Defence, in conjunction with the Engine Laboratory of the National Research Council Canada, initiated a project for the evaluation of gas path coatings on the Allison T56 engine. The objective of this work was to evaluate blade coatings in terms of engine performance effects and material durability. The project included a study of the influence of rebuilding the compressor on performance, since dismantling and rebuilding was required in the coating process. Described is the compressor rebuild study, including the overall objectives, the test set-up, the performance effects, and the uncertainty of the measured results. The impact of this work on the coatings project is also documented. Author

N89-16804# GEC Avionics Ltd., Rochester (England). Future Systems Group.
SYSTEM CONSIDERATIONS FOR INTEGRATED MACHINERY HEALTH MONITORING
R. M. TESTER *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p Oct. 1988
Avail: NTIS HC A20/MF A01

Aircraft engine health monitoring, and other related machinery condition monitoring, has been gaining in credibility and implementation over recent years. It is destined to become standard fit on all new major aircraft programs in the near future. To date the monitoring systems have mainly been stand-alone in form, and have been treated as separate functions. This paper discusses the considerations for integrating health monitoring into other aircraft systems, and reviews the potential benefits to be gained by such integration. In conclusion, the paper presents two products from both ends of the spectrum, representing a simple single unit integration, and a full aircraft-wide implementation. Author

N89-16805# Societe de Fabrication d'Instruments de Mesure, Massy (France). Measurement and Flight Test Dept.
MAINTENANCE AID SYSTEM FOR WIDE BODY AIRCRAFT
ALBERT LEVIONNOIS *In* AGARD, Engine Condition Monitoring: Technology and Experience 7 p Oct. 1988
Avail: NTIS HC A20/MF A01

Aircraft maintenance personnel, when troubleshooting aircraft failures, must first acquire a great deal of information about the aircraft's engines before being able to arrive at any kind of diagnosis. Computerized modern aircraft provide all necessary parameters with good precision. Aircraft condition monitoring systems centralize information from data buses, compute flight phases, determine the reports to be made per flight phase and function, and carry out automatic parameter identification. Should an incident occur, then the parameter's history is stored before and after the incident, together with its evolution. All this information is stored in static memory for transmission by data link, is printed during or after the flight, or downloaded when the aircraft is back at its base. Today between 35 and 40 reports are currently produced by wide body aircraft. This technology is easily adaptable to combat aircraft. Author

N89-16806# Computing Devices Co., Ottawa (Ontario).
INSTALLED THRUST AS A PREDICTOR OF ENGINE HEALTH FOR JET ENGINES
G. B. MACKINTOSH and M. J. HAMER *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p Oct. 1988
Avail: NTIS HC A20/MF A01

Extensive installed and uninstalled gross thrust measurements were made over one complete maintenance cycle on 19 afterburning turbojet engines. Installed measurements utilized a sensor which can compute the thrust in real time from engine tailpipe pressure measurements. Correlation of installed thrust with maintenance history indicated a maximum degradation below which engines were removed from service. The engines were trimmed uninstalled, using lapse rate charts to produce a specific value of uninstalled thrust, corrected to standard conditions. Significant variations in installed corrected thrust resulted. Higher initial values of installed corrected thrust resulted in more rapid engine degradation and a shorter time before maintenance was required. Author

N89-16809# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
FAULT MANAGEMENT IN AIRCRAFT POWER PLANT CONTROLS
S. MAZAREANU and A. NOBRE *In* AGARD, Engine Condition Monitoring: Technology and Experience 16 p Oct. 1988
Avail: NTIS HC A20/MF A01

The advent of Digital Electronics in aviation has opened new doors to fault management as a tool to enhance aircraft operability and safety in flight. Today it is possible to integrate flight control systems with power plant management systems. Operability of a battle-damaged aircraft can be enhanced under certain conditions through sophisticated fault management systems. This paper reviews some of the considerations applicable to engine control fault management systems in commercial aviation. Engine control systems have evolved in the last decade from being primarily hydromechanical to being primarily electronics. This rapid growth in acceptance of the electronic systems by the aviation industry was due to the improvement in reliability of the digital system over analog systems previously in use. The fault management system is a powerful tool to organize and optimize maintenance logistics. Operating costs can be significantly reduced with an appropriate fault management system on board. The paper presents: (1) a brief review of the evolution of engine controls; (2) the emergence of fault management systems (as part of engine control systems); (3) maturity of fault management systems (still evolving); and (4) future potential. Author

N89-16813# Aeronautical Research Labs., Melbourne (Australia).
IDENTIFICATION OF DYNAMIC CHARACTERISTICS FOR FAULT ISOLATION PURPOSES IN A GAS TURBINE USING CLOSED-LOOP MEASUREMENTS
G. L. MERRINGTON *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p Oct. 1988
Avail: NTIS HC A20/MF A01

Combat aircraft, because of the mission profiles involved, tend to rarely operate with their engines in a steady-state condition for extended periods. Furthermore, current generation aircraft contain Engine Monitoring Systems (EMS) which automatically capture a record of important engine parameters when a parameter exceedance is detected. It follows then that any subsequent post-flight data analysis for fault isolation purpose will often necessitate the extraction of the required diagnostic information from transient data records. This generally contrasts with past practice where most of the available fault diagnostic procedures have been derived from steady-state information. In an attempt to overcome this, and thereby provide effective tools for diagnosing faults from transient data records, a procedure is outlined to extract information about the dynamic characteristics of gas turbines from input/output measurements. The parameter estimator technique involved has the potential to provide a means of detecting changes in some unmeasured/unrecorded parameter, such as shifts in variable geometry schedules. Thus in essence, it provides a tool for identifying problems from simple transient test data which were previously inaccessible or difficult to obtain. Author

N89-16814# Canadian Forces Base Trenton, Astra (Ontario). Aerospace Maintenance Development Unit.
CF-18/F404 TRANSIENT PERFORMANCE TRENDING
J. R. HENRY *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p Oct. 1988
(Contract FE220786FRMC4; ARP-3610-147)
Avail: NTIS HC A20/MF A01

The on condition concept of aircraft engine maintenance has led to intensive analysis of the data recorded by Engine Health Monitoring systems during steady-state operation of the engine. To date however the transient data acquired during take-off or in-flight have received far less attention. Presented here are the results of an investigation into the feasibility of utilizing engine data acquired during take-off to trend the performance of a modern turbofan engine (GE-F404). Factors influencing the repeatability of take-off data such as throttle rate, variable geometry and instrumentation effects are discussed. Using engine data from operational aircraft, various trending parameters are evaluated using a data capture window developed to minimize the scatter of nominal engine performance. A statistical tool to identify performance shifts is briefly described, and is shown to successfully detect a shift in the take-off performance of a recently repaired engine. It is concluded that the trending of transient performance data is a viable means of detecting certain engine faults and recommendations are made concerning the implementation of such a program for the F404 engine. Author

N89-16821# Naval Postgraduate School, Monterey, CA. Dept. of Aeronautics and Astronautics.
MEASUREMENTS OF GAS TURBINE COMBUSTOR AND ENGINE AUGMENTOR TUBE SOOTING CHARACTERISTICS Final Report, Oct. 1986 - Sep. 1987
M. F. YOUNG, T. A. GRAFTON, H. CONNER, and DAVID W. NETZER Jul. 1988 57 p
(AD-A199768; NPS67-88-002) Avail: NTIS HC A04/MF A01 CSCL 21B

An experimental investigation was conducted to determine the changes in soot mean diameter across the combustor and exhaust nozzle of a T63 gas turbine engine, and across an exhaust augmentor tube. D32 within the combustor varied between 0.16 and 0.25 microns, depending upon fuel composition. Data correlation was most successful in this location using an index of refraction of 1.95 -0.66i with sigma = 1.5. In the aft can location (ahead of the exhaust nozzle) D32 was between 0.35 and 0.45 microns, depending upon the fuel-air ratio. Increasing fuel-air ratios decreased D32, also in agreement with the results presented in reference 1. Using NAPC 9 high aromatic fuel, D32 increased across the exhaust nozzle (0.35 to 1.2 microns) and across the augmentor tube (1.2 to 1.5 = 1.9 microns). Malvern data were in good agreement with the results obtained using larger scattering angles. GRA

N89-16825# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
TRANSONIC COMPRESSORS, VOLUME 1
1988 240 p Lecture series held in Rhode-Saint-Genese, Belgium, 1-4 Feb. 1988
(VKI-LS-1988-03-VOL-1; ISSN-0377-8312; ETN-89-93590) Avail: NTIS HC A11/MF A01

Loss development in transonic compressor cascades; incidence angle rules in supersonic cascades; exit angle rules in supersonic cascades; shock losses in transonic and supersonic compressor cascades; axial velocity density ratio influence on exit flow angle in transonic/supersonic cascades; analysis of 3D viscous flows in transonic compressors; and inverse methods for blade design, controlled diffusion blading for supercritical compressor flow were discussed. ESA

N89-16826# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (Germany, F.R.). Inst. fuer Strahlantrieb.
LOSS DEVELOPMENT IN TRANSONIC COMPRESSOR CASCADES
HANS STARKEN *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 17 p 1988
Avail: NTIS HC A11/MF A01

Loss in a supercritical cascade is discussed. It is argued that efficient transition of a compressor cascade to supersonic velocities requires a limitation of the suction surface Mach number to values below 1.3. This, in turn, limits pitch-chord ratio, front suction surface camber, and leading edge radius as the responsible parameters. In order to elucidate this, the influence of the blade suction surface and the pitch chord ratio is demonstrated by test results obtained at subsonic and low supersonic velocities. ESA

N89-16827# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (Germany, F.R.). Inst. fuer Strahlantriebe.
INCIDENCE ANGLE RULES IN SUPERSONIC CASCADES
HANS STARKEN *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 31 p 1988
Avail: NTIS HC A11/MF A01

Supersonic inlet flow of flat plate cascades, and blades having cambered suction surfaces is analyzed. The whole flow field is computed with the method of characteristics in cases where

supersonic velocity is assumed everywhere in the entrance region. Where the flow field contains local subsonic regions, approximations can be applied, if the subsonic regions are small enough. Calculations were performed for a straight flat plate profile. The maximum mass-flow of a two dimensional cascade is shown to be limited by the ratio of leading edge over blade pitch. The strong influence of leading edge radius, and the minor influence of stagger angle on the maximum axial Mach number are noted.
ESA

N89-16828# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (Germany, F.R.). Inst. fuer Strahlantriebe.
EXIT ANGLE RULES IN SUPERSONIC CASCADES
HANS STARKEN *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 19 p 1988
Avail: NTIS HC A11/MF A01

The infinitely thin flat plate cascade is used to describe the fundamental flow phenomena which apply to compressor and turbine cascades. With increasing flow angle at the blade trailing edges, which is equivalent to an increase in back pressure, left running oblique shock waves occur at the suction sides of the trailing edges and are reflected at the pressure sides of the adjacent blades. Up to these left running trailing edge shock waves the supersonic flow field in front and within the cascade remains unchanged. For the calculation of the exit flow field behind these shock waves it is necessary to realize that all left running characteristics emanate from the uniform flow field infinitely far downstream. Therefore, the exit flow field can be assumed, in first approximation, to be of the simple wave type, which means that the right running characteristics are straight lines with constant properties. In order to calculate the neutral exit characteristic, it would be necessary to continue the computation up to infinity downstream. But if the knowledge of the complete flow field behind the cascade is not required, a method based upon the simple wave approximation can be used. ESA

N89-16829# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (Germany, F.R.). Inst. fuer Strahlantriebe.
SHOCK LOSSES IN TRANSONIC AND SUPERSONIC COMPRESSOR CASCADES
H. A. SCHREIBER *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 58 p 1988
Avail: NTIS HC A11/MF A01

Flow phenomena and the associated losses of transonic blade sections for upstream Mach numbers of 0.8 to 1.2 are described. Shock losses of two supersonic blade sections of the so-called precompression type are analyzed. Theoretical results of a shock loss model are discussed, showing the influence of inlet Mach number and inlet flow angle. The shock structure and strength within the blade passage of a supersonic blade section is studied, and an insight into the problem of strong shock wave boundary layer interaction with turbulent boundary layer separation is given. Depending on inlet Mach number, inlet flow angle, and back pressure the shock loss level reaches 40 to 70 percent of the overall losses. The data show that shock loss calculations should not be oversimplified but should be carefully modeled according to the real flow conditions. The overall losses have their origins in the leading edge bow shock of supersonic blades that contributes up to 30 percent to the shock losses; the main compression shock or strong passage shock; and viscous losses related to the boundary layer evolution including regions of shock/boundary layer interactions. ESA

N89-16830# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (Germany, F.R.). Inst. fuer Strahlantriebe.
AXIAL VELOCITY DENSITY RATIO INFLUENCE ON EXIT FLOW ANGLE IN TRANSONIC/SUPERSONIC CASCADES
H. A. SCHREIBER *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 22 p 1988
Avail: NTIS HC A11/MF A01

Axial velocity density ratio (AVDR) influence on the cascade exit flow angle Beta sub 2 is discussed. A simple relationship between AVDR and Beta sub 2 is outlined. The AVDR influence on the exit flow properties of supersonic cascades which operate with started supersonic flow at cascade entrance is reviewed.
ESA

N89-16831# Cambridge Univ. (England).
ANALYSIS OF 3D VISCOUS FLOWS IN TRANSONIC COMPRESSORS
W. N. DAWES *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 27 p 1988
Avail: NTIS HC A11/MF A01

A computer code to solve the 3D Reynolds averaged compressible Navier-Stokes equations was applied to a linear cascade of compressor blades and the effect of mesh refinement on profile loss prediction studied. Secondary flow development in a cascade of compressor stator blades is predicted and compared with measurement. The code was applied to the study of the flow field in a transonic axial compressor rotor at design speed and maximum efficiency. The first test case shows that near grid independent predictions could be achieved for profile loss. The second case shows predictions of secondary flow development in a cascade of compressor stator blades comparing well with measurement. The third case shows predictions for the flow in a transonic compressor rotor with clearance. Good agreement with experimental evidence is achieved and valuable insight obtained into the loss production mechanisms associated with clearance flows. ESA

N89-16832# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aerodynamik und Gasdynamik.
INVERSE METHODS FOR BLADE DESIGN, CONTROLLED DIFFUSION BLADING FOR SUPERCRITICAL COMPRESSOR FLOW
E. SCHMIDT *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 1 56 p 1988
Avail: NTIS HC A11/MF A01

Cascade design methods are reviewed, and an inverse cascade design method on stream surfaces of revolution is presented. The method seems to be an effective procedure to design highly loaded axial compressor cascades on stream surfaces of revolution. It produces accurate results compared with complete flow field measurements and computations from other methods. It was applied to cascade and multisection compressor blade design. Lower losses are obtained, compared with conventional NACA blading. ESA

N89-16833# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
TRANSONIC COMPESSORS, VOLUME 2
1988 390 p Lecture series held in Rhode-Saint-Genese, Belgium, 1-4 Feb. 1988
(VKI-LS-1988-03-VOL-2; ISSN-0377-8312; ETN-89-93591) Avail: NTIS HC A17/MF A01

The design and development of transonic multistage compressors; design of critical compressor stages; supersonic compressors; supersonic throughflow fans; variable geometry in supersonic compressors; axial supersonic inlet components; design methodology for high pressure compressors; and holographic inteferometry for flow visualization studies in high speed fans, and in vibration and flutter study of fans were discussed.
ESA

N89-16834*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE DESIGN AND DEVELOPMENT OF TRANSONIC MULTISTAGE COMPRESSORS
C. L. BALL, R. J. STEINKE, and F. A. NEWMAN *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 2 97 p 1988
Avail: NTIS HC A17/MF A01

The development of the transonic multistage compressor is reviewed. Changing trends in design and performance parameters are noted. These changes are related to advances in compressor aerodynamics, computational fluid mechanics and other enabling technologies. The parameters normally given to the designer and those that need to be established during the design process are identified. Criteria and procedures used in the selection of these parameters are presented. The selection of tip speed, aerodynamic loading, flowpath geometry, incidence and deviation angles, blade/vane geometry, blade/vane solidity, stage reaction, aerodynamic blockage, inlet flow per unit annulus area, stage/overall velocity ratio, and aerodynamic losses are considered. Trends in these parameters both spanwise and axially through the machine are highlighted. The effects of flow mixing and methods for accounting for the mixing in the design process are discussed. ESA

N89-16835# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
DESIGN OF CRITICAL COMPRESSOR STAGES
A. J. WENNERSTROM *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 2 32 p 1988
Avail: NTIS HC A17/MF A01

The through blade design approach to axial compresor stages for which high performance is critical as to thermodynamic cycle, and difficult due to high aerodynamic loading and/or Mach number is introduced. The mathematical models used, and the treatment of empirical inputs and shock losses are outlined. Design control and optimization are explained. Other major design factors, including mass flow, solidity, ramp angle, flow distribution, airfoil stacking, and structural parameters are reviewed. Design system weaknesses and trends are indicated, and computational goals are mentioned. ESA

N89-16836# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
SUPERSONIC COMPRESSORS
A. J. WENNERSTROM *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 2 54 p 1988
Avail: NTIS HC A17/MF A01

The analysis of shock losses and tip clearance losses in supersonic compressors is introduced. Boundary layer control, including rotor vortex generators, casing vortex generators, and stator slots is reviewed. Unconventional design concepts such as splitter vanes, counterswirl, and nonsteady flow are discussed. ESA

N89-16837*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SUPERSONIC THROUGHFLOW FANS
C. L. BALL and R. D. MOORE *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 2 30 p 1988
Avail: NTIS HC A17/MF A01

Supersonic throughflow fan research, and technology needs are reviewed. The design of a supersonic throughflow fan stage, a facility inlet, and a downstream diffuser is described. The results from the analysis codes used in executing the design are shown. An engine concept intended to permit establishing supersonic throughflow within the fan on the runway and maintaining the supersonic throughflow condition within the fan throughout the flight envelope is presented. ESA

N89-16838# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Turbomachinery Dept.
VARIABLE GEOMETRY IN SUPERSONIC COMPRESSORS
F. A. E. BREUGELMANS *In its* Transonic Compressors, Volume 2 23 p 1988 Sponsored in part by the European Office of Aerospace Research
Avail: NTIS HC A17/MF A01

A flexible inlet guide vane was designed for an independent control of the pre- or counterswirl condition over the blade height. The model was investigated with a Mach 2 supersonic rotor. The vertical supersonic compressor characteristic can be adapted to important mass flow variations by introducing a limited amount of inlet swirl. The matching and flow problems of the rotor supersonic inlet conditions and the variable inlet guide vanes are demonstrated. Large changes in the rotor exit flow field are observed when operating the variable guide vane. The classical variable stagger stator vanes are not the solution to the large angle variations at high subsonic Mach numbers. A flexible blade is also proposed in the exit flow field. ESA

N89-16839# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Turbomachinery Dept.
AXIAL SUPERSONIC INLET COMPOUND
F. A. E. BREUGELMANS *In its* Transonic Compressors, Volume 2 25 p 1988 Sponsored in part by the European Office of Aerospace Research
Avail: NTIS HC A17/MF A01

A prototype rotor was designed to investigate the supersonic axial component at the inlet face of a compressor. A flexible inflatable nozzle is installed in the inlet duct in order to simulate a continuously variable inlet Mach number up to 1.5. A relative inlet Mach number of 2.4 is achieved at 90 percent of the design speed. The transition from the subsonic to the supersonic axial component is explored. A blade failure prevented completion of the research on the dynamic response of the compressor to throttle valve, speed, and inlet nozzle variations. ESA

N89-16840# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
DESIGN METHODOLOGY FOR ADVANCED HIGH PRESSURE (HP) COMPRESSOR FIRST STAGE
MARIUS GOUTINES *In* Von Karman Institute for Fluid Dynamics, Transonic Compressors, Volume 2 36 p 1988
Avail: NTIS HC A17/MF A01

The design methodology used for the first stage of a one stage high pressure compressor whose rotor blades are supersonic (relative Mach number varies from 1.1 at hub to 1.3 at tip) is outlined. Improvements brought by three-dimensional Euler calculations and secondary flow prediction method are discussed. Theoretical computations and experimental data are compared. The method can be improved by full 3-D aerodynamic calculations on the blade rows, particularly on the supersonic rotor. A 3-D Euler solver is necessary to give the correct shock shape. This method cancels the spanwise compatibility problem between the different 3-D profiles that occurs on classical quasi three-dimensional design methods. Spanwise detailed secondary flow calculation method provides inlet axisymetric aerodynamic conditions of the various blade rows which are useful for the upstream end adaptations. This method can also give the outlet end adaptation effects on secondary losses and on the downstream row inlet conditions. ESA

N89-17599*# Adiabatics, Inc., Columbus, IN.
ADIABATIC WANKEL TYPE ROTARY ENGINE
R. KAMO, P. BADGLEY, and D. DOUP Sep. 1988 208 p
(Contract NAS3-24880)
(NASA-CR-182233; NAS 1.26:182233; AI-120) Avail: NTIS HC A10/MF A01 CSCL 21E

This SBIR Phase program accomplished the objective of advancing the technology of the Wankel type rotary engine for aircraft applications through the use of adiabatic engine technology. Based on the results of this program, technology is in place to provide a rotor and side and intermediate housings with thermal barrier coatings. A detailed cycle analysis of the NASA 1007R Direct Injection Stratified Charge (DISC) rotary engine was performed which concluded that applying thermal barrier coatings to the rotor should be successful and that it was unlikely that the rotor housing could be successfully run with thermal barrier coatings as the thermal stresses were extensive. Author

N89-17600*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE EFFECT OF EXHAUST PLUME/AFTERBODY INTERACTION ON INSTALLED SCRAMJET PERFORMANCE

THOMAS ALAN EDWARDS Nov. 1988 86 p
(NASA-TM-101033; A-88293; NAS 1.15:101033) Avail: NTIS HC A05/MF A01 CSCL 21E

Newly emerging aerospace technology points to the feasibility of sustained hypersonic flight. Designing a propulsion system capable of generating the necessary thrust is now the major obstacle. First-generation vehicles will be driven by air-breathing scramjet (supersonic combustion ramjet) engines. Because of engine size limitations, the exhaust gas leaving the nozzle will be highly underexpanded. Consequently, a significant amount of thrust and lift can be extracted by allowing the exhaust gases to expand along the underbody of the vehicle. Predicting how these forces influence overall vehicle thrust, lift, and moment is essential to a successful design. This work represents an important first step toward that objective. The UWIN code, an upwind, implicit Navier-Stokes computer program, has been applied to hypersonic exhaust plume/afterbody flow fields. The capability to solve entire vehicle geometries at hypersonic speeds, including an interacting exhaust plume, has been demonstrated for the first time. Comparison of the numerical results with available experimental data shows good agreement in all cases investigated. For moderately underexpanded jets, afterbody forces were found to vary linearly with the nozzle exit pressure, and increasing the exit pressure produced additional nose-down pitching moment. Coupling a species continuity equation to the UWIN code enabled calculations indicating that exhaust gases with low isentropic exponents (gamma) contribute larger afterbody forces than high-gamma exhaust gases. Moderately underexpanded jets, which remain attached to unswept afterbodies, underwent streamwise separation on upswept afterbodies. Highly underexpanded jets produced altogether different flow patterns, however. The highly underexpanded jet creates a strong plume shock, and the interaction of this shock with the afterbody was found to produce complicated patterns of crossflow separation. Finally, the effect of thrust vectoring on vehicle balance has been shown to alter dramatically the vehicle pitching moment. Author

08

AIRCRAFT STABILITY AND CONTROL

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

A89-25008#
DEPARTURE RESISTANCE AND SPIN CHARACTERISTICS OF THE F-15 S/MTD
HERBERT L. TINGER (McDonnell Douglas Corp., Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p.
(AIAA PAPER 89-0012)

High angle of attack analyses for the F-15 S/MTD aircraft using six degree-of-freedom time histories, manned flight simulations, and a tethered free flight test are reported. The results show that the departure and spin resistance objectives for the aircraft have been met, even with lateral weight asymmetries of 200 ft-lb. The aircraft possesses adequate nose-down pitch authority at high angles of attack which is greatly enhanced when thrust vectorizing is utilized. C.D.

A89-25011#
AGILE FIGHTER AIRCRAFT SIMULATION
JOSEPH A. ANDERSON (Wright State University, Dayton; USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0015)

The Agile Fighter Aircraft Simulation, which studies the improvement in turning performance obtained by using vectored thrust for increased control at low airspeeds, is examined. A general description of the project is given, and the pitch rate flight control system (FCS) is analytically described. Results concerning flight characteristics and tactical utility evaluation using the simulation are discussed. C.D.

A89-25012#
INERTIAL ENERGY DISTRIBUTION ERROR CONTROL FOR OPTIMAL WIND SHEAR PENETRATION
K. KRISHNAKUMAR and J. E. BAILEY (Alabama, University, Tuscaloosa) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0016)

The principle of inertial energy distribution error control for optimal wind shear penetration is developed theoretically, and a controller based on this principle is experimentally tested for takeoff flight conditions using a Monte Carlo simulation. The trajectory results are compared with those of a controller based on inertial energy distribution error performance index. The results demonstrate the importance of distributing inertial energy error equally between potential energy and inertial kinetic energy of the aircraft system to minimize height losses. They also show that minimization of height loss results in maintaining an approximately constant inertial speed. C.D.

A89-25013#
AN ANALYSIS OF LATERAL-DIRECTIONAL HANDLING QUALITIES AND EIGENSTRUCTURE OF HIGH PERFORMANCE AIRCRAFT
MICHAEL J. COSTIGAN and ROBERT A. CALICO (USAF, Institute of Technology, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0017)

This paper uses eigenstructure assignment to develop a lateral aircraft control system. The eigenstructure of the primary lateral modes was chosen so as to lead to good lateral handling qualities. Several candidate controllers were designed and tested on YA-7D Digitac aircraft. The results of these tests are presented and pilot ratings for the various controllers are shown. Author

A89-25014*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
FAST HALF-LOOP MANEUVERS FOR A HIGH ALPHA FIGHTER AIRCRAFT USING A SINGULAR PERTURBATION FEEDBACK CONTROL LAW
FREDERICK E. GARRETT, JR. (Virginia Polytechnic Institute and State University, Blacksburg) and HAROLD L. STALFORD (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs
(Contract NAG1-873)
(AIAA PAPER 89-0018)

Singular perturbation analysis is used to derive an outer layer feedback control law for a high alpha fighter aircraft to perform the half-loop maneuver. Pitch rate and angle of attack are treated as fast variables in the derivation. Bang-bang controls are derived to transfer the aircraft state from trim to the outer layer and from the outer layer to specified final half-loop values. The pitch rate is treated as a varibale faster than the angle of attack in the transfer of the state to and from the outer layer. A simulation of the derived control law is conducted at Mach 0.6 and 15,000 feet altitude. The half-loop was performed in 13.12 seconds. It is compared with a NASA pilot simulated half-loop maneuver which took 22.42 seconds for the same initial conditions. Author

A89-25510#
MULTIPLE SOLUTIONS FOR AIRCRAFT SIDESLIP BEHAVIOUR AT HIGH ANGLES OF ATTACK
PETER J. LAMONT and ANDREW KENNAUGH (Manchester, Victoria University, England) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0645)

The advantages of using 'total incidence' plane aerodynamics to simplify problems of aircraft aerodynamics and flight dynamics at high angles of attack are demonstrated. Consideration is given to the problem of aircraft sideslip behavior at high angles of attack. It is shown how side force and yawing moment data at combined angles of attack can be synthesized from zero sideslip data. K.K.

A89-25683
AIRCRAFT VERTICAL PROFILE IMPLEMENTATION USING DIRECTED-GRAPH METHODS
L. T. BREWSTER and P. D. STIGALL (Missouri-Rolla, University, Rolla) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Nov. 1988, p. 682-692. refs

Aircraft vertical profile simulation is realized using a demand-driven minimal-calculation directed graph structure to reduce calculation time and to force synchronization of the performance measurement functions with the system state variables. Performance-directed model adaptation makes dynamic vertical profile path corrections, in the presence of fixed drag variations, possible. Drag variations ranging from +10 percent to -10 percent yielded fuel consumption improvements of less than 1 percent in the majority of the cases. Calculation time improvement for path simulation ranges from a factor of 1.19 in the worst case to 1.5 in the best case. I.E.

A89-25692
CONTROL OF NEARLY SINGULAR DECOUPLING SYSTEMS AND NONLINEAR AIRCRAFT MANEUVER
SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Nov. 1988, p. 775-784. refs
(Contract DAAL03-87-G-0004)

The author treats the question of control of a class of nonlinear systems using state variable feedback whose input/output map is nearly singular. Although the existing decoupling theory is applicable to such systems, this requires a large amount of control, which may not be permissible. Considered here is decoupling approach using state variable feedback in an approximate sense, but requiring a small control magnitude. A decoupling scheme is presented that gives rise to a singularly perturbed system describing the fast dynamics of the control vector. The quasi-steady-state solution of the system gives a control law that decouples the system in an approximate way. The controller includes a servocompensator and a reference trajectory generator. Based on this result, a control law for approximate decoupling of roll angle, angle of attack, and sideslip in rapid, nonlinear airplane maneuvers is derived. Simulated responses of the closed-loop system show that large, simultaneous lateral and longitudinal maneuvers can be accurately performed in spite of uncertainty in stability derivatives. I.E.

A89-25871
ACTIVE CONTROL OF AEROELASTIC SYSTEMS GOVERNED BY FUNCTIONAL DIFFERENTIAL EQUATIONS
SHYANG CHANG (National Tsing Hua University, Hsinchu, Republic of China) IN: International Conference on Advances in Communication and Control Systems, 1st, Washington, DC, June 18-20, 1987, Proceedings. New York, Optimization Software, Inc., 1988, p. 82-95. refs

The problem of modeling and control of aircraft flutter is studied in the framework of aeroelasticity theory. A time-domain model for unsteady aerodynamic loads is developed and coupled with a lumped model for the structural dynamics. The resulting input-output system, characterized by functional differential equations, can be endowed with a state space which is a reflexive Banach space. It is shown that the state equations have a unique semigroup solution. Moreover, the input-output stability for such an aeroelastic system is established. Author

A89-25934#
LONGITUDINAL STABILITY ANALYSIS FOR DEFORMABLE AIRCRAFT
RUIJUAN XU (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 6, Dec. 1988, p. 433-439. In Chinese, with abstract in English. refs

The longitudinal stability of a deformable aircraft with and without a flight control system, involving interaction between rigid motion modes and elastic vibration shapes of the aircraft and between the flight control system and the airframe dynamics, is studied. A numerical example is used to show that the effect of the structural distortion of the aircraft with a flight control system on its longitudinal stability is considerable. This effect not only degrades the flying qualities of the aircraft, it also sometimes causes an unacceptable new type of instability referred to as coupling instability between the flight control system and the elastic structural dynamics. Thus, in aircraft stability analysis and the design of a flight control system, the aircraft has to be considered as a deformable body, and high-order small-disturbance equations involving elastic degrees of freedom of the aircraft must be used. C.D.

A89-26193
FEEDBACK CONTROL OF VIBRATIONS IN AN EXTENDIBLE CANTILEVER SWEPTBACK WING
P. K. C. WANG (California, University, Los Angeles) IN: Analysis and optimization of systems; Proceedings of the Eighth International Conference, Juan-les-Pins, France, June 8-10, 1988. Berlin and New York, Springer-Verlag, 1988, p. 494-506. refs
(Contract AF-AFOSR-86-0132)

A cantilever wing which may extend or contract in flight is studied. A mathematical model for an extendible sweptback cantilever wing is presented, and the qualitative behavior of the motion-induced vibrations is examined. A Galerkin-type approximation based on an appropriate time-dependent basis is used to obtain an approximate finite dimensional model for the numerical solution of the system equations. Feedback controls for damping the motion-induced vibrations are derived by considering the time rate of change of the total vibrational energy of the wing. Numerical results for a typical straight extendible wing with specified and feedback-controlled translational motions are presented. The results show that an extensional motion has a destabilizing effects on the wing vibrations, while a contractional motion has a stabilizing effect. These effects are enhanced when the extension or contraction speed is increased. A simplified control law which reduces the peak amplitude of the vibrations is proposed. C.D.

A89-26688
MEASUREMENTS OF THE OSCILLATORY LATERAL DERIVATIVES OF A HIGH INCIDENCE RESEARCH MODEL (HIRM 1) AT SPEEDS UP TO M = 0.8
C. O. O'LEARY and E. N. ROWTHORN (Royal Aerospace Establishment, Bedford, England) Aeronautical Journal (ISSN 0001-9240), vol. 93, Jan. 1989, p. 11-21. refs

Tests were made to investigate the effects of Mach number on the oscillatory lateral derivatives of a three-surface, high-incidence research model, HIRM 1. Effects of Reynolds number and frequency parameter were also investigated at low speed. A new flexible sting and hydraulic actuator system were designed for the tests in the 2.4 m x 2.4 m Pressurized Wind Tunnel. Results showed that the effects of Reynolds number and frequency parameter were not very significant at low speeds but there were quite large effects of Mach number on some derivatives, notably yawing and rolling moments due to sideslip and rate of yaw. Author

A89-27734*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF WINDSHEAR FROM AIRLINE FLIGHT DATA
R. E. BACH, JR. and R. C. WINGROVE (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 103-109. Previously cited in issue 23, p. 3414, Accession no. A86-47690. refs

A89-27736*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
REAL-TIME COMPARISON OF X-29A FLIGHT DATA AND SIMULATION DATA

JOSEPH GERA (NASA, Ames Research Center, Moffett Field, CA), DOMINICK ANDRISANI, II (Purdue University, West Lafayette, IN), JEFFREY E. BAUER, and DAVID B. CRAWFORD Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 117-123. Previously cited in issue 08, p. 1052, Accession no. A87-22570.

A89-27737*# Massachusetts Inst. of Tech., Cambridge.
DYNAMIC RESPONSE OF AIRCRAFT AUTOPILOT SYSTEMS TO ATMOSPHERIC DISTURBANCES
R. JOHN HANSMAN, JR. and JAMES L. STURDY (MIT, Cambridge, MA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 124-130. Previously cited in issue 07, p. 952, Accession no. A88-22518.
(Contract DOT-FA03-86-C-00016; NGL-22-009-640)

A89-28185
ADVANCED FLIGHT CONTROL FOR THE FOKKER 100
L. G. LAFORGE (Rockwell International Corp., Collins Air Transport Div., Cedar Rapids, IA) and A. H. VAN GENT (Fokker Aircraft, Amsterdam, Netherlands) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 13 p.
(SAE PAPER 881373)

The Automatic Flight Control and Augmentation System recently certified on the Fokker F28 - Mk0100, provides this aircraft with a full flight regime autoflight system including CAT IIIb autoland capability and a fully integrated autothrottle. The FCS-1000 is based upon a classical triplex architecture interfaced with dual electromechanical servos. Additional new features designed to decrease the flight crew's workload in critical flight phases and to achieve a higher level of flight safety include ultimate aircraft speed protection functions, coupled windshear escape, and a new flight mode annunciation philosophy. Author

A89-28205* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SIMULATION EVALUATION OF TRANSITION AND HOVER FLYING QUALITIES OF THE E-7A STOVL AIRCRAFT
JAMES A. FRANKLIN, MICHAEL W. STORTZ, RONALD M. GERDES, GORDON H. HARDY, JAMES L. MARTIN, and SHAWN A. ENGELLAND (NASA, Ames Research Center, Moffett Field, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 15 p. refs
(SAE PAPER 881430)

The generalized simulation model developed for the E-7A STOVL fighter-type aircraft configuration has attempted to define the limits of acceptibility for a vertical-to-horizontal-to-vertical flight transition envelope. An effort was also made to determine the control power required during hover and transition, and to evaluate whether the integration of flight and propulsion controls thus far effected achieves good flying qualities throughout the low-speed flight envelope. The results thus obtained furnish a general view of the acceptable transition corridor, expressed in terms of the minimum-climb capability. O.C.

A89-28236
REAL-TIME SIMULATION FOR SURVIVABLE PENETRATION
V. P. BAGLIO (Grumman Corp., Aircraft Systems Div., Bethpage, NY) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 14 p. refs
(SAE PAPER 881515)

An initial terrain-following/terrain-avoidance (TF/TA) simulation is described, which combines the features of aggresive trajectory generation, control coupling for trajectory tracking, map navigation, and aircraft and flight control system dynamic elements. A typical scenario of an advanced low-level penetration and attack mission is described together with the components of the simulation. Finally, an integration approach to this real-time simulation problem is discussed, including the simulation set-up, functional partitioning between computers, information flow between simulation components, the requirements of the intercomputer communication, the interface software, and data transfer. Functional block diagrams and flow diagrams are included. I.S.

A89-28396
DYNAMICS OF LONGITUDINAL MOTION OF AN AEROPLANE AFTER DROP OF LOADS
Z. DZYGADLO and K. SIBILSKI (Wojskowa Akademia Techniczna, Warsaw, Poland) Journal of Technical Physics (ISSN 0324-8313), vol. 28, no. 3, 1987, p. 365-379. refs

An analysis is presented of uncontrolled and controlled longitudinal motion of a jet aircraft after symmetric load drops. Both a single drop and a series of drops were considered assuming that the initial motion of the aircraft was steady and horizontal or that the initial motion was curvilinear in the vertical plane. The resulting motion of the aircaraft was analyzed for a case of uncontrolled flight and for a case where the control surface was displaced and the thrust of the power plant was varied by the pilot in order to preserve the original parameters. A control law is proposed which, if applied for the case of uncontrolled flight, can minimize the disturbances; the motion of the aircraft can then be reduced to a steady motion, with the values of parameters approaching those before the drop of loads. I.S.

A89-28454*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DETERMINATION OF LONGITUDINAL AERODYNAMIC DERIVATIVES USING FLIGHT DATA FROM AN ICING RESEARCH AIRCRAFT
R. J. RANAUDO, A. L. REEHORST, T. H. BOND (NASA, Lewis Research Center, Cleveland, OH), J. G. BATTERSON (NASA, Langley Research Center, Hampton, VA), and T. M. O'MARA (NASA, Langley Research Center, Hampton, VA; George Washington University, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 18 p. Previously announced in STAR as N89-15121. refs
(AIAA 89-0754)

A flight test was performed with the NASA Lewis Research Center's DH-6 icing research aircraft. The purpose was to employ a flight test procedure and data analysis method, to determine the accuracy with which the effects of ice on aircraft stability and control could be measured. For simplicity, flight testing was restricted to the short period longitudinal mode. Two flights were flown in a clean (baseline) configuration, and two flights were flown with simulated horizontal tail ice. Forty-five repeat doublet maneuvers were performed in each of four test configurations, at a given trim speed, to determine the ensemble variation of the estimated stability and control derivatives. Additional maneuvers were also performed in each configuration, to determine the variation in the longitudinal derivative estimates over a wide range of trim speeds. Stability and control derivatives were estimated by a Modified Stepwise Regression (MSR) technique. A measure of the confidence in the derivative estimates was obtained by comparing the standard error for the ensemble of repeat maneuvers, to the average of the estimated standard errors predicted by the MSR program. A multiplicative relationship was determined between the ensemble standard error, and the averaged program standard errors. In addition, a 95 percent confidence interval analysis was performed for the elevator effectiveness estimates, C sub m sub delta e. This analysis identified the speed range where changes in C sub m sub delta e could be attributed to icing effects. The magnitude of icing effects on the derivative estimates were strongly dependent on flight speed and aircraft wing flap configuration. With wing flaps up, the estimated derivatives were degraded most at lower speeds corresponding to that configuration. With wing flaps extended to 10 degrees, the estimated derivatives were degraded most at the higher corresponding speeds. The effects of icing on the changes in longitudinal stability and control derivat Author

N89-16845*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MODAL CONTROL OF AN OBLIQUE WING AIRCRAFT
JAMES D. PHILLIPS Jan. 1989 49 p
(NASA-TP-2898; A-88250; NAS 1.60:2898) Avail: NTIS HC A03/MF A01 CSCL 01C

A linear modal control algorithm is applied to the NASA Oblique

Wing Research Aircraft (OWRA). The control law is evaluated using a detailed nonlinear flight simulation. It is shown that the modal control law attenuates the coupling and nonlinear aerodynamics of the oblique wing and remains stable during control saturation caused by large command inputs or large external disturbances. The technique controls each natural mode independently allowing single-input/single-output techniques to be applied to multiple-input/multiple-output systems. Author

N89-18401*# National Aeronautics and Space Administration, Washington, DC.
CONTROLS AND GUIDANCE: AERONAUTICS
JOHN D. DIBATTISTA *In its* NASA Information Sciences and Human Factors Program p 83-103 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 01C

The overall objective is to provide a validated technology base leading to the development and exploitation of new concepts, analysis and design methodologies, and flight systems for future civil and military aircraft. This will provide increased efficiency, effectiveness, reliability, and safety. The program is organized into generic elements and vehicle-specific elements. The generic elements are control theory, guidance and display concepts, and flight crucial systems. Vehicle-specific elements are generic hypersonics, subsonic transport/commuter/general aviation, rotorcraft, and fighter/attack. Research in the control theory element is directed toward the improved flight control analysis and design methodologies for highly integrated, robust flight control designs. Flight Crucial Systems research is directed toward the development of design, assessment, and validation methodologies for flight crucial systems. The generic hypersonics research concentrates on the integration of flight control, propulsion control, sensors, and displays. The Aeronautical Controls and Guidance Program involves analytical and experimental research by in-house, university, and industry personnel. Extensive use of ground-based simulation is a characteristic of the program with selected flight experiments in a variety of aircraft. Author

09

RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A89-25035#
MICROTUFT FLOW VISUALIZATION AT MACH 10 AND 14 IN THE NSWC HYPERVELOCITY WIND TUNNEL NO. 9
MARK E. KAMMEYER, JOHN F. LAFFERTY, and W. CHARLES SPRING, III (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0041)

This paper describes efforts of the past year that have demonstrated the use of microtufts for flow visualization in a hypersonic, high Reynolds number, blow-down wind tunnel. A variation of the fluorescent method of Crowder using the standard nylon monofilament tuft material has been successful at both Mach 10 and 14 on leeward surfaces. An alternate high-temperature tuft material has been found which is capable of surviving the higher heat transfer rates associated with windward surfaces. A new method of viewing the high temperature tufts with an infrared camera has also been demonstrated at Mach 14. Author

A89-25036#
INFRARED THERMOGRAPHY IN BLOWDOWN AND INTERMITTENT HYPERSONIC FACILITIES
G. SIMEONIDES, J. F. WENDT (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium), P. VAN LIERDE, S. VAN DER STICHELE, and D. CAPRIOTTI AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0042)

Some results and conclusions from the application of IR thermography to the measurement of heat transfer in two distinctly different short-duration hypersonic facilities are presented. First results from a blowdown tunnel are discussed; they demonstrate the advantage of the IR technique in providing two-dimensional heat-transfer maps as opposed to the zero-dimension measurements enabled by discrete-point gages. The spatial resolution characteristics of the IR scanning radiometer is sufficient to sense localized hot spots which may be quantified by concentrating the field of view onto the area of interest. Author

A89-25042#
THE DESIGN AND DEVELOPMENT OF A DYNAMIC PLUNGE-PITCH-ROLL MODEL MOUNT
SEUNGKI AHN, KWANG-YOON CHOI, and ROGER L. SIMPSON (Virginia Polytechnic Institute and State University, Blacksburg, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by the Virginia State Council of Higher Education, Virginia Polytechnic Institute and State University, and U.S. Navy. refs
(AIAA PAPER 89-0048)

In this paper, a newly designed and developed dynamic model support system for the Stability Wind Tunnel of the Virginia Polytechnic Institute and State Universiy is discussed. The design objectives of this new apparatus are the generation of a random motion of sting mounted model, a dynamic stability test using oscillation method, and an aircraft landing simulation. Details of the system are discussed along with hardware problems and their solutions faced during the development phase. Author

A89-25131*# Vigyan Research Associates, Inc., Hampton, VA.
SIDEWALL BOUNDARY-LAYER REMOVAL EFFECTS ON WALL ADAPTATION IN THE LANGLEY 0.3-METER TRANSONIC CRYOGENIC TUNNEL
A. V. MURTHY (Vigyan Research Associates, Inc., Hampton, VA) and E. J. RAY (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0148)

This paper describes the Langley 0.3-m transonic cryogenic tunnel sidewall boundary-layer removal system and is integrated operation with the adaptive wall adjustment. Empty test section measurements show the sidewall boundary-layer displacement thickness at the model station is reduced from about 1.0 to 0.6 percent of the test section width when the maximum boundary-layer removal conditions are applied. Tests with a supercritical airfoil model show the iterative top and bottom wall adaptation process performs satisfactorily with sidewall boundary-layer removal. Author

A89-25132#
WIND TUNNEL WALL BOUNDARY LAYER CONTROL BY COANDA WALL JETS
N. J. WOOD, L. ROBERTS (Stanford University, CA), and S. WARD AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0149)

An experiment is described which evaluates the feasibility of using a Coanda wall jet boundary layer removal system for application to VSTOL testing in ground effect. This concept is particularly suited to large scale facilities where the alternatives, such as moving belts, are inadequate in terms of scale and robustness. In addition, the Coanda wall jet provides a significant improvement in the power required to maintain a negligible wall boundary layer. Author

A89-25135*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SOLUTION TO WATER VAPOR IN THE NATIONAL TRANSONIC FACILITY

BLAIR B. GLOSS and ROBERT A. BRUCE (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0152)

As cryogenic wind tunnels are utilized, problems associated with the low temperature environment are being discovered and solved. Recently, water vapor contamination was discovered in the National Transonic Facility, and the source was shown to be the internal insulation which is a closed-cell polyisocyanurate foam. After an extensive study of the absorptivity characteristics of the NTF thermal insulation, the most practical solution to the problem was shown to be the maintaining of a dry environment in the circuit at all times. Utilizing a high aspect ratio transport model, it was shown that the moisture contamination effects on the supercritical wing pressure distributions were within the accuracy of setting test conditions and as such were considered negligible for this model. Author

A89-25159#
FACILITY REQUIREMENTS FOR HYPERSONIC PROPULSION SYSTEM TESTING
M. G. DUNN, J. A. LORDI, C. E. WITTLIFF, and M. S. HOLDEN (Calspan Corp., Buffalo, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 16 p. refs
(AIAA PAPER 89-0184)

Facility requirements for hypersonic propulsion system testing are reviewed with attention given to significant contributions of previous and current studies. It is found that many of the current hypersonic flow problems are the same as those identified 20 yrs ago. Sample calculations performed to examine real-gas effects on the simulation of flows about hypersonuc vehicles are presented. Shock-tunnel testing of both scramjet combustor and exhaust nozzle configurations at conditions corresponding to flight at Mach numbers of 10-12 at altitudes of 100,000 ft are considered. K.K.

A89-25511*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN AND DEVELOPMENT OF A COMPRESSIBLE DYNAMIC STALL FACILITY
L. W. CARR (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) and M. S. CHANDRASEKHARA (U.S. Navy-NASA Joint Institute of Aeronautics, Monterey, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. Research supported by the U.S. Navy and USAF. refs
(AIAA PAPER 89-0647)

A dynamic stall facility offering a unique new capability for studies of compressibility effects on dynamic stall is described. This facility features complete visual access by mounting the test airfoil between optical-quality glass windows which are rotated in unison to produce the oscillating airfoil motion associated with helicopter rotor dynamic stall. By using the density gradients associated with the rapidly changing dynamic stall flow field, this facility permits simultaneous detailed investigation of the flow on the surface as well as in the flow field surrounding airfoils experiencing dynamic stall. Author

A89-25512*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DRAG MEASUREMENTS ON A MODIFIED PROLATE SPHEROID USING A MAGNETIC SUSPENSION AND BALANCE SYSTEM
DAVID A. DRESS (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0648)

Low-speed wind tunnel drag force measurements were taken on a modified prolate spheroid free of support interference. This body was tested at zero incidence in the NASA Langley 13 inch Magnetic Suspension and Balance System. This shape was one of two bodies tested to determine the drag force measuring capabilities of the 13 inch MSBS. In addition, support interference on this shape at zero incidence was quantified by using a dummy sting. The drag force calibrations and wind-on repeatability data make it possible to assess the drag force measuring capabilities of the 13 inch MSBS. Comparisons with and without the sting showed differences in the drag coefficients with the dummy sting case resulting in lower drag coefficients. Author

A89-25591*# Massachusetts Inst. of Tech., Cambridge.
COCKPIT DISPLAY OF HAZARDOUS WEATHER INFORMATION
R. JOHN HANSMAN, JR. and CRAIG WANKE (MIT, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by MIT and FAA. refs
(Contract NGL-22-009-640; NAG1-690)
(AIAA PAPER 89-0808)

Information transfer and display issues associated with the dissemination of hazardous-weather warnings are studied in the context of wind-shear alerts. Operational and developmental wind-shear detection systems are briefly reviewed. The July 11, 1988 microburst events observed as part of the Denver TDWR operational evaluation are analyzed in terms of information transfer and the effectiveness of the microburst alerts. Information transfer, message content, and display issues associated with microburst alerts generated from ground-based sources (Doppler radars, LLWAS, and PIREPS) are evaluated by means of pilot opinion surveys and part-task simulator studies. Author

A89-27653*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NATIONAL FULL-SCALE AERODYNAMIC COMPLEX INTEGRATED SYSTEMS TEST DATA SYSTEM
OSCAR JUNG and EVERETT MAYNARD (NASA, Ames Research Center, Moffett Field, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 29-41.

The data acquisition system of the 80 by 120 foot wind tunnel of the National Full-Scale Aerodynamic Facility (NFAC) is described. How the various satellite data stations are connected to the data acquisition system is shown. As an illustrative example, a strain gage signal is traced from one of the satellite data locations to its final destination in the data system where the signal is processed, observed in real time on various parallel graphic displays, and stored on magnetic disks for postrun data reduction. C.D.

A89-27654*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UTILIZATION OF WIND TUNNEL INSTRUMENTATION WITH SOFTWARE VERIFICATIONS
BETTY W. SILVA and NORMAN H. MICHAUD (NASA, Ames Research Center, Moffett Field, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 43-53.

Software tools developed for the National Full-Scale Aerodynamic Complex (NFAC) for verifying data integrity and troublehooting problems are discussed. The Hardware Check verifies that the incoming signals are properly connected and are being acquired into the real time data system. The Zero/Cal Check program verifies the reliability of the wind tunnel instrumentation by checking the zero and calibration points. The Power Spectral Density Plots help to identify the frequency components of a signal. Drift Program and Thermal Plots tools are also described. C.D.

A89-27655#
A MICROPROCESSOR-BASED PROPORTIONAL-INTEGRAL CONTROLLER FOR HYDRAULICALLY ACTUATED MECHANISMS
MARC N. SMOTHERMAN (Calspan Corp., Arnold AFB, TN) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 55-64.

A microprocessor-based position servocontroller for hydraulically actuated wind tunnel mechanisms is described. The servocontroller uses a part-time proportional-integral control algorithm, and its features include decreased setup and calibration, simplified operator interface, and increased positioning control accuracy. This servocontroller has decreased test installation times, decreased maintenance, and increased productivity when compared to previous analog servocontrollers. C.D.

A89-27674*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SIGNAL FILTER WITH ZERO PHASE LAG
T. J. FORSYTH and T. S. BURNETT (NASA, Ames Research Center, Moffett Field, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 417-427.

Rotorcraft and rotorcraft models are tested at the NASA Ames National Full-Scale Aerodynamics Complex (NFAC). The models tested in the NFAC wind tunnels are controlled by a remote control console located in a control room. Certain critical information must be displayed on the control console to monitor the rotor to insure that the rotor is within operational limits. The signal for these parameters is complex (with ac and dc components) and is derived from pitch and flapping transducers on the rotor head. The pitch and flapping cyclics are derived from resolver circuits that indicate the magnitude and phase of the cyclics. Conventional filter circuits used to separate the ac and dc components have a phase lag on the ac component, which will introduce an error in the cyclic vector. To overcome this error, a filter with zero phase lag needed to be developed. This paper discusses a rotorcraft circuit that was designed to have an ac/dc filter with zero phase lag over the frequency range. Author

A89-27675*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A FREE-TRAILING VANE FLOW DIRECTION INDICATOR EMPLOYING A LINEAR OUTPUT HALL EFFECT TRANSDUCER
PETER T. ZELL and ROBERT D. MCMAHON (NASA, Ames Research Center, Moffett Field, CA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 429-436.

The Hall effect vane (HEV) was developed to measure flow angularity in the NASA 40-by-80-foot and 80-by-120-foot wind tunnels. This indicator is capable of sensing flow direction at air speeds from 5 to 300 knots and over a + or - 40 deg angle range with a resolution of 0.1 deg. A free-trailing vane configuration employing a linear output Hall effect transducer as a shaft angle resolver was used. The current configuration of the HEV is designed primarily for wind tunnel calibration testing; however, other potential applications include atmospheric, flight or ground research testing. The HEV met initial design requirements. Author

A89-28193
AIRPORT ACCIDENT-POTENTIAL AND SAFETY AREAS
MAURICE A. GARBELL (M.A.G. Consultants, Inc., San Francisco, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p. refs
(SAE PAPER 881388)

The present study sets forth criteria for the design of airport safety areas and land uses therein. The mainstay of this study in identifying and defining airport safety areas is the avoidance of residential land use and any land use harboring large concentrations of people in certain accident-potential zones adjacent to the ends of airport runways. Two new developments are embodied in this study: (1) a separation within primary airport safety areas between those in which the number of people on the ground exposed to the impact of crashing or crash-landing airplanes is reduced to a minimum, while the value of the land is protected by judicious, less impact-sensitive use, and areas in which the safety of crashing or crash-landing airplanes and their occupants, as well as people on the ground, is safeguarded to the highest extent possible; and (2) the tracing of other airport safety areas, termed, 'transitional airport safety areas,' in which mass assemblies of people should be proscribed. S.A.V.

A89-28196* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SUMMARY OF RECENT AIRCRAFT/GROUND VEHICLE FRICTION MEASUREMENT TESTS
THOMAS J. YAGER (NASA, Langley Research Center, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 9 p. refs
(SAE PAPER 881403)

Tests were carried out to evaluate a variety of runway surface types and wetness conditions, using specially instrumented NASA B-737 and B-727 aircraft and several ground friction measuring devices. The performance data for aircraft braking on dry, wet, snow-covered, and ice-covered runway conditions are presented and compared to ground-vehicle friction data obtained under similar runway conditions. The relationships between ground vehicles and the aircraft friction data are identified, and the effects on friction of major test parameters, such as the speed, the tire characteristics, and the type of surface-contaminant are discussed. The results demonstrated that properly maintained and calibrated ground vehicles can be used to monitor the runway friction conditions. I.S.

A89-28219
PRELIMINARY TEST RESULTS OF NDA CRYOGENIC WIND TUNNEL AND ITS SYSTEM
YUTAKA YAMAGUCHI, HIDEKI KABA, NOBUMITSU KURIBAYASHI (Defense Academy, Yokosuka, Japan), and SHIZUYUKI YOSHIDA (Japan Defense Agency, Tokyo) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 16 p. refs
(SAE PAPER 881449)

This paper presents the major design specifications of the National Defense Academy (NDA) cryogenic wind tunnel, together with the results on the preliminary calibration tests of the tunnel. The NDA tunnel designed for the two-dimensional airfoil testings, was constructed using the SUS 304 stainless steel as the material for pressure shell. The results of the operational and the calibration tests at ambient and cryogenic temperatures demonstrated that the NDA cryogenic tunnel has sufficient potential as a tunnel for performing low-temperature transonic flow experiments. I.S.

A89-28220* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EMERGING TECHNOLOGY FOR TRANSONIC WIND-TUNNEL-WALL INTERFERENCE ASSESSMENT AND CORRECTIONS
P. A. NEWMAN (NASA, Langley Research Center, Hampton, VA), W. B. KEMP, JR., and J. A. GARRIZ (Vigyan Research Associates, Inc., Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 19 p. refs
(SAE PAPER 881454)

Several nonlinear transonic codes and a panel method code for wind tunnel/wall interference assessment and correction (WIAC) studies are reviewed. Contrasts between two- and three-dimensional transonic testing factors which affect WIAC procedures are illustrated with airfoil data from the NASA/Langley 0.3-meter transonic cyrogenic tunnel and Pathfinder I data. Also, three-dimensional transonic WIAC results for Mach number and angle-of-attack corrections to data from a relatively large 20 deg swept semispan wing in the solid wall NASA/Ames high Reynolds number Channel I are verified by three-dimensional thin-layer Navier-Stokes free-air solutions. R.B.

A89-28455*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INVESTIGATION OF THE FLOW IN THE DIFFUSER SECTION OF THE NASA LEWIS ICING RESEARCH TUNNEL
HAROLD E. ADDY, JR. (NASA, Lewis Research Center, Cleveland, OH) and THEO G. KEITH, JR. (Toledo, University, OH) AIAA,

Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA 89-0755)

The flow in the diffuser section of the Icing Research Wind Tunnel at NASA Lewis Research Center is investigated using both tunnel calibration measurements and numerical simulation techniques. Local pressure and temperature measurements are made to establish velocity and temperature profiles in the diffuser of the tunnel. These profiles are compared with similar measurements made prior to renovating the equipment which generates the tunnel's icing cloud. This comparison indicates the manner in which this change affected the flow. The measured data were also compared with a numerical simulation of the flow to help understand how such changes may favorably alter the tunnel flow. Author

A89-28457*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE DEVELOPMENT OF A CAPABILITY FOR AERODYNAMIC TESTING OF LARGE-SCALE WING SECTIONS IN A SIMULATED NATURAL RAIN ENVIRONMENT
GAUDY M. BEZOS, BRYAN A. CAMBELL (NASA, Langley Research Center, Hampton, VA), and W. EDWARD MELSON (NASA, Wallops Flight Center, Wallops Island, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA 89-0762)

A research technique to obtain large-scale aerodynamic data in a simulated natural rain environment has been developed. A 10-ft chord NACA 64-210 wing section wing section equipped with leading-edge and trailing-edge high-lift devices was tested as part of a program to determine the effect of highly-concentrated, short-duration rainfall on airplane performance. Preliminary dry aerodynamic data are presented for the high-lift configuration at a velocity of 100 knots and an angle of attack of 18 deg. Also, data are presented on rainfield uniformity and rainfall concentration intensity levels obtained during the calibration of the rain simulation system. R.B.

A89-28458#
DEVELOPMENT OF A NEW SUBSONIC ICING WIND TUNNEL
GARY V. TENISON (BFGoodrich Co., Aerospace Div., Uniontown, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA 89-0773)

A new subsonic icing tunnel has been designed and constructed at the BFGoodrich De-Icing Systems facilities in Uniontown, Ohio. This tunnel has been three years in the research, design, building and calibration and was designated to be a medium sized world class icing facility for the use of BFGoodrich, BFGoodrich customers, select researchers and others to further the development of ice protection systems as well as the general understanding of ice formation and its removal. Presented here is background information, a description of the facility, and some preliminary calibration information. Diagrams and pictures of various tunnel components and calibration equipment are also shown, along with descriptions of how each are used. Author

N89-16848# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
EXPRIMENTS ON THE DFVLR-F4 WING BODY CONFIGURATION IN SEVERAL EUROPEAN WINDTUNNELS
G. REDEKER, R. MUELLER, P. R. ASHILL, A. ELSENAAR, and V. SCHMITT (Office National d'Etudes et de Recherches Aeronautiques, Paris, France) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 15 p Jul. 1988
Avail: NTIS HC A22/MF A01

Attempts are made to improve design methods for three-dimensional configurations in transonic flow and to increase the confidence in wind tunnel data. The selected configuration was the DFVLR-F4 wing-body combination incorporating a transonic wing of high aspect ratio and a fuselage of Airbus type. The experimental part of the exercise is examined, where the same model of the wing-body configuration was tested in three European Transonic wind tunnels. The tests followed an agreed test program comprised of force and moment measurement as well as measurements of pressure distribution on wing and fuselage. Selected test results from the three wind tunnel tests are compared, the main emphasis being placed on the comparison of results from different wind tunnels on physically the same model. The results show that the data of the three wind tunnels are in reasonable agreement, although the severe accuracy requirements of industry for judging performance data from different wind tunnels could not be met. Author

N89-16852# Naval Air Systems Command, Washington, DC. Aerodynamics and Flight Controls.
WIND TUNNEL PREDICTED AIR VEHICLE PERFORMANCE: A REVIEW OF LESSONS LEARNED
E. C. ROONEY and R. F. LAUER, JR. (Calspan Field Services, Inc., Arnold AFS, TN.) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 11 p Jul. 1988
Avail: NTIS HC A22/MF A01

Air vehicle development programs continue to experience difficulty in preformacne prediction of new aircraft configurations. Advances in the state-of-the-art in wind tunnel simulation techniques, flight performance measurements and computational fluid dynamics have provided the basis for investigating the accuracy of the aerodynamic element used in the performance prediction process. The force accounting procedures, model and wind tunnel simulation techniques and correction procedures are reviewed, along with full scale adjustments used to predict the performance of air vehicles. The lesson learned in this review should enhance the capability to predict aircraft performance for future air vehicle development programs. Author

N89-16855# Royal Aircraft Establishment, Bedford (England).
THE ACCURATE MEASUREMENT OF DRAG IN THE 8 FT X 8 FT TUNNEL
M. N. WOOD and D. S. CAPPS *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 9 p Jul. 1988 Previously announced as X88-72373
Avail: NTIS HC A22/MF A01

The techniques currently adopted in the 8 ft by 8 ft wind tunnel at RAE for the accurate measurement of drag are described in detail. Data are presented from three series of tests on a model of the A-310 aircraft and these demonstrate the level of accuracy which can be achieved. Author

N89-16856# British Aerospace Public Ltd. Co., Preston (England).
ACCURATE DRAG ESTIMATION USING A SINGLE COMPONENT DRAG MODEL TECHNIQUE
A. M. CASSIE *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p Jul. 1988
Avail: NTIS HC A22/MF A01

The design, development and operation of an advance afterbody drag rig at the high speed wind tunnel at Warton is reviewed. The rig has been extensively used over a 16 year period for minimization of modern combat aircraft afterbody drag. Accurate incremental drag data is produced by measurement of the axial force on a fully representative metric afterbody section. A full description of the rig is given along with techniques for data correction and presentation of typical data. Author

N89-16857# Aircraft Research Association Ltd., Bedford (England).
DEVELOPMENT OF TESTING TECHNIQUES IN A LARGE TRANSONIC WIND TUNNEL TO ACHIEVE A REQUIRED DRAG ACCURACY AND FLOW STANDARDS FOR MODERN CIVIL TRANSPORTS
E. C. CARTER and K. C. PALLISTER *In* AGARD, Aerodynamic

Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 20 p Jul. 1988
Avail: NTIS HC A22/MF A01

Experience and results obtained in the ARA 9 ft by 8 ft transonic wind tunnel are used to address the questions of measurement and flow quality, data accuracy and achieved performance. The discussions relate primarily to experience with civil transports for which accurate drag prediction and efficient drag reduction through reliable experimental techniques is of major importance. The quality of results is studied via the definition of the problem areas, the correction methods and analysis of dynamics of the flow and the associated measurements. Techniques specific to a large development transonic tunnel are discussed in detail with a constant awareness of the cost and efficiency in relation to the required accuracy and repeatability standards. Author

N89-16863# National Aerospace Lab., Amsterdam (Netherlands).
ACCURACY OF VARIOUS WALL-CORRECTION METHODS FOR 3D SUBSONIC WIND-TUNNEL TESTING
R. A. MAARSINGH, TH. E. LABRUJERE, and J. SMITH *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 13 p Jul. 1988
Avail: NTIS HC A22/MF A01

On the basis of wind-tunnel measurements on a (simple, unpowered, but complete) transport aircraft model in a small and a very large solid-wall test section the accuracy of four measured-boundary-condition (MEC) methods, as well as two classical methods, was analyzed at low-speed conditions. Large reductions in the amount of in situ measured data are shown to be possible, yet yielding results which match almost with those of calculations using multiples of input data. Classical methods need not be abandoned at once in low-speed solid-wall testing. Higher priority should be given to the well-known interpretation problem: the determination of the actual model reaction upon the wall-induced flow field. Author

N89-16864*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WIND TUNNEL-SIDEWALL-BOUNDARY-LAYER EFFECTS IN TRANSONIC AIRFOIL TESTING-SOME CORRECTABLE, BUT SOME NOT
F. T. LYNCH (Douglas Aircraft Co., Inc., Long Beach, CA.) and C. B. JOHNSON *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p Jul. 1988
Avail: NTIS HC A22/MF A01 CSCL 14B

The need to correct transonic airfoil wind tunnel test data for the influence of the tunnel sidewall boundary layers, in addition to the wall accepted corrections for the analytical investigation was carried out in order to evaluate sidewall boundary layer effects on transonic airfoil characteristics, and to validate proposed correction and the limit to their applications. This investigation involved testing of modern airfoil configurations in two different transonic airfoil test facilities, the 15 x 60 inch two-dimensional insert of the National Aeronautical Establishment (NAE) 5 foot tunnel in Ottawa, Canada, and the two-dimensional test section of the NASA Langley 0.3 m Transonic Cryogenic Tunnel (TCT). Results presented included effects of variations in sidewall-boundary layer bleed in both facilities, different sidewall boundary layer correction procedures, tunnel-to-tunnel comparisons of corrected results, and flow conditions with and without separation. Author

N89-16870# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
ACCURACY REQUIREMENTS FOR HIGH-SPEED TEST WITH ENGINE SIMULATION ON TRANSPORT AIRCRAFT MODELS IN THE NLR-HST
W. BURGSMUELLER, J. W. KOOI, and K MOELLER, W. (National Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p Jul. 1988
Avail: NTIS HC A22/MF A01

Air-driven turbo-powered simulators, so-called TPS units, are being used in wind tunnel testing to simulate the engine flow for an aircraft model. These simulators provide substantial improvement in testing as compared to simple through-flow nacelles used earlier. In order to fully explore the improvement potential in aerodynamic simulation it is mandatory to assure a high level of accuracy or in case of increment testing a good repeatability because the effects of engine interference drag are of the order of a few counts. For increment testing a repeatability of at least + or - 1 drag count must be achieved. The efforts made to demonstrate that this repeatability can be achieved in the NLR high speed wind tunnel (HST) for a half model with a wing-mounted TPS engine are described. The test was performed in a joint program of NLR and MBB-UT, where MBB delivered the model and TPS unit with engine cowlings, while NLR was responsible for engine calibration, wind tunnel instrumentation, and the test. To obtain the desired quality of the final test results the investigation was subdivided into several steps. These steps and the technical problems and questions encountered will be described in detail. Author

N89-16873# Technische Univ., Darmstadt (Germany, F.R.).
BALANCE ACCURACY AND REPEATABILITY AS A LIMITING PARAMETER IN AIRCRAFT DEVELOPMENT FORCE MEASUREMENTS IN CONVENTIONAL AND CRYOGENIC WIND TUNNELS
B. EWALD *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 12 p Jul. 1988
Avail: NTIS HC A22/MF A01

The success of a commercial transport development is heavily influenced by the accuracy of drag measurements during the aerodynamic development in the wind tunnel. It is shown, that the internal balance in one limiting factor of accuracy. The accuracy standard of modern internal balances is compared to the accuracy and repeatability requirement of the aerodynamicist. The comparison with high precision single component load cells promises a large improvement potential in multi-component balance design and calibration. The following fields of improvement are discussed: balance design, balance material selection and treatment, calibration methods, calibration software, and thermal effects. Perfect correction of the thermal effects is the key to the successful use of cryogenic tunnels. An approach for the crucial problem of balance body distortion due to temperature gradients is demonstrated. Author

N89-16877# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
ACCURACY PROBLEMS IN WIND TUNNELS DURING TRANSPORT AIRCRAFT DEVELOPMENT
GUENTER KRENZ *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 9 p Jul. 1988
Avail: NTIS HC A22/MF A01

Wind tunnel test data accuracy requirements for transport aircraft are derived. Airline performance guarantees, model and tunnel test techniques available and the quality of prediction methods used form the concept for wind tunnel test programs and set accuracy requirements for test data. Procedures which were followed in high speed cruise and low speed takeoff and landing are described. The accuracy of the wind tunnel tests is limited by several parameters, the most important being flow quality, model and model suspension quality, and balance accuracy. Problems which occurred during the test with small models in the transonic regime led to the concepts presented: the use of large models on a specific suspension with a range-limited balance and the improvement of small model test techniques in connection with the requirements for measurements in cryogenic facilities. Low speed tests are ambitious and extensive due to the many configurations at takeoff and landing. Furthermore, the work is complicated by the many details like closing plates and shutters, which can have a strong effect on the performance data. Some examples are presented. Author

N89-16878# National Aerospace Lab., Amsterdam (Netherlands).
REQUIREMENTS AND CAPABILITIES IN UNSTEADY WINDTUNNEL TESTING
R. D. DENBOER, R. HOUWINK, and R. J. ZWAAN *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 18 p Jul. 1988
Avail: NTIS HC A22/MF A01

The accuracy required for aeroelastic applications concerning full-scale aircraft is discussed, after which the accuracy in current unsteady wind tunnel testing is considered. Author

N89-16879# Institut de Mecanique des Fluides de Lille (France).
PARTICULAR FLIGHT MECHANICS SPECIFICATIONS RELATED TO WIND TUNNEL TEST RESULTS [SPECIFICATIONS PARTICULIERES CONCERNANT LES RESULTATS DES ESSAIS EN SOUFFLERIE POUR LA MECANIQUE DU VOL]
MARC PIANKO *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 19 p Jul. 1988 In FRENCH Original language document was announced in IAA as A88-28859
Avail: NTIS HC A22/MF A01

A flight mechanics analysis of requirements and recommendations for the quality and precision of wind tunnel measurements is presented. The effect of imprecision in modeling flight behavior is examined in order to determine the sensitivity of the individual aerodynamic coefficients. Problems in the characterization of flight at large angles of incidence and sideslip, where unsteady phenomena and perturbations play a large role, are considered. Difficulties in the use of the wind tunnel for aircraft design are also reviewed. Author

N89-17601# Eidgenoessisches Flugzeugwerk, Emmen (Switzerland). Aerodynamik und Flugmechanik.
NEW DESIGN OF THE NOZZLE SECTION OF A LARGE SUBSONIC WIND TUNNEL
FELIX HIRT 24 May 1988 112 p In GERMAN; ENGLISH summary
(F+W-TF-1926; ETN-89-93539) Avail: NTIS HC A06/MF A01

The tunnel contraction of large subsonic wind tunnels was redesigned in order to optimize the nozzle contour with respect to length, wall pressure distribution, and boundary layer thickness development. The longitudinal contour was generated using a polynomial of high degree, such that all relevant boundary conditions can be fulfilled. The optimization shows that contours with a continuous wall curvature variation toward the exit of the contraction produce the smallest wall pressure peak. The analytically defined contour was realized with the help of longitudinal ribs and a rigid foam filling. Pressure measurements confirm the theoretical results quite well. ESA

N89-18384*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE VERTICAL MOTION SIMULATOR
TODD HOSEIN *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 33-37 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 14B

Today's flight simulators, such as NASA's multimillion dollar Vertical Motion Simulator (VMS), recreate an authentic aircraft environment, and reproduce the sensations of flight by mechanically generating true physical events. In addition to their application as a training tool for pilots, simulators have become essential in the design, construction, and testing of new aircraft. Simulators allow engineers to study an aircraft's flight performance and characteristics without the cost or risk of an actual test flight. Because of their practicality, simulators will become more and more important in the development and design of new, safer aircraft. Author

N89-18388*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE WIND TUNNELS OF THE NATIONAL FULL-SCALE AERODYNAMICS COMPLEX
JOHN MOON *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 55-61 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 14B

A brief overview is given of the National Full-scale Aerodynamics Complex. Its geometry, design, construction and testing conditions and models are examined. E.R.

10

ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A89-25208*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRESSURE AND HEAT TRANSFER INVESTIGATION OF A MODIFIED NASP BASELINE CONFIGURATION AT M = 6
DAVID E. REUBUSH (NASA, Langley Research Center, Hampton, VA) and M. EMMETT OMAR (Boeing Advanced Systems, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0246)

A cooperative NASA Langley-Boeing investigation was conducted in the Langley eight-Foot High Temperature Tunnel to obtain hypersonic pressure and heat transfer data. In this investigation a large scale (1/20), modified version of the National Aero-Space Plane configuration known as the 'Government Baseline' was tested at a nominal Mach number of 6; at two Reynolds numbers (0.6 and 1.6 million per foot); and at angles of attack from about 0 to 15 deg. There were several purposes for the investigation: to provide a windward and leeward pressure and heat transfer data base for a realistic configuration for verification of computational methods, to provide these data for a large-scale model, and to provide these data for true temperature conditions because of concern about data from low temperature tunnels. Author

A89-25568*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
NASP NATURAL ENVIRONMENT DEFINITIONS FOR DESIGN
ORVEL E. SMITH, DALE L. JOHNSON, and ROBERT E. SMITH (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 3 p.
(AIAA PAPER 89-0764)

Problems that emerged during the development of the natural environment definitions for the design of the National Aerospace Plane (NASP) are discussed. The NASP program objectives are reviewed. It is found that some of the data needed to determine the environmental parameters for designing the aircraft are unavailable. It is suggested that this is due to a lack of technology for making the necessary measurements. R.B.

A89-26701
PLANS '88 - IEEE POSITION LOCATION AND NAVIGATION SYMPOSIUM, ORLANDO, FL, NOV. 29-DEC. 2, 1988, RECORD
Symposium sponsored by IEEE. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, 569 p. For individual items see A89-26702 to A89-26752.

The present conference discusses topics in state-of-the-art space-based navigation systems, land vehicle navigation and position reporting, digital map technology, integrated navigation and flight control systems, GPS applications and equipment, geodetic surveying, radio navigation systems, and the positioning and pointing of space systems. Attention is also given to topics in the fields of inertial systems and technologies, differential GPS, aircraft navigation and traffic control, Federal radio-navigation policy, GPS/inertial navigation, integrated communication and navigation systems, and marine navigation and harbor traffic advisory systems. I.E.

A89-26711
EURONAV - A STATE OF THE ART MILITARY GPS RECEIVER
ANIL K. AGGARWAL (Magnavox Advanced Products and Systems Co., Torrance, CA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 153-164.

Two- and five-channel EURONAV GPS receivers for military applications are presented. Both types of receivers have a wide range of features in addition to providing the basic GPS (Global Positioning System) navigation functions. These receivers provide high performance, selective availability/antispoofing, and high antijam GPS capabilities. By the use of advanced technology components, it was possible to reduce the size of a five-channel GPS receiver from the GPS Phase II qualified three-fourths ATR long to three-eights ATR short, with a corresponding weight and power reduction. The author describes the EURONAV product specifications, the hardware, and the software design. I.E.

A89-26738
RANGING AND PROCESSING SATELLITE (RAPSAT)
WILLIAM R. HERSHEY, THOMAS HSIAO, CURTIS A. SHIVELY, and KAREN J. VIETS (Mitre Corp., McLean, VA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 394-401.

The following features of RAPSAT are described: performance requirements, operations, onboard processor architecture, and power and spectrum requirements. The proposed RAPSAT would provide surveillance and data link services for aviation. A feasibility study conducted over the past year shows the system can serve 50,000 peak instantaneous users with a total aircraft-to-satellite bandwidth of 4-5 MHz. The results reflect realistic message sizes and frequencies, plus the projected geographic distribution of air traffic in the year 2010. The system offers both automatic dependent surveillance and cooperative independent surveillance services. It uses two or more geostationary satellites, a cross link for coordination between the satellites, and an onboard processor for each satellite. By carefully scheduling discrete polls to aircraft, the system prevents garbling of aircraft replies at the satellite receive antenna and thus achieves higher spectral efficiency than previously proposed satellite-based surveillance systems. I.E.

A89-27175#
STRUCTURAL RELIABILITY IN AEROSPACE DESIGN
A. V. PATKI (ISRO, Satellite Centre, Bangalore, India) ESA Journal (ISSN 0379-2285), vol. 12, no. 3, 1988, p. 397-400.

The concept of a reliability figure is widely used in aerospace design. Though very common and well developed for electronics systems and components, it is not used directly for structural systems. This note attempts to show how reliability estimates can be incorporated in present aerospace design practice. A typical simple case is worked out to show the implicit reliability figures using these margins. Author

11

CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A89-25190#
CORRELATIONS OF HIGH DENSITY FUEL EFFECTS
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract F33615-86-C-2604)
(AIAA PAPER 89-0216)

An extensive testing of the T56-A-15 engine combustion system was carried out for a baseline JP-4 fuel and four high density fuels to evaluate the impact of the burning of high density fuel on combustor performance. The data evaluation phase involved the utilization of proven empirical correlations based on reaction rate, residence time, and mixing concepts. The prediction capability of the correlations was improved by incorporating detailed spray and evaluation calculation methods and the appropriate modifications to address the high-density fuel properties. K.K.

A89-25193#
3-D COMBUSTOR PERFORMANCE VALIDATION WITH HIGH DENSITY FUELS
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract F33615-86-C-2604)
(AIAA PAPER 89-0219)

High-density fuel data were used to validate a combustor performance model that utilizes flow field representations based on analytical three-dimensional codes as well as empirical correlations. This performance model is capable of assessing the impact of systematic modifications to the combustor on its performance. In addition, it eliminates the need for engineering estimates of certain combustor parameters. K.K.

A89-25403#
EXPERIMENTAL AND ANALYTICAL STUDY ON EXIT RADIAL TEMPERATURE PROFILE OF EXPERIMENTAL 2D COMBUSTOR
JI-BAO LI (Chinese Gas Turbine Establishment, People's Republic of China) and JU-SHAN CHIN (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0493)

A semiempirical and semianalytical model was developed for predicting the exit radial temperature profile from gas turbine combustors. The model can predict the effect of a change in the dilution zone design or combustor operating conditions on the change in the combustor exit radial temperature profile on the basis of the exit temperature before the change. This model is shown to be instrumental in the adjustment of the temperature profile of the gas turbine combustor. K.K.

A89-25902
A NEW TECHNIQUE FOR THE PRODUCTION OF GAS ATOMIZED POWDER
CHRISTER ASLUND and TORBJORN TINGSKOG (Anval Nyby Powder AB, Torshalla, Sweden) IN: Modern developments in powder metallurgy; Proceedings of the International Powder Metallurgy Conference, Orlando, FL, June 5-10, 1988. Volume 20. Princeton, NJ, Metal Powder Industries Federation, 1988, p. 181-186.

A new principal of atomization, the vertical horizontal (VH) atomization technique, is described. The advantage of this technique is a low gas consumption and low gas pressures combined with a fine screen cut ideal for applications such as spray powder and consolidated products where max grain sizes of about 100 microns are required. Author

A89-25915

SUPERPLASTICITY OF HIPPED PM SUPERALLOYS MADE FROM ATTRITED PREALLOY POWDER

N. UENISHI, Y. TAKEDA, and K. KUROISHI (Sumitomo Electric Industries, Ltd., Itami, Japan) IN: Modern developments in powder metallurgy; Proceedings of the International Powder Metallurgy Conference, Orlando, FL, June 5-10, 1988. Volume 20. Princeton, NJ, Metal Powder Industries Federation, 1988, p. 599-612. Research sponsored by the Agency of Industrial Science and Technology.

This paper describes a P/M process which was shown to enhance the superplasticity of Ni-base superalloys IN100, Astroloy, and TMP-3. The process involves the strain energizing of the prealloy powder, by using an attritor, and the HIP consolidation of the strain-energized powder. The mechanical properties measurements showed that the hardness of the strain-energized powders was above 600 mHv, which is 200 mHv higher than that of original powders. HIPped billets of strain-energized powder exhibited good superplasticity. The mechanical properties of HIPped and heat treated billets of strain-energized powder could be significantly improved eliminating oxygen and iron contamination. I.S.

A89-25919

MATERIAL DEFECTS IN A PM-NICKEL-BASE SUPERALLOY

B. NOWAK, G. KOENIG, E. AFFELDT (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany), H. LAHODNY, and E. ARZT (Max-Planck-Institut fuer Metallforschung, Stuttgart, Federal Republic of Germany) IN: Modern developments in powder metallurgy; Proceedings of the International Powder Metallurgy Conference, Orlando, FL, June 5-10, 1988. Volume 20. Princeton, NJ, Metal Powder Industries Federation, 1988, p. 745-750.

Procedures used in the determination of the type, the size, and the frequency of defects in the nickel-base superalloy U700 (Ni-16 Cr-18 Co-5.5 Mo-3.7 Ti-4.2 Al-0.04 C-0.03 B-0.06 Zr, in wt pct) are described, and the results of the analyses are presented. Eight different types of defects were documented in Viton-doped U700. These defects could be categorized among three classes, including pores, ellipsoid reactive inclusions, and Viton defects. The frequency of these defects as a function of size was determined. I.S.

A89-26361

THERMAL CONDUCTIVITY AND MICROSTRUCTURE STABILITY OF HEAT TREATED AMZIRC COPPER-BASED ALLOYS

CARL E. NEWBERG and WALTER W. WALKER (Hughes Aircraft Co., Tucson, AZ) IN: Metallography of advanced materials; Proceedings of the Twentieth Annual Technical Meeting of the International Metallographic Society, Monterey, CA, July 29, 30, 1987. Columbus/Metals Park, OH, International Metallographic Society/ASM International, 1988, p. 231-243. refs

Prompted by the need for microelectronic alloys that do not soften at brazing temperatures, two candidate copper-based alloys have been investigated: one involves Zr additions, the other Mg, Zr, and Cr. Both alloys are precipitation-hardenable and have high electrical and thermal conductivities; an attempt was made to obtain optimum thermal and mechanical properties. Optical microscopy, SEM, and energy-dispersive spectroscopy were used to ascertain the microstructures yielded by various heat treatments and cold working. The Zr-containing Cu alloy exhibits significantly higher thermal conductivity in every condition examined. O.C.

A89-27733#

LOCAL BUCKLING AND CRIPPLING OF THIN-WALLED COMPOSITE STRUCTURES UNDER AXIAL COMPRESSION

A. D. REDDY, L. W. REHFIELD, R. I. BRUTTOMESSO (Georgia Institute of Technology, Atlanta), and N. E. KREBS (Sikorsky Aircraft, Stratford, CT) (Structures, Structural Dynamics, and Materials Conference, 26th, Orlando, FL, Apr. 15-17, 1985, Technical Papers. Part 1, p. 804-810) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 97-102. Research supported by Sikorsky Aircraft. Previously cited in issue 13, p. 1859, Accession no. A85-30314. refs
(Contract DAAG29-82-K-0094)

A89-28242

AN INVESTIGATION OF THE PHYSICAL AND CHEMICAL FACTORS AFFECTING THE PERFOMANCE OF FUELS IN THE JFTOT

RICHARD H. CLARK and LORRAINE THOMAS (Shell Research, Ltd., Thornton Research Centre, Chester, England) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 15 p. Research supported by the Ministry of Defence. refs
(SAE PAPER 881533)

Using a jet fuel thermal oxidation tester (JFTOT), the physical and chemical factors which control the fuel performance were investigated in flow rate experiments in which seven different fuels, chosen to represent current refinery production, were used. Results on the flow-rate and the activation energy measurements indicated that the JFTOT response to a fuel depended on the relative roles of chemical reaction and physical transport, and that the contribution of the two effects was fuel dependent. I.S.

A89-28243

DEVELOPMENT OF A LABORATORY METHOD FOR STUDYING WATER COALESCENCE OF AVIATION FUEL

STEVEN T. SWIFT (Exxon Research and Engineering Co., Linden, NJ) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 11 p. refs
(Contract N00140-85-C-E184)
(SAE PAPER 881534)

A laboratory-scale coalescence test device is described, which makes it possible to investigate the water coalescence of aviation fuels under controlled conditions. The test device consists of a small-scale filter/separator unit incorporating both a coalescer and a separator stages and operating at a 800-fold reduction in flow rate from a full-scale filter/coalescer element. Using this device, the effects of various commercial fuel additives, including antioxidants, corrosion inhibitors, antiicing additives, and static dissipator additives, on the extent of water coalescence in the JP-5 aviation fuel were determined. The results were very similar to those obtained using conventional single-element tests. I.S.

A89-28244

BALL-ON-CYLINDER TESTING FOR AVIATION FUEL LUBRICITY

W. G. DUKEK SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p. refs
(SAE PAPER 881537)

The use of the ball-on-cylinder evaluator (BOCLE) to measure the lubrication properties of aviation fuels is described, summarizing the results of recent test evaluations. The fundamental problems of lubricity testing are reviewed, and the advantages offered by BOCLE are discussed: BOCLE measures lubricity in terms of mean ball wear and can detect the presence of lubrication-improvement additives and the abscence of natural lubricity agents in jet fuel. Typical results from comparative tests are presented in extensive graphs, with particular attention to Coordinating Research Council efforts to improve BOCLE. Significant improvements are obtained by using cylinders instead of rings. A.A.F.

A89-28344*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

COMPOSITE MECHANICS FOR ENGINE STRUCTURES

CHRISTOS C. CHAMIS (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 228-241. Previously announced in STAR as N88-12552. refs

Recent research activities and accomplishments at Lewis

Research Center on composite mechanics for engine structures are summarized. The activities focused mainly on developing procedures for the computational simulation of composite intrinsic and structural behavior. The computational simulation encompasses all aspects of composite mechanics, advanced three-dimensional finite-element methods, damage tolerance, composite structural and dynamic response, and structural tailoring and optimization. Author

A89-28433
MATERIALS FOR INTERIORS - A BRIEF REVIEW OF THEIR CURRENT STATUS [MATERIALES PARA INTERIORES - UN BREVE REPASO A LA SITUACION ACTUAL]
JOSE A. MARTINEZ CABEZA Ingenieria Aeronautica y Astronautica (ISSN 0020-1006), no. 309, 1989, p. 21-33. In Spanish.

An evaluation is made of the development status and characteristic products used in commercial aircraft interiors, pursuant to such flammability, smoke-generation, and smoke-toxicity minimization requirements as those set out in appendix F of FAR 25's section II. Intensive development has been prompted by FAR 25-59's call for materials applicable to passenger seating that would meet 'fire blocking layer' criteria while being as light as 300 g/sq m; also intensively sought have been seat cushion polymeric foams that could yield the requisite degree of inflammability without the use of a fire blocking layer material. FAR 25-61 and FAR 121 are also discussed. O.C.

N89-17017*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL VERIFICATION OF THE THERMODYNAMIC PROPERTIES FOR A JET-A FUEL
CARMEN M. GRACIASALCEDO, THEODORE A. BRABBS, and BONNIE J. MCBRIDE Sep. 1988 10 p Presented at the 196th National Meeting of the American Chemical Society, Los Angeles, CA, 25-30 Sep. 1988 Prepared in cooperation with Army Aviation Systems Command, Cleveland, OH; and Sverdrup Technology, Inc., Cleveland, OH
(NASA-TM-101475; E-4593; NAS 1.15:101475) Avail: NTIS HC A02/MF A01 CSCL 21D

Thermodynamic properties for a Jet-A fuel were determined by Shell Development Company in 1970 under a contract for NASA Lewis Research Center. The polynomial fit necessary to include Jet-A fuel (liquid and gaseous phases) in the library of thermodynamic properties of the NASA Lewis Chemical Equilibrium Program is calculated. To verify the thermodynamic data, the temperatures of mixtures of liquid Jet-A injected into a hot nitrogen stream were experimentally measured and compared to those calculated by the program. Iso-octane, a fuel for which the thermodynamic properties are well known, was used as a standard to calibrate the apparatus. The measured temperatures for the iso-octane/nitrogen mixtures reproduced the calculated temperatures except for a small loss due to the non-adiabatic behavior of the apparatus. The measurements for Jet-A were corrected for this heat loss and showed excellent agreement with the calculated temperatures. These experiments show that this process can be adequately described by the thermodynamic properties fitted for the Chemical Equilibrium Program. Author

N89-17325*# Engineering Science Software, Inc., Smithfield, RI.
CONSTITUTIVE MODELLING OF SINGLE CRYSTAL AND DIRECTIONALLY SOLIDIFIED SUPERALLOYS
KEVIN P. WALKER and ERIC H. JORDAN (Connecticut Univ., Storrs.) *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 299-301 Oct. 1987
(Contract NAG3-512)
Avail: NTIS HC A20/MF A01 CSCL 11F

Successful attempts were made to model the deformation behavior of nickel base superalloys to be used in gas turbine engines based on both a macroscopic constitutive model and a micromechanical formulation based on crystallographic slip theory. These models were programmed as FORTRAN subroutines, are currently being used to simulate thermomechanical loading predictions expected at the fatigue critical locations on a single crystal turbine blade. Such analyses form a natural precursor to the application of life prediction methods to gas turbine airfoils. Author

N89-17334*# Pratt and Whitney Aircraft, East Hartford, CT.
HIGH TEMPERATURE CONSTITUTIVE AND CRACK INITIATION MODELING OF COATED SINGLE CRYSTAL SUPERALLOYS
THOMAS G. MEYER, DAVID M. NISSLEY, and GUSTAV A. SWANSON *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 401-412 Oct. 1987
(Contract NAS3-23939)
Avail: NTIS HC A20/MF A01 CSCL 11B

The purpose of this program is to develop life prediction models for anisotropic materials used in gas turbine airfoils. In the base portion of the program, two coated single crystal alloys are being tested. They are PWA 286 overlay coated and PWA 273 aluminide coated PWA 1480 and PWA 286 overlay coated Alloy 185. Viscoplastic constitutive models for these materials are also being developed to predict the cyclic stress-strain histories required for life prediction of the lab specimens and actual airfoil designs. Author

N89-17681# Battelle Columbus Labs., OH.
FUEL-ADDITIVE SYSTEM FOR TEST CELLS Final Report, 5 Aug. 1987 - 25 Feb. 1988
DALE W. FOLSOM Aug. 1988 34 p
(Contract F08635-85-C-0122)
(AD-A200801; AFESC/ESL-TR-88-17) Avail: NTIS HC A03/MF A01 CSCL 21E

The purpose of this project was to provide the U.S. Air Force with design data and a prototype of a fuel-additive system capable of reducing plume opacity during testing of a jet engine in a test cell. Jet engines are tested in a test cell after servicing and before placement in an aircraft. Certain jet engines, J-57, J-79, and TF-33 in particular, generate soot which exits the test cell in a plume of greater than 20 percent opacity (Ringelmann number of 1 or greater). This opacity exceeds the opacity limit (20 percent) set by the Environmental Protection Agency (EPA). The U.S. Air Force has previously funded projects that found two jet fuel additives, ferrocene and cerium octoate, that reduce the plum opacity. The scope of this project included the design, construction, and testing of a prototype fuel-additive system. The following report describes the fuel-additive system requirements, design parameters, design, fabrication, and testing of the prototype system. The prototype fuel-additive system, properly built and operated, will provide the U.S. Air Force a means of testing jet engines in test cells while staying within EPA opacity limits. GRA

N89-17696# Royal Armament Research and Development Establishment, Christchurch (England).
TEST SPECIMENS FOR BEARING AND BY-PASS STRESS INTERACTION IN CARBON FIBRE REINFORCED PLASTIC LAMINATES
M. B. SNELL and G. P. BURKITT *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 21 p Mar. 1988 Original document contains color illustrations
Avail: NTIS HC A14/MF A01

Compact test specimens for measuring the strength interaction behaviour of bolted joints subject to combined bearing and by-pass stresses have been studied. Multi-bolt specimens which have been successfully used to study these effects in aluminum alloy were found to be unsatisfactory because of the uncertainty in load transfer, and a new specimen based on parallel plates was developed. Bearing load at the holes is achieved through load transfer from the central carbon fiber reinforced plastic (CFRP) coupon to the parallel plates. The maximum ratio of bearing to bypass loads is limited by the initial fit of the bolt and by subsequent bolt/hole deformation under load. However the specimens recommended are capable of applying a wide range of bearing/bypass load ratios. Sample strength interaction envelopes were produced for a Hercules IM6 fiber and Ciba-Geigy Fibredux 6376 resin laminate of typical wing skin lay-up, 5.5 mm thick. Both tension and compression quadrants were studied, with two hole sizes, in both double shear and single shear. The interaction behavior was similar in both tension and compression for 6.35 mm holes in double shear, but in the case 0f 9.5 mm bolts there was less interaction in compression than in tension. Countersunk fasteners in tension appeared to suffer little reduction in net strength due to bearing stresses. Author

N89-17701# Aeritalia S.p.A., Naples (Italy).
JOINING OF CARBON FIBER COMPOSITE WITH FASTENERS
SALVATORE PAGLIUSO *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 5 p Mar. 1988
Avail: NTIS HC A14/MF A01

This paper deals with the Aeritalia experience on drilling techniques and fastener selection for advanced composite assembly. Details are provided on fabrication techniques. Information is given on corrosion prevention. Author

N89-17702# Avions Marcel Dassault, Saint-Cloud (France).
BOLTED SCARF JOINTS IN CARBON COMPOSITE MATERIALS. COMPARISON BETWEEN ASSEMBLIES WITH AN INTERFERENCE FIT AND THOSE WITH PLAY [ENTURES BOULONNEES EN MATERIAUX COMPOSITE CARBONE COMPARAISON ENTRE MONTAGES A INTERFERENCE ET MONTAGE A JEU]
DANIEL CHAUMETTE *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 10 p Mar. 1988 In FRENCH
Avail: NTIS HC A14/MF A01

Experimental results on the behavior of carbon assemblies with mechanical fasteners mounted with and without interference are presented. Interference tests have been conducted for the cases of unstressed joints and scarf joints. In contrast to the predictions of elastic stress theory, interference fit is not found to have a significant influence on the static strength of test specimens, even after fatigue loading. The present results can be explained by the fracture mode of the drilled composite parts which leads to delamination. Author

12

ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A89-24995#
AUTOMATIC GENERATION OF COMPONENT MODES FOR ROTORDYNAMIC SUBSTRUCTURES
S. H. CRANDALL and N. A. YEH (MIT, Cambridge, MA) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 111, Jan. 1989, p. 6-10. refs

A program for the automatic generation of the component modes for substructures modeled as Timoshenko beams connected to other substructures by bearings, couplings, and localized structural joints is described. The method makes use of the singularity functions commonly used in beam analysis, and it has been applied to a simplified system with a single rotor structure and a single stator structure. The accuracy of the method is demonstrated by comparison of the results with those obtained by an exact analytical solution and by a component mode synthesis using true eigenfunctions as internal modes. R.R.

A89-25065*# Sundstrand Corp., Rockford, IL.
AN EXPERIMENTAL STUDY AND PREDICTION OF A TWO-PHASE PRESSURE DROP IN MICROGRAVITY
I. Y. CHEN, R. S. DOWNING (Sundstrand Corp., Rockford, IL), E. KESHOCK, and M. M. AL-SHARIF (Tennessee, University, Knoxville) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAS9-17195)
(AIAA PAPER 89-0074)

Experimental two-phase pressure drop results obtained in normal gravity and in nearly zero-gravity aboard a NASA-JSC reduced-gravity KC-135 aircraft are used to evaluate several empirically based correlations and flow-regime dependent models. Pressure drops in reduced gravity and those in normal gravity are shown to be related to flow pattern models for each. Two annular flow models are developed which are found to accurately predict the reduced-gravity data. R.R.

A89-25082#
CFD APPLICATIONS - PROPULSION PERSPECTIVE
SAADAT A. SYED (United Technologies Corp., West Palm Beach, FL) and GORDON F. PICKETT (United Technologies Corp., East Hartford, CT) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0093)

The current status of Computational Fluid Dynamics (CFD) as applied to propulsion devices is discussed. The traditional code development cycle is described, and it is argued that this cycle needs to be improved if the explosive growth in CFD codes is to be harnessed profitably. It is also argued that the government funding agencies have to take a leading role in the modification of this cycle. The technical issues relating to internal flows in propulsion systems are discussed, and it is suggested that mesh generation, mesh adaptation, and turbulence model development require major emphasis in the future. Author

A89-25101#
A COMPARATIVE STUDY OF ITERATIVE ALGORITHMS FOR THE EULER EQUATIONS OF GASDYNAMICS
DANIEL J. DORNEY, GEORGE S. DULIKRAVICH (Pennsylvania State University, University Park), and KI D. LEE (Illinois, University, Urbana) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0114)

A comparative study for the solution of the Euler equations has been performed using four flux-vector-splitting (FVS) schemes and a central difference scheme with two different dissipation models. All schemes were tested for the case of steady, inviscid, transonic airfoil flow. Van Leer's FVS scheme was found to be robust and appears to generate little numerical dissipation. The FVS schemes of Deese (1983, 1985) and Steger-Warming (1981) yield results similar to Van Leer's, though not quite as robust. Whitfield's (1984) FVS scheme generates large amounts of numerical dissipation and causes delayed post-shock pressure recovery. A new, physically based dissipation model for central difference schemes has been compared to the artificial dissipation model of Jameson et al. (1981). Author

A89-25118*# Pennsylvania State Univ., University Park.
DIVERGING BOUNDARY LAYERS WITH ZERO STREAMWISE PRESSURE GRADIENT
WAYNE R. PAULEY (Pennsylvania State University, University Park), JOHN K. EATON (Stanford University, CA), and ANDREW D. CUTLER (NASA, Langley Research Center; George Washington University, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract DE-FG03-86ER-13608; NAGW-581)
(AIAA PAPER 89-0134)

The effects of spanwise divergence on the boundary layer forming between a pair of embedded streamwise vortices with the common flow between them directed toward the wall was studied. Measurements indicate that divergence controls the rate of development of the boundary layer and that large divergence significantly retards boundary layer growth and enhances skin friction. For strongly diverging boundary layers, divergence accounts for nearly all of the local skin friction. Even with divergence, however, the local similarity relationships for two-dimensional boundary layers are satisfactory. Although divergence modifies the mean development of the boundary layer, it does not significantly modify the turbulence structure. In the present experiments with a zero streamwise pressure gradient, it was found that spanwise divergence dit not significantly affect the Reynolds stress and the turbulent triple product distributions. Author

A89-25119#
MEASUREMENTS OF A SUPERSONIC TURBULENT BOUNDARY LAYER WITH MASS ADDITION
WILLIAM J. YANTA, ARNOLD S. COLLIER, and TIMOTHY S. SMITH (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p. refs
(AIAA PAPER 89-0135)
Boundary-layer measurements were carried out on two 8-deg sphere-cones with mass addition at a Mach Number of 2.5 and a freestream Reynolds Number of 8.86 million/m). These cones were fabricated from two different grades of porous materials. Measurements were made with two-dimensional LDV, from which the mean velocity, turbulence intensities, Reynolds stresses, eddy viscosity and mixing length were determined. Measurements were carried out for four different mass-addition rates at two stations on the model. Air was used as the injection gas. Author

A89-25150#
SINGLE AND MULTIPLE JET IMPINGEMENT HEAT TRANSFER ON ROTATING DISKS
D. E. METZGER and V. A. PARTIPILO (Arizona State University, Tempe) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0174)
In some gas turbine engine designs cooling air jets are directed at the rotating disk in an atempt to enhance the convection coefficients and reduce the amount of gas flow required for cooling. The jet-impingement scheme is particularly attractive for achieving intense cooling at a specific radial location, such as the blade attachment region. In earlier single-jet studies, the interaction between an impinging jet and rotating disk has been found to involve a flow regime transition. The present study extends the previously acquired data base with new results from both heat-transfer and flow-visualization testing, including effects of hub size, jet travel distance, and the number of jets. Results include a superposition scheme for predicting heat transfer for multiple jets and a criterion for the minimum amount of flow required through each jet nozzle to assure enhancement of the disk convection. Author

A89-25181*# Mississippi State Univ., Mississippi State.
A SIMPLE TIME-ACCURATE TURBOMACHINERY ALGORITHM WITH NUMERICAL SOLUTIONS OF AN UNEVEN BLADE COUNT CONFIGURATION
J. MARK JANUS and DAVID L. WHITFIELD (Mississippi State University, Mississippi State) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. refs
(Contract NAG3-767; NAG3-869)
(AIAA PAPER 89-0206)
The present computer algorithm for the time-accurate flow analysis of rotating turbomachines is based on the finite-volume method and employs a high-resolution approximate Riemann solver for interface flux definitions and an implicit numerical scheme that possesses apparent unconditional stability. Block-block interfaces, including dynamic ones, are treated in such a way as to mimic interior block communication. The turbomachine configurations treated by way of illustration are 8-8-bladed and 11-9-bladed versions of a contrarotating unducted fan engine. O.C.

A89-25183#
PASSAGE-AVERAGED NAVIER-STOKES EQUATIONS WITH FINITE ELEMENT APPLICATIONS
ANDRE GARON, DOMINIQUE PELLETIER, and RICARDO CAMARERO (Ecole Polytechnique, Montreal, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 26 p. Research supported by NSERC and Centre de Recherche Informatique de Montreal. refs
(AIAA PAPER 89-0208)
The passage-averaged formulation of the Navier-Stokes equations describing viscous flow over stationary or rotating blades in a turbomachine is investigated analytically. A closure model is developed for the case where the axial, radial, and peripheral components of the force on the volume swept by a single blade row are specified, and particular attention is given to the extension of this model to multiple blade rows and the applicability of weak Galerkin FEMs to the passage-averaged Navier-Stokes equations. Results from successful simulations of flow past a propeller and flow in a mixed-flow pump are presented graphically and briefly characterized. T.K.

A89-25191#
AIRBLAST ATOMIZATION AT CONDITIONS OF LOW AIR VELOCITY
J. BECK, A. LEFEBVRE, and T. KOBLISH (Thermal Science and Propulsion Center, West Lafayette, IN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0217)
The process of prefilming airblast atomization under conditions of reduced air velocity is examined. Spray quality is determined by a series of measurements of drop size distribution and mean drop size. A two-dimensional atomizer which produces a flat liquid sheet of variable thickness between two coflowing nitrogen gas streams is used. The results confirm that spray quality improves when air velocity and air/liquid mass flow ratio are increased and liquid surface tension and viscosity are decreased. It is suggested that a threshold of relative velocity exists below which atomization is not possible for a given set of conditions. The dependence of the spray Sauter mean diameter on initial liquid film thickness is weak for the system studied. It is suggested that this is because the airstreams impinge on the liquid sheet at a 30 deg angle and extrude the sheet between the two colliding streams, thus nullifying the influence of the initial sheet thickness. R.B.

A89-25275#
INFLUENCE OF CLEARANCE LEAKAGE ON TURBINE HEAT TRANSFER AT AND NEAR BLADE TIPS - SUMMARY OF RECENT RESULTS
D. E. METZGER, K. RUED, and M. K. CHYU (Arizona State University, Tempe) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0327)
In gas turbine engines, the unshrouded blades of axial turbine stages rotate in close proximity to the stationary outer wall, or seal, of the turbine housing. The pressure difference between pressure and suction sides of the blade drives a leakage flow through the gap between the rotating blade tip and adjacent wall. Flow and heat transfer at the blade tips have long been subjects of interest to gas turbine engine designers because of effects on aerodynamic performance and because material failures are frequently observed in that region. However, until quite recently only a very incomplete and largely qualitative understanding existed of the clearance gap flowfield, and virtually no information was available on the heat transfer effects. In this paper, an overview is given of recent published efforts to elucidate more features of the leakage-related flowfield and convection heat transfer on and near unshrouded turbine blade tips. Author

A89-25307*# University of Wales, Swansea.
AN ADAPTIVE IMPLICIT/EXPLICIT FINITE ELEMENT SCHEME FOR COMPRESSIBLE VISCOUS HIGH SPEED FLOW
O. HASSAN, K. MORGAN, and J. PERAIRE (University of Wales, Swansea) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV,

Jan. 9-12, 1989. 10 p. refs
(Contract NAGW-478; SERC-GR/E/64046)
(AIAA PAPER 89-0363)

An adaptive implicit/explicit finite element procedure for the solution of three-dimensional problems of steady compressible viscous high-speed flows is presented. In the vicinity of solid walls, a grid-exhibiting structure in the normal direction is employed, while away from this region the grid is totally unstructured. The implicit form of the algorithm is used near solid walls, with the grid structure being utilized in an equation solution approach based upon line relaxation. The explicit form of the algorithm is used elsewhere. Grid adaptation is achieved by means of adaptive remeshing. To illustrate the performance of the proposed method, solutions are obtained for the problems of shock-boundary layer interaction and shock-shock interaction on a swept cylindrical leading edge. Comparisons are made with experimental observations. Author

A89-25337*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
HIGH-TEMPERATURE CONTAINERLESS AIRCRAFT FURNACE EXPERIMENTATION IN THE MICROGRAVITY ENVIRONMENT ABOARD A KC-135 AIRCRAFT
RICHARD M. POORMAN, BUDDY V. GUYNES, ROBERT SHURNEY, and JACK WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 5 p.
(AIAA PAPER 89-0402)

This paper describes a materials processing research furnace, the High-Temperature Containerless Aircraft Furnace (HITCAF), which uses an electric arc to melt and resolidify materials in the microgravity environment aboard a KC-135 aircraft. The HITCAF is designed to process almost every electrically conductive material, including such high-melting-point materials as tungsten, within a 15 to 20 sec microgravity period. It operates on tungsten/inert gas welding principles, using an adapted commercially available tube welder. The HITCAF is fully operational and available for use by researchers representing the Government agencies, as well as industry and academia. I.S.

A89-25376*# Boeing Advanced Systems Co., Seattle, WA.
A MODEL FOR 3-D SONIC/SUPERSONIC TRANSVERSE FUEL INJECTION INTO A SUPERSONIC AIR STREAM
THOMAS R. A. BUSSING and GARY L. LIDSTONE (Boeing Advanced Systems, Seattle, WA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract NAS1-18560)
(AIAA PAPER 89-0460)

A model for sonic/supersonic transverse fuel injection into a supersonic airstream is proposed. The model replaces the hydrogen jet up to the Mach disk plane and the elliptic parts of the air flow field around the jet by an equivalent body. The main features of the model were validated on the basis of experimental data. K.K.

A89-25440*# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
AN INVESTIGATION OF CELL CENTERED AND CELL VERTEX MULTIGRID SCHEMES FOR THE NAVIER-STOKES EQUATIONS
R. RADESPIEL (DFVLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) and R. C. SWANSON (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0548)

Two efficient and robust finite-volume multigrid schemes for solving the Navier-Stokes equations are investigated. These schemes employ either a cell centered or a cell vertex discretization technique. An explicit Runge-Kutta algorithm is used to advance the solution in time. Acceleration techniques are applied to obtain faster steady-state convergence. Accuracy and convergence of the schemes are examined. Computational results for transonic airfoil flows are essentially the same, even for a coarse mesh. Both schemes exhibit good convergence rates for a broad range of artificial dissipation coefficients. Author

A89-25445#
THE INFLUENCE OF FREESTREAM VORTICITY ON PARTICLE LIFT, DRAG, AND HEAT TRANSFER
DAVID S. DANDY (Sandia National Laboratories, Livermore, CA) and HARRY A. DWYER (California, University, Davis) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by DOE and U.S. Army. refs
(AIAA PAPER 89-0555)

Numerical solutions have been obtained for steady, linear shear flow past a heated spherical particle for a wide range of Reynolds numbers and shear rates. The three-dimensional solutions for velocity, pressure and temperature calculated in this work will be the basis for future correlations for drag, lift, and heat transfer rate. The particle was kept at a fixed temperature different from the far-field temperature. It was found that although the dimensionless heat transfer (that is, the Nusselt number) increased with increasing Reynolds number for fixed shear rate, the rate of heat transfer was insensitive to changes in shear rate for fixed values of the Reynolds number. Author

A89-25450#
SHOCK CAPTURING USING A PRESSURE-CORRECTION METHOD
JAMES J. MCGUIRK and GARY J. PAGE (Imperial College of Science and Technology, London, England) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by the Ministry of Defence Procurement Executive. refs
(AIAA PAPER 89-0561)

A pressure-correction scheme is presented which is applicable to the calculation of flows covering a wide range of Mach number. The method provides precise shock capturing results over two nodes with no overshoots or undershoots, and it is much faster than either the MacCormack (1969) or Jameson (1975) explicit schemes. Results are presented for a turbulent underexpanded axisymmetric impinging jet. R.R.

A89-25478#
A NOVEL INFRARED THERMOGRAPHY HEAT TRANSFER MEASUREMENT TECHNIQUE
HENRY M. EPPICH (Avco Research Laboratory, Inc., Everett, MA) and JOHN C. KREATSOULAS (Digital Equipment Corp., Marlboro, MA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0601)

This paper presents results of proof-of-concept experiments for a nonintrusive diagnostic technique capable of rapid measurement of convective heat transfer distributions over broad surface areas with high spatial resolution. IR thermography, based on video camera technology, is used to obtain surface temperature distributions. These distributions plus surface substrate temperatures obtained by a few thermocouples are all that is required to infer accurate, highly resolved distributions of local heat transfer coefficient behavior. Comparisons of heat transfer coefficient behavior measured by this technique with those by conventional techniques are presented to illustrate this technique's capabilities for convective heat transfer resulting from an air jet impinging on a heated plate. Author

A89-25526#
THE TURBULENT FREE JET ISSUING FROM A SHARP-EDGED ELLIPTICAL SLOT
W. R. QUINN (Saint Francis Xavier University, Antigonish, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NSERC-A-5484)
(AIAA PAPER 89-0664)

Experimental results on the mean flow and turbulence characteristics of a turbulent free jet of air issuing from a sharp-edge elliptical slot of aspect ratio 5 are presented. Hot-wire anemometry was used to obtain such measurements as the mean streamwise velocity, turbulence intensities, and the Reynolds shear stress. It is found that the jet rotates counterclockwise about its central streamwise axis before attaining an axisymmetric shape at about 30 equivalent slot diameters downstream of the exit plane. R.R.

A89-25554*# Dayton Univ., OH.
A NUMERICAL INVESTIGATION OF THE INFLUENCE OF SURFACE ROUGHNESS ON HEAT TRANSFER IN ICE ACCRETION
J. N. SCOTT and W. L. HANKEY (Dayton, University, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(Contract NAG3-665)
(AIAA PAPER 89-0737)
The flowfield and resulting heat transfer rate over a series of ice accretion shapes is obtained by solving the Navier-Stokes equations. The influence of surface roughness on surface heat transfer is examined by including blockage, form drag, and stagnation heating effects as source terms in the governing equations. The results indicate increases of a factor of three in cooling rates due to distributed roughness compared to smotth surfaces. In addition, droplet impingement efficiencies are studied for the same series of ice accretion shapes using a time-dependent solution procedure. R.B.

A89-25570*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PERFORMANCE OF THE FORWARD SCATTERING SPECTROMETER PROBE IN NASA'S ICING RESEARCH TUNNEL
EDWARD A. HOVENAC (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) and ROBERT F. IDE (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Previously announced in STAR as N89-12845.
(AIAA PAPER 89-0769)
Two Forward Scattering Spectrometer Probes were used to measure droplet distributions in the NASA Lewis Icing Research Tunnel. The instruments showed good agreement when the median volume diameter (MVD) was approximately 16 micrometers. Coincidence events affected much of the data and caused the measured MVD to be about 2 to 3 micrometers larger than expected. Coincidence events were reduced by shutting down half of the spray bars in the tunnel during certain tests. Author

A89-25590#
TDWR DISPLAY EXPERIENCES
WAYNE R. SAND and CLEON BITER (National Center for Atmospheric Research, Boulder, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(Contract DOT-FA01-82-Y-10513)
(AIAA PAPER 89-0807)
Displays developed for a prototype of the Terminal Doppler Weather Radar (TDWR) are discussed with reference to results of the operational demonstration of the TDWR display system. In particular, the discussion covers the manner in which data and information are handled in the TWDR system, specific displays that were developed and used in the demonstration, lessons learned from the operational use of these displays, and some future work to further develop the user interface. V.L.

A89-25608#
A STUDY OF TURBOMACHINE FLOW VELOCITIES
DAVID L. CEMAN AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0839)
A study of the air flows through a high-speed ducted fan was conducted, utilizing the laser Doppler velocimetry (LDV) technique. By precise orientation and positioning of the LDV probe volume, it was possible to survey the inlet and exit areas of the fan in operation. It was expected that detailed velocity component data would yield estimates of thrust and energy transfer for the turbomachine. Investigation into nonuniformities in the exit flow due to internal structures was attempted. Difficulties in the operation of the LDV system precluded the study of flow nonuniformities, although estimates of thrust and energy transfer were obtained. Author

A89-25609#
A MODEL OF PRESSURE DISTRIBUTIONS ON IMPELLER BLADES FOR DETERMINING PERFORMANCE CHARACTERISTICS
MARK A. HINZ (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. Research supported by the Undergraduate Research Opportunities Program. refs
(AIAA PAPER 89-0840)
A model for pressure distributions over an impeller blade is presented, which can be used to determine the structural integrity of a particular design and to provide performance data that can assist in the development of a new effective design. The model, developed as an interactive computer program, uses blade configuration data from an existing computer-aided design package in which the blade is divided into many panel elements; the resulting pressure distribution is determined by applying a conservation-of-momentum theory to each panel to determine the pressure. The model's output is provided in tabular form as well as in the form of a thee-dimensional representation of the pressure vectors. I.S.

A89-25860
BOUNDARY LAYER TRANSITION AND TURBULENCE MODELLING IN THREE-DIMENSIONAL FLOW
J. COUSTEIX and D. ARNAL (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: Numerical simulation of the transonic DFVLR-F5 wing experiment; Proceedings of the International Workshop on Numerical Simulation of Compressible Viscous-Flow Aerodynamics, Goettingen, Federal Republic of Germany, Sept. 30-Oct. 2, 1987. Brunswick, Federal Republic of Germany, Friedr. Vieweg und Sohn, 1988, p. 122-138. refs
The first part of this paper is devoted to a survey on transition problems in three-dimensional flow. Emphasis is given on practical calculation methods which enable to predict transitions induced by streamwise instability, cross-flow instability or leading edge contamination. In the second part, the difficulties encountered when facing with turbulence modelling are examined. The attention is essentially focused on simple boundary layer flows such as those developing on swept wings. Author

A89-26171
ELECTRICAL EQUIPMENT OF AIRCRAFT [ELEKTROTEKHNICHESKIE USTROISTVA LETATEL'NYKH APPARATOV]
VLADIMIR P. TUZOV Moscow, Izdatel'stvo Vysshaia Shkola, 1987, 152 p. In Russian. refs
The general design and operation of various kinds of electrical equipment used on aircraft are reviewed. In particular, attention is given to the general requirements for the electrical equipment of aircraft, electromagnetic circuits and devices, transformers, asynchronous and synchronous motors, DC motors and generators, and static power supply devices. The discussion also covers electrical converters, electric drives for aircraft mechanisms, and electric power transmission and distribution systems for aircraft. V.L.

A89-26273
VIBRATION AND FLUTTER ANALYSIS OF COMPOSITE WING PANELS
H. V. L. NARAYANA, P. RAJAGOPAL, T. S. RAMANI, and M. R. RAMAMURTHY (National Aeronautical Laboratory, Bangalore, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 216-227.
Several composite wing panels are analyzed to predict their

vibration and flutter characteristics. The panels studied are used in a research project on aeroelastic tailoring which is being conducted by NAL. The NASTRAN (NASA STructural ANalysis program) was used to perform both vibration as well as flutter analysis. A thorough investigation is made of the free-vibration and flutter characteristics of three panel configurations with results compared to published data. Author

A89-26274
FREE VIBRATION AND PANEL FLUTTER OF QUADRILATERAL LAMINATED PLATES
B. J. C. BABU (Indian Institute of Technology, Madras, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 228-237. refs

The present treatment of the free vibration and aeroelastic stability of flat plates with planform geometries of interest to aircraft designers gives attention to the effects of the orthotropicity ratio, panel dimensions, and the yaw angle, on flutter behavior boundaries. Two fourth-order governing differential equations were obtained from equations-of-equilibrium; the stress function and lateral displacements are used as variables. The study is confined to panels having cross-ply layup characteristics. It is found that the critical flow parameter increases significantly as modulus ratio increases. O.C.

A89-26281
AEROELASTIC FLUTTER OF LOW ASPECT RATIO CANTILEVER COMPOSITE PLATE
SRIJAYA MOHAN, V. P. RANGAIAH (Aeronautical Development Establishment, Bangalore, India), and S. DURVASULA (Indian Institute of Science, Bangalore, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 295-304. refs

The aeroelastic flutter behavior of low-aspect-ratio trapezoidal composite cantilever plates is studied. Orthonormal polynomials as assumed modes are used in flutter analysis. The assumed modes are set up as product functions of orthonormal polynomials in the spanwise and chordwise directions. Numerical calculations for vibration frequencies are made for: (1) a graphite/epoxy rectangular plate, (2) a glass/epoxy swept tapered plate, and (3) a graphite/epoxy low-aspect-ratio trapezoidal plate. Vibration results obtained by varying ply orientation show the effect of lamination scheme and sweep on vibration and flutter. Author

A89-26284
FINITE ELEMENT ANALYSIS OF COMPOSITE RUDDER FOR DO 228 AIRCRAFT
K. GURUPRASAD, M. SUBBA RAO, and RAMESH CHANDRA (National Aeronautical Laboratory, Bangalore, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 327-337.

This paper describes design and analysis of composite rudder for DO 228 aircraft. Stress analysis is carried out using finite element general purpose software ASKA. Automatic mesh generation and postprocessing are carried out using FEMGEN and FEMVIEW. Stress analysis of the existing metallic rudder is carried out to determine permissible deformations in composite rudder. Design variables considered are: geometrical parameters (widths and thicknesses of spar-flange and rib-flanges and thicknesses of spar-web and rib-webs) and lamination parameters (fiber orientation and stacking sequence) of spar, ribs, and leading edge. Many iterations on these design variables are attempted to match the stiffness of composite rudder to that of metallic rudder. Author

A89-26542
SOME NEW IDEAS IN RADAR ANTENNA TECHNOLOGY
BENITO PALUMBO (Selenia S.p.A., Rome, Italy) Microwave Journal (ISSN 0192-6225), vol. 32, Jan. 1989, p. 95, 96, 98 (3 ff.).

An evaluation is presently made of emerging modular antenna design and construction technologies through which significant cost reductions may be realized in ATC and surveillance radars. The factor of modularity in design permits a specialized tailoring of operational characteristics for the given application. Extensive use of CAD techniques is recommended for these ends, from feasibility studies through design and development to production and performance testing. Attention is given to the design features of a dual-mode beamforming network for a three-dimensional surveillance radar. O.C.

A89-26548
TEMPERATURE COMPENSATION USING GAAS MMIC DEVICES
Microwave Journal (ISSN 0192-6225), vol. 32, Jan. 1989, p. 167, 168, 170, 172, 174.

A major problem faced by the designer of interceptor aircraft electronics in the EW environment context is the prevention of catastrophic system failures due to power dissipation or cooling system overloads. Attention is presently given to external-passive solutions to this problem that are predicated on the use of existing GaAs MMIC devices. All temperature-compensation components have been implemented on a single GaAs MMIC, the TCTC-0100 chip, which incorporates a diode ladder, tho GaAs operational amplifiers, a linear attenuator, and resistors. O.C.

A89-26721
EVALUATION OF A KALMAN FILTER FOR SAR MOTION COMPENSATION
DAVID J. DIFILIPPO, GEORGE E. HASLAM (Defence Research Establishment Ottawa, Canada), and WILLIAM S. WIDNALL IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 259-268. refs

A synthetic-aperture radar motion compensation system (SARMCS) is being developed at the Defence Research Establishment Ottawa to compensate an airborne SAR for spurious motions of the radar antenna that may be caused by air turbulence of aircraft maneuvers. A Kalman filter has been developed as part of this SAR motion compensation system which uses a low-cost strapdown IMU (inertial measurement unit), to measure antenna motion. The function of the Kalman filter is to control misalignments of the strapdown analytical platform, since analysis has indicated that these errors are dominant contributors to motion compensation error. Representative results from processing raw recorded flight data have verified the proper operation of all aspects of the Kalman filter and have indicated that the filter performance is consistent with the motion compensation requirements. Some examples of actual SAR strip-map imagery are shown in order to demonstrate the enhancement provided by the SARMCS. I.E.

A89-27632
ENGINEERING CERAMICS - APPLICATIONS AND TESTING REQUIREMENTS
E. G. BUTLER (Rolls-Royce, PLC, Bristol, England) (National Physical Laboratory and Institute of Ceramics, Symposium on Mechanical Testing of Engineering Ceramics at High Temperatures, London, England, Apr. 11, 12, 1988) International Journal of High Technology Ceramics (ISSN 0267-3762), vol. 4, no. 2-4, 1988, p. 93-102. refs

The high stiffness and the damage-intolerant mechanical behavior of advanced engineering ceramics applicable to turbine engine hot section components, in conjunction with very high temperature testing requirements, pose severe difficulties for test method development. The generation of data base properties must be much more accurate than heretofore, while reflecting both intrinsic material properties and the turbine engine environment; both static and dynamic loading must be taken into account over a range of operating temperatures and stresses in a corrosive environment. Test equipment must be capable of operating at up to 1600 C. O.C.

A89-27651
INTERNATIONAL INSTRUMENTATION SYMPOSIUM, 34TH, ALBUQUERQUE, NM, MAY 2-6, 1988, PROCEEDINGS
Symposium sponsored by ISA. Research Triangle Park, NC, Instrument Society of America, 1988, 759 p. For individual items see A89-27652 to A89-27686.
Various papers on aerospace instrumentation are presented. The general topics addressed include: blast and shock, wind tunnel instrumentations and controls, digital/optical sensors, software design/development, special test facilities, fiber optic techniques, electro/fiber optical measurement systems, measurement uncertainty, real time systems, pressure. Also discussed are: flight test and avionics instrumentation, data acquisition techniques, computer applications, thermal force and displacement, science and government, modeling techniques, reentry vehicle testing, strain and pressure. C.D.

A89-27659*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MINIATURIZED COMPACT WATER-COOLED PITOT-PRESSURE PROBE FOR FLOW-FIELD SURVEYS IN HYPERSONIC WIND TUNNELS
GEORGE C. ASHBY (NASA, Langley Research Center, Hampton, VA) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 159-166. refs
An experimental investigation of the design of pitot probes for flowfield surveys in hypersonic wind tunnels is reported. The results show that a pitot-pressure probe can be miniaturized for minimum interference effects by locating the transducer in the probe support body and water-cooling it so that the pressure-settling time and transducer temperature are compatible with hypersonic tunnel operation and flow conditions. Flowfield surveys around a two-to-one elliptical cone model in a 20-inch Mach 6 wind tunnel using such a probe show that probe interference effects are essentially eliminated. C.D.

A89-27661
FIBER OPTIC TORQUEMETER DESIGN AND DEVELOPMENT
R. E. RUDD, B. R. KLINE, F. G. HOFF, and W. B. SPILLMAN, JR. (Hercules Aerospace Co., Aircraft Systems Div., Vergennes, VT) IN: International Instrumentation Symposium, 34th, Albuquerque, NM, May 2-6, 1988, Proceedings. Research Triangle Park, NC, Instrument Society of America, 1988, p. 199-204.
An optical torque measurement system has been developed that provides an accurate measurement of angular deflection over a known length of a torsionally loaded rotating shaft. The main advantages of this configuration, as compared to a conventional electromechanical system, are EMI immunity, reference sleeve elimination, and dc operation. Independent optical measurements of shaft speed are compared in phase. Shaft torque can then be computed from knowledge of phase difference and shaft spring constant in subsequent signal processing. System accuracy of 0.005 deg was demonstrated using a prototype device that had an operating range of + or - 15 deg of relative shaft twist. Author

A89-27692#
EFFECTS OF A DOWNSTREAM DISTURBANCE ON THE STRUCTURE OF A TURBULENT PLANE MIXING LAYER
M. M. KOOCHESFAHANI and P. E. DIMOTAKIS (California Institute of Technology, Pasadena) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 161-166. Research supported by California Institute of Technology. Previously cited in issue 08, p. 1098, Accession no. A87-22476. refs
(Contract AF-AFOSR-84-0120)

A89-27693*# General Motors Corp., Indianapolis, IN.
EVOLUTION OF PARTICLE-LADEN JET FLOWS - A THEORETICAL AND EXPERIMENTAL STUDY
A. A. MOSTAFA, H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), V. G. MCDONELL, and G. S. SAMUELSEN (California, University, Irvine) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 167-183. Previously cited in issue 20, p. 3220, Accession no. A87-45457. refs
(Contract NAS3-24350)

A89-27744*# National Central Univ., Chung-Li (Taiwan).
TECHNIQUE FOR THE PREDICTION OF AIRFOIL FLUTTER CHARACTERISTICS IN SEPARATED FLOW
JIUNN-CHI WU (National Central University, Chung-Li, Republic of China), L. N. SANKAR (Georgia Institute of Technology, Atlanta), and K. R. V. KAZA (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 2B, p. 664-673) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 168-177. Previously cited in issue 14, p. 2173, Accession no. A87-33719. refs
(Contract NAG3-730)

A89-27745#
ALUMINUM QUALITY BREAKTHROUGH FOR AIRCRAFT STRUCTURAL RELIABILITY
C. R. OWEN, R. J. KEGARISE (Aluminum Company of America, Davenport, IA), and R. J. BUCCI (Alcoa Laboratories, Alcoa Center, PA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 178-184. refs
A statistically designed experiment has been undertaken to evaluate effects of processing on thick plate metal quality. An outgrowth of this program is a breakthrough in quality and resultant property improvements that can be exploited for fatigue and fracture-critical structures. This paper describes the statistical quality control effort, and gives evidence of the improved capabilities typical of recently produced high-quality material. Among conventional mechanical property tests, the smooth fatigue test is shown to be the most discriminating for initial metal quality. Author

A89-27787
PHOTO-BASED THREE DIMENSIONAL GRAPHICS MODELS FOR MULTI-SENSOR SIMULATION
TIM M. WITTENBURG (Honeywell Systems and Research Center, Minneapolis, MN) IN: Recent advances in sensors, radiometry, and data processing for remote sensing; Proceedings of the Meeting, Orlando, FL, Apr. 6-8, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 322-327. Research supported by USAF and Honeywell, Inc.
A methodology has been developed and demonstrated for semiautomated generation of high fidelity terrain databases suitable for flight simulator applications. The technique has been demonstrated using electro-optic (EO), IR, and Synthetic Aperture Radar (SAR) sensor imagery. Extensions of the methodology are described for the generation of sensor image-based representations of vegetation terrain features. In contrast to polygon based databases in use by many simulators today, the simulator databases described here are gridded in nature. Finally, a realtime image generation architecture capable of exploiting this new database technology is currently in development, and is briefly summarized here. Author

A89-28070* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPUTATIONAL PROCEDURE FOR AUTOMATED FLUTTER ANALYSIS
DURBHA V. MURTHY (NASA, Lewis Research Center, Cleveland; Toledo, University, OH) and KRISHNA RAO V. KAZA (NASA, Lewis Research Center, Cleveland, OH) Communications in Applied Numerical Methods (ISSN 0748-8025), vol. 5, Jan. 1989, p. 29-37. refs
A direct solution procedure for computing the flutter Mach number and the flutter frequency is applied to the aeroelastic analysis of propfans using a finite element structural model and an unsteady aerodynamic model based on a three-dimensional subsonic compressible lifting surface theory. An approximation to the Jacobian matrix that improves the efficiency of the iterative process is presented. The Jacobian matrix is indirectly

approximated from approximate derivatives of the flutter matrix, which are updated only in the direction of the last move. Examples are used to illustrate the convergence properties. The direct solution procedure facilitates the automated flutter analysis in addition to contributing to the efficient use of computer time as well as the analyst's time. Author

A89-28210
THE COMPARATIVE ANALYSIS AND DEVELOPMENT OF AN 8000 PSI ROTARY VANE ACTUATOR
MAHMOUD A. ELZANKALY (Hydraulic Units, Inc., Duarte, CA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p.
(SAE PAPER 881435)

A study is described that was initiated to design and develop an 8000-psi rotary actuator which would meet high performance requirements and would have a configuration that would have minimal weight and envelope and be practical for manufacturing. Individual factors considered in the selection of the type of actuator configuration included weight, performance, complexity, reliability, envelope, survivability, maintainability, and stiffness. The results of this study show that the actuator performance depends mainly on the following parameters: the vane sealing system (seal and loading device), the diametrical clearance between the shaft vanes and the housing, the diametrical clearance between the housing vanes and the shaft, the diametrical clearance between bearing and the shaft, and the diametrical clearance between the bearing and the housing. I.S.

A89-28267
T-100 MULTIPURPOSE SMALL POWER UNIT - TECHNOLOGY FOR THE NEXT GENERATION AUXILIARY POWER UNITS
J. C. NAPIER and R. G. THOMPSON (Sundstrand Corp., Sundstrand Turbomach Div., San Diego, CA) IN: Aerospace power systems technology; Proceedings of the Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 115-121. refs
(SAE PAPER 881501)

This paper describes the features and capabilities of the T-100 Mulltipurpose Small Power Unit (MPSPU), an advanced technology gas turbine engine demonstrator sponsored by the U.S. Army. The MPSPU technology is intended to provide an improved acquisition outlook for users of small turbine power units for airborne and vehicular auxiliary power and ground power applications. This will be accomplished by applying the newest existing component technologies for improved performance and designing for versatility so a wide range of applications can be derived from the same frame. Author

A89-28345#
COMBUSTOR AIR FLOW PREDICTION CAPABILITY COMPARING SEVERAL TURBULENCE MODELS
D. L. RHODE (Texas A & M University, College Station) and S. T. STOWERS Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Mar.-Apr. 1989, p. 242-248. refs

A finite-difference computer program with reduced false diffusion was developed for use in an application-oriented study involving axisymmetric swirling flows. A prediction evaluation using four turbulence models was conducted via comparison of predictions with corresponding measurements. Measured inlet values were employed where possible to minimize approximations in specifying inlet boundary conditions. The k-e, algebraic Reynolds stress, and modified algebraic Reynolds stress are the turbulence models used in this investigation. A modified k-e model gave unrealistic results and was eliminated. Reasonable overall agreement with the measurements of mean flow quantities was generally obtained. However, the mean swirl velocity predictions were rather inaccurate. In addition, useful recommendations are given for a numerically stable implementation of an algebraic stress model into the widely used TEACH computing procedure. Author

N89-17069# Air Force Weapons Lab., Kirtland AFB, NM.
FIELD ENHANCEMENT OF UHF-VHF AIRCRAFT ANTENNAS Final Report, 16 Oct. - 18 Nov. 1986
RAYMOND W. NETHERS, DAVID W. METZGER, and ALBERT B. GRIFFIN Aug. 1988 11 p
(AD-A200180; AFWL-TR-88-41) Avail: NTIS HC A03/MF A01 CSCL 09A

Results of high voltage electrical discharge tests of various electrode enhancement geometries are reported along with test conduct. Four antennas (collins, unknown 2- and 3-ft rods) were tested with both positive and negative voltages. It was found that on the negative electrode in large gaps, a large enhancement is needed to degrade the gap holdoff. GRA

N89-17215# Hughes Aircraft Co., El Segundo, CA. Electro-optical and Data Systems Group.
LASER COMMUNICATION TEST SYSTEM Final Report, Sep. 1986 - Sep. 1987
G. S. MECHERLE, A. K. RUE, G. T. POPE, P. T. BENGUHE, and M. A. TWETE Jun. 1988 73 p
(Contract F33615-86-C-1073)
(AD-A199612; AFWAL-TR-88-1042) Avail: NTIS HC A04/MF A01 CSCL 25C

A Hughes-developed laser communication terminal related to aircraft applications was delivered for Air Force testing. The terminals employ laser diode transmitters, PIN diode receivers, and provide automatic tracking with a gimbal-mounted video camera and off-gimbal video tracker. The terminals are capable of 20 Kbps full duplex operation over 8 to 10 miles at sea level. Video tracking offers a legitimate alternative to quadrant tracking. The terminals were modified to provide performance monitors for transmitted signal, received signal, AGC voltage, tracking error, tracker status, and angular position. An automatic acquisition capability with spiral scans was implemented and performed well. GRA

N89-17255# University Coll., London (England). Dept. of Mechanical Engineering.
REVIEW OF EXISTING NDT TECHNOLOGIES AND THEIR CAPABILITIES
LEONARD J. BOND *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 16 p Nov. 1988
Avail: NTIS HC A06/MF A01

A review of selected nondestructive test (NDT) technologies is presented with regard to their reliability and capability to detect and characterize defects in critical aero-engine components such as discs and blisks (integrally bladed discs), both in production and after service. The performance of non-destructive testing is considered both at the time of manufacture and after service for parts fabricated from powder metals including AP1 and with particular consideration given to the needs of the European Fighter Aircraft (EFA). Various NDT technologies have been considered with the aim of establishing the current capability of each technology in terms of defect detection capability and probability of detection rates. The cause of the limits on performance are reviewed and areas where development can be expected in these and other NDT technologies within the next 5 to 10 years have been identified. Author

N89-17256# Pratt and Whitney Aircraft, West Palm Beach, FL. Dept. of Materials Engineering.
RELATIONSHIPS OF NONDESTRUCTIVE EVALUATION NEEDS AND COMPONENT DESIGN
JOHN A. HARRIS, JR. and M. C. VANWANDERHAM *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 8 p Nov. 1988
Avail: NTIS HC A06/MF A01

Several well publicized engine and airframe failures which occurred in the late 1960 to mid 1970's time frame resulted in emphasis on development, application and quantification of nondestructive evaluation (NDE) as opposed to reliance on a Zero Defects design philosophy. As the use of fracture mechanics as a basis for damage tolerance and retirement analysis of components became established, additional emphasis was placed on screened flaw sizes, NDE and quantification of reliability. In the late 1970's a structural assessment was conducted on the design of the F100 engine which resulted in a series of relatively sophisticated safety inspections for selected critical components. The Retirement for Cause philosophy also coupled NDE and component lifing analyses to enable return to service decisions for engine components. These activities were (and are) performed usually after the component designs have been finalized. The establishment of Engine Structural Integrity Programs (ENSIP) for new U.S. military engine systems has now made NDE considerations an integral part of the design process. Classification of components, fracture mechanics analyses, critical flaw sizes, material quality, NDE and quantification of inspection reliability are now incorporated in the initial design process and directly influence the resultant component designs. Statistically based probabilistic approaches are supplementing the deterministic methods previously used. The relationships of NDE needs and component design in light of the evolution of the ENSIP approach for gas turbine engine component designs are discussed. Author

N89-17257# National Research Council of Canada, Ottawa (Ontario). Structures and Materials Lab.
IMPORTANCE OF SENSITIVITY AND RELIABILITY OF NDI TECHNIQUES ON DAMAGE TOLERANCE BASED LIFE PREDICTION OF TURBINE DISCS
A. K. KOUL, A. FAHR, G. GOULD, and N. BELLINGER (Carleton Univ., Ottawa, Ontario) *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 22 p Nov. 1988
Avail: NTIS HC A06/MF A01

The results of a demonstration program carried out to determine the influence of the sensitivity and reliability of nondestructive inspection (NDI) techniques on the damage tolerance based life assessment of aero engine turbine discs are discussed. The program was carried out on the 5th stage compressor discs of the J85-CAN40 engine, made from the AM-355 stainless steel. The sensitivity and reliability of several NDI techniques, in detecting service induced low cycle fatigue (LCF) cracks in the disc bolt hole regions, are assessed on the basis of detectable crack sizes at 90 percent probability of detection (POD) and 90 percent POD with 95 percent confidence level. The NDI techniques examined are the liquid penetrant inspection (LPI) technique, a manual eddy current inspection (ECI) technique using two gain settings and an ultrasonic leaky wave (ULW) technique using an automated C-scan system. The safe inspection intervals (SIIs) for the 5th stage compressor disc are calculated using deterministic fracture mechanics (DFM) and probabilistic fracture mechanics (PFM) principles. These calculations involve the use of the NDI data, finite element analysis and the experimental fatigue crack growth rate (FCGR) data generated on compact tension specimens machined from discs. The results indicate that the manual ECI technique with a high gain setting and the automated ULW technique are the most sensitive and reliable in detecting LCF cracks. Author

N89-17258# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
SHORT TERM DEVELOPMENTS IN NON-DESTRUCTIVE EVALUATION APPLICABLE TO TURBINE ENGINE PARTS [LES DEVELOPPEMENTS A COURT TERME DES CONTROLES NONDESTRUCTIFS APPLICABLES AUX PIECES DE TURBOMACHINES]
J. VAERMAN *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 29 p Nov. 1988 In FRENCH
Avail: NTIS HC A06/MF A01

An analysis of the principles forming the basis of non-destructive evaluation (NDE) techniques is presented. Excitation energy sources, medium interaction (perturbation), and sensors and signal processing are examined. Factors affecting the evolution and adaptation of NDE methods are discussed and recent developments in acoustic microscopy, ultrasonic techniques, Foucault current methods, and X-ray tomography are described. Author

N89-17259# Naval Air Development Center, Warminster, PA.
LONG TERM POSSIBILITIES FOR NONDESTRUCTIVE EVALUATION FOR US NAVY AIRCRAFT
W. R. SCOTT *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 13 p Nov. 1988
Avail: NTIS HC A06/MF A01

The majority of nondestructive inspection (NDI) techniques currently in use for U.S. Navy aircraft are labor intensive, operator dependent and result in excessive aircraft down-time. For this reason NDI R and D efforts currently are directed toward developing rapid automated systems capable of remote or unattended inspection of large areas and inaccessible structures. Ongoing programs of this type that are discussed include laser ultrasonics, acoustic emission, and quantitative imaging. The primary thrust of the presentation will cover the advantages of each technique and the technical obstacles preventing its implementation. Author

N89-17260# Rolls-Royce Ltd., Derby (England). Dept. of Non-Destructive Testing Applications.
NEED FOR COMMON AGARD APPROACH AND ACTIONS
R. G. TAYLOR *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 3 p Nov. 1988
Avail: NTIS HC A06/MF A01

While there is no direct evidence that the different approaches used in nondestructive tests (NDT) have affected airworthiness, there are many pressures, both technical and commercial, for requiring a common approach within the community in the future. The technical pressures arise from a need to achieve the same technical standard of product, irrespective of the place of manufacture, in order to meet the stringent damage tolerance requirements now being placed on NDE, while the commercial pressures arise from the need for industry to rationalize the methodolgy, so that components are processed in the same way, irrespective of the customer. An example of the problems associated with the lack of a common approach, is shown in the differing requirements of the major aero engine manufactures, for the ultrasonic inspection of turbine discs. A study of the physics of the different methods demanded by the engine companies, shows that the same technical standard cannot be achieved, and the commercial problems are obvious when it is recognized that these different techniques are imposed on a common forging supplier. As a result of recent collaboration activities with a number of other engine manufacturers, Rolls-Royce has carried out a survey of the differences that currently exist and these are summarized. Author

N89-17261# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
STATE-OF-THE-ART IN NON-DESTRUCTIVE EVALUATION OF TURBINE ENGINE PARTS [L'ETAT DE L'ART EN CONTROLE NONDESTRUCTIF DES PIECES DE TURBOMACHINE]
J. L. MEIFFREN *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 16 p Nov. 1988 In FRENCH
Avail: NTIS HC A06/MF A01

An overview of non-destructive evaluation (NDE) methods used in aeronautical engineering is presented. The use of NDE during the fabrication of turbine engine components is discussed with particular emphasis on the ultrasonic evaluation of compressor and turbine disks, thickness measurement of turbine blades, and the evaluation of welds in compressor rotors. In addition, the application of NDE techniques to the evaluation of in-service engines is discussed. The detection of fatigue cracks and ruptures in operational engine parts is addressed along with statistical approaches to NDE. Author

N89-17263 Purdue Univ., West Lafayette, IN.
VIBRATION AND AEROELASTIC TAILORING OF ADVANCED COMPOSITE PLATE-LIKE LIFTING SURFACES Ph.D. Thesis
RICHARD Y. L. LIU 1987 199 p
Avail: Univ. Microfilms Order No. DA8814556

Modern flight vehicles are often designed to meet requirements of high structural and aerodynamic performance. One way to attain this objective is to implement the techniques of aeroelastic tailoring. In this work, the lifting surface of a fighter aircraft is structurally idealized as a composite laminated plate element. By modifying the interactions between the surface deformation modes (e.g., bending and twisting), the elastic properties of the anisotropic plate can be controlled to satisfy a specific design criterion. The study is aimed at the conceptual understanding of the effect of elastic coupling upon the dynamic and aeroelastic behavior of a wing. The structural analysis is performed using the Rayleigh-Ritz method. A group of five non-dimensional parameters is identified to characterize the stiffness properties of a laminated plate. Three of these parameters measure the amount of elastic coupling present in the plate, and their influences on the vibration modes (natural frequencies and mode shapes) are evaluated in the vibration analysis. Dissert. Abstr.

N89-17298*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TURBINE ENGINE HOT SECTION TECHNOLOGY, 1987
Oct. 1987 464 p Workshop held in Cleveland, OH, 20-21 Oct. 1987
(NASA-CP-2493; E-3745; NAS 1.55:2493) Avail: NTIS HC A20/MF A01 CSCL 20K

Presentations were made concerning the development of design analysis tools for combustor liners, turbine vanes, and turbine blades. Presentations were divided into six sections: instrumentation, combustion, turbine heat transfer, structural analysis, fatigue and fracture, surface protective coatings, constitutive behavior of materials, stress-strain response and life prediction methods. For individuals titles, see N89-17299 through N89-17337.

N89-17304*# General Motors Corp., Indianapolis, IN. Gas Turbine Div.
AEROTHERMAL MODELING PROGRAM. PHASE 2, ELEMENT B: FLOW INTERACTION EXPERIMENT
M. NIKJOOY, H. C. MONGIA, S. N. B. MURTHY, and J. P. SULLIVAN (Purdue Univ., West Lafayette, IN.) *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 91-99 Oct. 1987
(Contract NAS3-24350)
Avail: NTIS HC A20/MF A01 CSCL 20D

NASA has instituted an extensive effort to improve the design process and data base for the hot section components of gas turbine engines. The purpose of element B is to establish a benchmark quality data set that consists of measurements of the interaction of circular jets with swirling flow. Such flows are typical of those that occur in the primary zone of modern annular combustion liners. Extensive computations of the swirling flows are to be compared with the measurements for the purpose of assessing the accuracy of current physical models used to predict such flows. Author

N89-17311*# United Technologies Research Center, East Hartford, CT.
MEASUREMENT OF AIRFOIL HEAT TRANSFER COEFFICIENTS ON A TURBINE STAGE
ROBERT P. DRING, MICHAEL F. BLAIR, and H. DAVID JOSLYN *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 169-179 Oct. 1987
(Contract NAS3-23717)
Avail: NTIS HC A20/MF A01 CSCL 20D

A combined experimental and analytical program was conducted to examine the impact of a number of variables on the midspan heat transfer coefficients of the three airfoil rows in a one and one-half stage large scale turbine model. Variables included stator/rotor axial spacing, Reynolds number, turbine inlet turbulence, flow coefficient, relevant stator 1/stator 2 circumferential position, and rotation. Heat transfer data were acquired on the suction and pressure surfaces of the three airfoils. High density data were also acquired in the leading edge stagnation regions. Extensive documentation of the steady and unsteady aerodynamics was acquired. Finally, heat transfer data were compared with both a steady and an unsteady boundary layer analysis. Author

N89-17314*# Pratt and Whitney Aircraft, East Hartford, CT.
COOLANT PASSAGE HEAT TRANSFER WITH ROTATION
T. J. HAJEK, J. H. WAGNER, and B. V. JOHNSON (United Technologies Research Center, East Hartford, CT.) *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 211-223 Oct. 1987
(Contract NAS3-23691)
Avail: NTIS HC A20/MF A01 CSCL 20D

The objective is to develop a heat transfer and pressure drop data base, computational fluid dynamic techniques and heat transfer correlations for rotating multipass coolant passages, with and without flow tabulators. The experimental effort is focused on the simulation of configurations and conditions expected in the blades of advanced aircraft high pressure turbines. With the use of this data base, the effects of Coriolis and buoyancy forces on the coolant side flow can be included in the design of turbine blades. Author

N89-17316*# Pratt and Whitney Aircraft, East Hartford, CT.
THREE-DIMENSIONAL INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS
E. S. TODD *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 239-240 Oct. 1987
(Contract NAS3-23697)
Avail: NTIS HC A20/MF A01 CSCL 20K

The objective of this program is to produce a series of new computer codes that permit more accurate and efficient three-dimensional inelastic structural analysis of combustor liners, turbine blades, and turbine vanes. Each code embodies a progression of mathematical models for increasingly comprehensive representation of the geometrical features, loading conditions, and forms of nonlinear material response that distinguish these three groups of hot section components. Author

N89-17329*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
STRUCTURAL RESPONSE OF AN ADVANCED COMBUSTOR LINER: TEST AND ANALYSIS
PAUL E. MOORHEAD, ROBERT L. THOMPSON, M. TONG, and M. HIGGINS (Sverdrup Technology, Inc., Cleveland, OH.) *In its* Turbine Engine Hot Section Technology, 1987 p 349-356 Oct. 1987
Avail: NTIS HC A20/MF A01 CSCL 20K

An advanced (segmented) combustor liner supplied by Pratt and Whitney Aircraft was tested in the structural component test rig at Lewis Research Center. It was found that the segmented liner operated at much lower temperatures than the conventional liner (about 400 F lower) for the same heat flux. At the lower temperatures and low thermal gradients, little distortion to the segments was observed. The operating conditions were not severe enough to distort or damage the segmented liner. Author

N89-17333*# Pratt and Whitney Aircraft, East Hartford, CT.
THERMAL BARRIER COATING LIFE PREDICTION MODEL DEVELOPMENT
J. T. DEMASI, S. L. MANNING, M. ORTIZ, and K. D. SHEFFLER *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 385-399 Oct. 1987
(Contract NAS3-23944)
Avail: NTIS HC A20/MF A01 CSCL 20K

The objectives of this program are to increase understanding of thermal barrier coating (TBC) degradation and failure modes, to generate quantitative ceramic failure life data under cyclic thermal conditions which simulate those encountered in gas turbine engine service, and to develop an analytical methodology for prediction of coating life in the engine. Observations of degradation and failure modes in plasma deposited ceramic indicate that spallation failure results from progressive cracking of the ceramic parallel to and adjacent to, but not coincident with the metal-ceramic interface. Author

N89-17336*# Pratt and Whitney Aircraft, East Hartford, CT.
CREEP FATIGUE LIFE PREDICTION FOR ENGINE HOT SECTION MATERIALS (ISOTROPIC) FIFTH YEAR PROGRESS REVIEW
RICHARD S. NELSON and PETER R. HARVEY *In* NASA, Lewis Research Center, Turbine Engine Hot Section Technology, 1987 p 423-434 Oct. 1987
(Contract NAS3-23288)
Avail: NTIS HC A20/MF A01 CSCL 20K

The need for advanced life prediction methods for hot section components for gas turbine engines is becoming more and more evident. The complex local strain and temperature histories at critical locations must be accurately interpreted to account for the effects of various damage mechanisms and their possible interactions. This program is designed to investigate these fundamental damage processes, identify modeling strategies, and develop practical models which can be used to guide the early design and development of new engines and to increase the durability of existing engines. Author

N89-17700# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Airplane Div.
MECHANISM OF SINGLE SHEAR FASTENED JOINTS
J. BAUER *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 6 p Mar. 1988
Avail: NTIS HC A14/MF A01

The problems arising with the strength of single shear fastened joints are considerably greater than those of double shear joints. The additional (or secondary) bending moment loads not only the cover plates, but also causes considerably bending in the fasteners. If one of the cover plates is of composite material its brittleness and relatively low bearing strength lead to new problems. Experimental data were produced with a 100 percent load transfer specimen using a carbon fiber reinforced plastic (CFRP) to metal joint. Taking the specimen configuration as a basis, the interaction of bolt bending and local load introduction into the two plates is shown in form of diagrams based on theoretical investigations. Author

13

GEOSCIENCES

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

A89-25549*# Computer Sciences Corp., Huntsville, AL.
ANALYSIS OF EXTREME WIND SHEAR
STANLEY I. ADELFANG and ORVEL E. SMITH (Computer Sciences Corp., Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. Research supported by NASA.
(AIAA PAPER 89-0710)

New methods utilizing extreme value statistical theory are applied in the analysis of the largest wind component shear in a wind profile as a function of shear layer thickness and season. Seasonal variability of extreme shear decreases as the shear layer thickness decreases. Wind profile measurement system smoothing and its effect upon extreme wind shear statistics is simulated by application of digital low-pass filters to Jimsphere wind profiles. Author

A89-25562#
USE OF THE MEDIAN VOLUME DROPLET DIAMETER IN THE CHARACTERIZATION OF CLOUD DROPLET SPECTRA
KAREN J. FINSTAD, EDWARD P. LOZOWSKI (Alberta, University, Edmonton, Canada), and LASSE MAKKONEN (Technical Research Centre of Finland, Espoo) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 5 p. Research supported by NSERC, Finnish Broadcasting Co., Imatran Voima Co., and Finnish Post and Telecommunications Administration. refs
(AIAA PAPER 89-0756)

A mathematical justification is presented for using the median volume diameter (MVD) to calculate the collision efficiency or liquid water content of a spectrum of cloud droplet sizes. The MVD is derived from a single-point numerical integration formula, which can be extended to derive approximation formulas using 2-4 droplet sizes. The spectrum weighted average collision efficiences for circular cylinders and NACA 0015 airfoils are calculated from several droplet size spectra (Finstad et al., 1986). The results are in good agreement with those using the MVD. It is shown that the MVD schemes introduced significantly improve accuracy. R.B.

A89-25578#
NATIONAL LIGHTNING DETECTION - A REAL-TIME SERVICE TO AEROSPACE
KENNETH G. BAUER, WALTER A. LYONS, NOEL J. PETIT, and JEROME A. SCHUH (R-Scan Corp., Minneapolis, MN) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p.
(AIAA PAPER 89-0787)

The National Lightning Detection Network (NLDN), which combines time-of-arrival lightning detection technology and computer resources to locate and track lightning, is examined. The importance of lightning detection for the aerospace community is reviewed. The network uses the time-of-arrival technology described by Casper et al. (1988). The products available from the Lightning Data and Information System, which distributes data from the NLDN are discussed, including the real-time location, time, and polarity of observed lightning strokes. R.B.

A89-25583#
SEVERE WEATHER - IMPACT ON AVIATION AND FAA PROGRAMS IN RESPONSE
ERIC MANDEL (FAA, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(AIAA PAPER 89-0794)

The involvement of the FAA in programs to improve the acquisition, synthesis, and dissemination of weather data to lessen the impact of severe weather on aviation operations is reviewed. The programs considered include the Automated Surface Observing Systems, the Low Level Wind Shear Alert System, the Terminal Doppler Weather Radar, and the Next Generation Weather Radar. In addition, the development of improved forecasting techniques is examined, including programs such as the Center and Central Flow Weather Service Units, the Meteorologist Weather Processor, the Real-Time Weather Processor, data links, flight service automation, and the Advanced Automation System for air traffic controllers. R.B.

A89-25593#
THE EFFECT OF A GROUND-BASED INVERSION LAYER ON AN IMPACTING MICROBURST
J. W. YOUNG, III, F. D. LANE (Colorado, University, Boulder), and A. J. BEDARD, JR. (NOAA, Wave Propagation Laboratory, Boulder, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0810)

A scaled water tank experiment was performed in order to investigate the microburst interaction with stable layers, with special attention given to the influence of the ground-based inversion on the impacting microburst. A buoyant puff equation is used to predict the path a particle will take when it interacts with an inversion interface. The results suggest that microburst events can be more complex, and possibly more dangerous, when strong inversion layers are involved. R.R.

A89-25594#
AN UNSTEADY VORTEX-RING MODEL FOR MICROBURST SIMULATION
TUNG WAN (California Polytechnic State University, San Luis Obispo) and FRED R. PAYNE (Texas, University, Arlington) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0811)

A microburst, or low-level wind shear, is generated by a thunderstorm or a small rain cloud, and presents hazardous condition for aircraft during take-off and landing maneuvers. An unsteady vortex-ring model of microburst is developed by first solving the trajectory equations via the DFI or Runge-Kutta methods, then the velocity field can be computed by using the primary and image inviscid vortex-ring equations in the outer region and the assumed profile in the viscous region. Also, the boundary layer profiles are added to the mean flow field. Results show that this model can produce physically realistic transient velocity profiles, and the CPU time of this model is efficient enough for real time flight simulation. Author

A89-25599#
NUMERICAL SIMULATION OF MICROBURST DOWNDRAFTS - APPLICATION TO ON-BOARD AND LOOK AHEAD SENSOR TECHNOLOGY
KELVIN K. DROEGEMEIER and MICHAEL R. BABCOCK (Oklahoma, University, Norman) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(Contract NSF ATM-87-57013)
(AIAA PAPER 89-0821)

The subcloud structure of microburst downdrafts is simulated using a high-resolution, multidimensional numerical cloud model. The morphology of severe downflows in a variety of scenarios is studied by systematically varying the prescribed rainwater content of the microburst. Aircraft trajectories through the evolving model fields are constructed to provide guidance for the development of on-board windshear detection systems. The relationship of meterological conditions along the flight path to variations in time, location and speed of penetration is examined by systematically varying flight parameters. A measurable drop in air temperature at the aircraft location occurred in conjunction with an increasing headwind, but prior to the onset of performance-deteriorating tailwinds. It is found that the magnitude of meteorlogical variables measured at the aircraft location during descent are a function of the flight path relative to the microburst in some cases. R.B.

A89-26214* National Severe Storms Lab., Norman, OK.
LIGHTNING INITIATION ON AIRCRAFT IN THUNDERSTORMS
VLADISLAV MAZUR (NOAA, National Severe Storms Laboratory, Norman, OK) IN: International Conference on Atmospheric Electricity, 8th, Uppsala, Sweden, June 13-16, 1988, Proceedings. Uppsala, Sweden, Institute of High Voltage Research, 1988, p. 347-356. Research supported by NASA. refs

A physical model of the initiation of lightning flashes by aircraft in thunderstorms is presented. The model is based on the 'bidirectional uncharged leader' concept of Kasemir, and is verified with airborne data from lightning strikes to instrumented airplanes (NASA F-106B and FAA CV-580). A triggered flash starts with either a negative corona or a positive leader that depends on the ambient electric field vector and the airplane form factor. The positive leader with continuous current that increases with time is followed in several milliseconds by the negative stepped leader with current pulses of several kA. The two leaders develop in space simultaneously and bidirectionally from the oppositely charged extremities of the airplane. Author

A89-26215
LIGHTNING TRIGGERED BY THE PRESENCE OF AEROSPACE VEHICLES
RODNEY A. PERALA and TERENCE H. RUDOLPH (Electro Magnetic Applications, Inc., Lakewood, CO) IN: International Conference on Atmospheric Electricity, 8th, Uppsala, Sweden, June 13-16, 1988, Proceedings. Uppsala, Sweden, Institute of High Voltage Research, 1988, p. 363-370. refs

The triggering of lightning by in-flight vehicles is investigated. Specific attention is placed on the NASA F-106B Thunderstorm Research Aircraft. Thunderstorm and vehicle parameters relevant to triggered lightning initiation are identified. A numerical simulation technique using finite difference techniques and an air chemistry model is applied to triggered lightning events. Results from this model's use in the F-106B program are shown and compared to measured data from actual lightning strikes to the aircraft. Conditions under which the F-106B triggers lightning are presented. Finally, questions still unresolved in the physics of triggered lightning are identified. Author

A89-28461#
IMPACT OF SEVERE WEATHER ON AVIATION - A PILOT VIEWPOINT
DON S. CORNWELL (Air Line Pilots Association, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 4 p.
(AIAA 89-0798)

The impact of severe weather avoidance on pilots and the safe operation of an aircraft in severe weather are discussed. The problems caused by fog and low ceiling are considered and airborne and ground deicing procedures are reviewed. Also, the impact of thunderstorms and windshear are examined. It is suggested that the problem of deicing aircraft might be solved by placing deicing stations near the end of the runway and spraying the aircraft just prior to take-off. R.B.

N89-17978 Wyoming Univ., Laramie.
THE MEASUREMENT OF TEMPERATURE FROM AN AIRCRAFT IN CLOUD Ph.D. Thesis
R. PAUL LAWSON 1988 363 p
Avail: Univ. Microfilms Order No. DA8817691

The problem of wetting of thermometers used in research aircraft in cloud and precipitation has been previously recognized. Recently, a prototype radiometric thermometer became available for aircraft use which makes possible comprehensive evaluation of the immersion thermometers. This radiometer measures brightness temperature at 4.25 micron wavelength. At this wavelength, the fairly short path length and fast response of the sensing technique, makes comparisons with the immersion sensors meaningful. Based upon insights obtained in this research, a new immersion thermometer was designed to overcome the problems with the conventional sensors. The design is based upon the principle of inertial separation of the water, and allows predictable response characteristics. Preliminary tests show that water does not reach the sensing element. Dissert. Abstr.

15

MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A89-25305#
EFFICIENT APPLICATION TECHNIQUES OF THE EAGLE GRID CODE TO COMPLEX MISSILE CONFIGURATIONS
JOE F. THOMPSON, BOYD GATLIN (Mississippi State University, Mississippi State), and LAWRENCE E. LIJEWSKI (USAF, Armament

Laboratory, Eglin AFB, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 19 p. refs
(Contract F08635-84-C-02281)
(AIAA PAPER 89-0361)

New features incorporated in the 1988 version of the EAGLE algebraic/elliptic grid generation code are discussed, and examples of techniques of application to complex aircraft configurations are given. These new features allow changes in parameters to be localized, removing the need for corresponding changes throughout the input runstream. Applications to multiple-store configurations are shown. Author

A89-25310*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE DESIGN AND APPLICATION OF UPWIND SCHEMES ON UNSTRUCTURED MESHES
TIMOTHY J. BARTH and DENNIS C. JESPERSEN (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0366)

Solution and mesh generation algorithms for solving the Euler equations on unstructured meshes consisting of triangle and quadrilateral control volumes are presented. Cell-centered and mesh-vertex upwind finite-volume schemes are developed which utilize multi-dimensional monotone linear reconstruction procedures. These algorithms differ from existing algorithms (even on structured meshes). Numerical results in two dimensions are presented. Author

A89-25385*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
TWO-DIMENSIONAL EULER COMPUTATIONS ON A TRIANGULAR MESH USING AN UPWIND, FINITE-VOLUME SCHEME
D. L. WHITAKER, B. GROSSMAN (Virginia Polytechnic Institute and State University, Blacksburg, VA), and R. LOHNER (U.S. Navy, Naval Research Laboratory, Washington, DC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(Contract NAG1-776)
(AIAA PAPER 89-0470)

A numerical procedure was developed for the finite-volume solution of the Euler equations on unstructured triangular meshes based on a flux-difference split upwind method. Techniques for implementing Roe's (1985) approximate Reimann solver together with the preprocessing MUSCL differencing on unstructured grids are presented. Applications and comparisons with structured grid problems are carried out for a supersonic shock reflection problem, the supersonic flow over a blunt body, the transonic flow over NACA 0012 and RAE 2822 airfoils, and the flow about a double element Karman-Trefftz airfoil. K.K.

A89-25870
ON A DISTRIBUTED PARAMETER MODEL FOR DETECTING CRACKS IN A ROTOR
ROBERTO ARAYA (Universidad de Chile, Santiago) IN: International Conference on Advances in Communication and Control Systems, 1st, Washington, DC, June 18-20, 1987, Proceedings. New York, Optimization Software, Inc., 1988, p. 73-81.

The dynamic behavior of a cracked rotor is modeled analytically as a three-dimensional parameter-identification problem, extending and refining the results obtained by Davies and Mayes (1984) using a slotted-beam model. Expressions for the Green function, the frequency spectrum, and the variation of the fundamental frequencies are derived on the basis of three parameters (the crack width, the crack position, and the ratio of the polar moments of the rotor and the cracked area). The feasibility of detecting rotor cracks by applying this torsional-beam model to vibration data is discussed. T.K.

A89-26038
MODAL CONTROL IN SYSTEMS WITH AFTEREFFECT [MODAL'NOE UPRAVLENIE V SISTEMAKH S POSLEDEISTVIEM]
V. M. MARCHENKO Avtomatika i Telemekhanika (ISSN 0005-2310), Nov. 1988, p. 73-83. In Russian. refs

For linear stationary systems with many delays, effective necessary and sufficient conditions are determined for modal controllability in a class of linear controllers with control and state delays. The relationship between problems of modal and point control is clarified. The problem of modal control in systems with incomplete information is analyzed, and a flight control problem is examined as an example. V.L.

A89-26187
AN H(INFINITY) METHOD FOR THE DESIGN OF LINEAR TIME-INVARIANT MULTIVARIABLE SAMPLED-DATA CONTROL SYSTEMS
JIANN-SHIOU YANG and WILLIAM S. LEVINE (Maryland, University, College Park) IN: Analysis and optimization of systems; Proceedings of the Eighth International Conference, Juan-les-Pins, France, June 8-10, 1988. Berlin and New York, Springer-Verlag, 1988, p. 89-100. refs
(Contract NSF OIR-85-00108)

A procedure by which H(infinity) methods can be used to design a MIMO control system is described. A procedure to approximate the nearly optimal H(infinity) controller with a lower-order controller. These techniques are then used to produce a controller for a benchmark control problem. This controller, a version of the pitch axis control of the F-14 aircraft, is then compared with a design produced using LQ techniques and with a design using Delight. C.D.

A89-26196
AN ALTERNATIVE METHOD TO SOLVE A VARIATIONAL INEQUALITY APPLIED TO AN AIR TRAFFIC CONTROL EXAMPLE
GERARD B. M. HEUVELINK and HENK A. P. BLOM (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Analysis and optimization of systems; Proceedings of the Eighth International Conference, Juan-les-Pins, France, June 8-10, 1988. Berlin and New York, Springer-Verlag, 1988, p. 617-628. refs

Some important problems of air traffic control, such as collision avoidance, can mathematically be formuated as problems of optimal stopping a diffusion. An optimal stopping policy can be characterized by a Variational Inequality (VI). To compute the solution of such a VI, a new iteration scheme is developed. The simplicity of this scheme is explicitly due to the assumption that the cost of stopping is a sufficiently smooth function of the state, which often holds for stopping problems. The scheme is applied to a simple example of air traffic control. Author

A89-27405
DETERMINATION OF THE NUMERICAL INTEGRATION STEP DURING THE ANALOG-DIGITAL MODELING OF DYNAMIC SYSTEMS [OPREDELENIE SHAGA CHISLENNOGO INTEGRIROVANIIA PRI ANALOGO-TSIFROVOM MODELIROVANII DINAMICHESKIKH SISTEM]
ARKADII S. SHALYGIN and OLEG E. SLAVIANSKII (Leningradskii Mekhanicheskii Institut, Leningrad, USSR) Elektronnoe Modelirovanie (ISSN 0204-3572), vol. 11, Jan.-Feb. 1989, p. 84-88. In Russian. refs

A procedure for selecting the step and method of numerical integration is proposed which is based on the analysis of the total error and its approximation by an analytical relation. Computations are distributed between analog and digital processors by introducing reference traffic and using the linearization method. Equations of flight dynamics are considered as an example of a nonlinear nonstationary system. V.L.

A89-27602* Tennessee Univ., Tullahoma.
PATTERN-BASED FAULT DIAGNOSIS USING NEURAL NETWORKS

W. E. DIETZ, E. L. KIECH, and M. ALI (Tennessee, University, Tullahoma) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 13-23. refs
(Contract NAGW-1195)

An architecture for a real-time pattern-based diagnostic expert system capable of accommodating noisy, incomplete, and possibly erroneous input data is outlined. Results from prototype systems applied to jet and rocket engine fault diagnosis are presented. The ability of a neural network-based system to be trained via the presentation of behavioral patterns associated with fault conditions is demonstrated. K.K.

A89-27609* Bolt, Beranek, and Newman, Inc., Cambridge, MA.
INTEGRATING CAUSAL REASONING AT DIFFERENT LEVELS OF ABSTRACTION
EVA HUDLICKA and KEVIN CORKER (BBN Laboratories, Inc., Cambridge, MA) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 157-163. Research supported by BBN Laboratories, Inc. refs
(Contract NAS1-17335)

In this paper, a problem-solving system which uses a multilevel causal model of its domain is described. The system functions in the role of a pilot's assistant in the domain of commercial air transport emergencies. The model represents causal relationships among the aircraft subsystems, the effectors (engines, control surfaces), the forces that act on an aircraft in flight (thrust, lift), and the aircraft's flight profile (speed, altitude, etc.). The causal relationships are represented at three levels of abstraction: Boolean, qualitative, and quantitative, and reasoning about causes and effects can take place at each of these levels. Since processing at each level has different characteristics with respect to speed, the type of data required, and the specificity of the results, the problem-solving system can adapt to a wide variety of situations. The system is currently being implemented in the KEE(TM) development environment on a Symbolics Lisp machine. Author

A89-27611
AN APPLICATION OF HEURISTIC SEARCH TECHNIQUES TO THE PROBLEM OF FLIGHT PATH GENERATION IN A MILITARY HOSTILE ENVIRONMENT
VERLYNDA S. DOBBS, HENRY W. DAVIS, and CARL LIZZA (Wright State University, Dayton, OH) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 273-280. refs
(Contract F49620-85-C-0013)

The effectiveness of heuristic search algorithms in generating flight paths is studied. The execution speed and solution quality are of particular importance due to the need to generate and revise paths dynamically. Extensive tests were carried out with three search algorithms in a simple threat model. On the basis of straight-forward heuristics, it is found that the A-asterisk algorithm and a bidirectional search perform well when their weights are appropriately adjusted. K.K.

A89-27614
FLIGHT MISSION SCENARIO GENERATION WITH KNOWLEDGE-BASED SYSTEM
SOWMYAN RAMAN (Boeing Computer Services, Seattle, WA) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 341-346.

The paper discusses the development and current status of ScenGen (flight mission scenario generator), a prototype knowledge-based expert system. The objective of ScenGen is to develop a full mission scenario for a given flight plan. The user input consists of the scenario type, aircraft model, crew member, and flight plan. The production system will shorten the crew workload analysis time in the evaluation of flight deck design. In effect, it will facilitate workload analysis time in the evaluation of flight deck design. K.K.

A89-27618
APPLICATIONS OF AN AI DESIGN SHELL ENGINEOUS TO ADVANCED ENGINEERING PRODUCTS
CAROL J. RUSSO (General Electric Co., Aircraft Engine Business Group, Lynn, MA) and DAVID J. POWELL (General Electric Co., Schenectady, NY) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 413-420.

This paper describes the most recent work on developing ENGINEOUS, an Artificial Intelligent (AI) shell that automates the iteration of existing analysis codes to produce designs that are optimized for multiple requirements. ENGINEOUS is product independent and has been applied to the design of advanced turbomachinery components for jet engines and electric motors among others. Initial productivity improvements of factors of 5-10 have been demonstrated. Author

A89-27622* Tennessee Univ., Tullahoma.
HIERARCHICAL REPRESENTATION AND MACHINE LEARNING FROM FAULTY JET ENGINE BEHAVIORAL EXAMPLES TO DETECT REAL TIME ABNORMAL CONDITIONS
U. K. GUPTA and M. ALI (Tennessee, University, Tullahoma) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 2. Tullahoma, TN, University of Tennessee, 1988, p. 710-720. refs
(Contract NAGW-1195)

The theoretical basis and operation of LEBEX, a machine-learning system for jet-engine performance monitoring, are described. The behavior of the engine is modeled in terms of four parameters (the rotational speeds of the high- and low-speed sections and the exhaust and combustion temperatures), and parameter variations indicating malfunction are transformed into structural representations involving instances and events. LEBEX extracts descriptors from a set of training data on normal and faulty engines, represents them hierarchically in a knowledge base, and uses them to diagnose and predict faults on a real-time basis. Diagrams of the system architecture and printouts of typical results are shown. T.K.

A89-27623
MLS, A MACHINE LEARNING SYSTEM FOR ENGINE FAULT DIAGNOSIS
MIN KE and M. ALI (Tennessee, University, Tullahoma) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 2. Tullahoma, TN, University of Tennessee, 1988, p. 721-727.

The design and operation of MLS, a machine-learning system for jet-engine performance monitoring and fault prediction, are discussed. The behavior of the engine is modeled in terms of four parameters (the rotational speeds of the high- and low-speed sections and the exhaust and combustion temperatures). Data on these parameters are preprocessed and transformed into relational statements involving instances and events (the faults considered being fuel interruption and bearing failure). The MLS algorithm itself employs an inductive learning method similar to STAR (Michalsky, 1983); the preference criteria, the generalization rules, the use of domain knowledge to guide the learning process, and the generation of concept descriptions are characterized. T.K.

A89-27629
APPLYING EVIDENTIAL REASONING TO AVIONICS TROUBLESHOOTING
ASDRUBAL GARCIA-ORTIZ and PATRICIA A. CUNDIFF (Emerson Electric Co., Electronics and Space Div., Saint Louis, MO) IN:

International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 2. Tullahoma, TN, University of Tennessee, 1988, p. 940-945. Research supported by Emerson Electric Co. and Automatic Test Equipment Directorate. refs

The applicability of Dempster-Schafer evidential-reasoning theory (DSERT, an extension of Bayesian probability theory) to knowledge-based systems for avionics diagnostics is considered analytically. The current status of avionics maintenance problems is surveyed; the fundamental principles of DSERT are reviewed; and results from a sample application of DSERT (using simulated data from BIT and Failure Modes and Effects Analysis as the primary sources of evidence) are presented in tables and graphs. DSERT is shown to improve the diagnostic process by combining information from different sources and providing meaningful responses even when the limitations of the knowledge base are exceeded. T.K.

A89-28215
RELIABLE INFORMATION FROM ENGINE PERFORMANCE MONITORING
D. A. FRITH (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p. refs
(SAE PAPER 881444)

The use of uncertainty analysis in assessing aircraft engine performance during the system design stage provides reliable information for engine maintenance. An engine performance monitoring system in operation represents a dynamic situation, since information on the engine type is being continually acquired. The system should adapt to this changing situation if it is to maximize the use of the information obtained to indicate engine condition. Two design examples, the test cell system and the on-wing system, are discussed. A.A.F.

A89-28217
SUPPORTABILITY DESIGN REQUIREMENTS FOR ARMY AIRCRAFT AND EQUIPMENT
RAYMOND J. DROLL (Grumman Corp., Grumman Aircraft Systems Div., Bethpage, NY) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 8 p.
(SAE PAPER 881447)

Design requirements for the tactical aircraft, vehicles, and equipment of the U.S. Army are determined primarily by the existing support structure, operational doctrine and the operating environments. The support structure is based on high-frequency on-aircraft maintenance tasks; aviation intermediate, and depot maintenance. Operational doctrine describes how aircraft and equipment will be used to emphasize worldwide deployment and maneuver as a combat multiplier. The operational environments include climatic extremes and operating requirements. The design approach must emphasize easy operation and maintenance of equipment, and minimization of operating and support resources. A.A.F.

A89-28382
PHASE-ONLY FILTERS WITH IMPROVED SIGNAL TO NOISE RATIO
B. V. K. VIJAYA KUMAR and ZOUHIR BAHRI (Carnegie-Mellon University, Pittsburgh, PA) Applied Optics (ISSN 0003-6935), vol. 28, Jan. 15, 1989, p. 250-257. refs

The notion of optimal phase-only filters (OPOFs) that yield improved SNRs is introduced. The improvement in SNR resulting from the use of OPOFs is illustrated with the help of several analytical examples and simulation results. Author

N89-18046*# Illinois Univ., Urbana-Champaign. Coordinated Science Lab.
IMPACT OF DEVICE LEVEL FAULTS IN A DIGITAL AVIONIC PROCESSOR
HO KIM SUK Jan. 1989 55 p
(Contract NAG1-602)
(NASA-CR-184783; NAS 1.26:184783; UILU-ENG-89-2210; CSG-99) Avail: NTIS HC A04/MF A01 CSCL 09B

This study describes an experimental analysis of the impact of gate and device-level faults in the processor of a Bendix BDX-930 flight control system. Via mixed mode simulation, faults were injected at the gate (stuck-at) and at the transistor levels and, their propagation through the chip to the output pins was measured. The results show that there is little correspondence between a stuck-at and a device-level fault model, as far as error activity or detection within a functional unit is concerned. In so far as error activity outside the injected unit and at the output pins are concerned, the stuck-at and device models track each other. The stuck-at model, however, overestimates, by over 100 percent, the probability of fault propagation to the output pins. An evaluation of the Mean Error Durations and the Mean Time Between Errors at the output pins shows that the stuck-at model significantly underestimates (by 62 percent) the impact of an internal chip fault on the output pins. Finally, the study also quantifies the impact of device fault by location, both internally and at the output pins. Author

16

PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A89-26630* Iowa Univ., Iowa City.
MERGING OF AIRCRAFT VORTEX TRAILS - SIMILARITIES TO MAGNETIC FIELD MERGING
DONALD A. GURNETT (Iowa, University, Iowa City) Geophysical Research Letters (ISSN 0094-8276), vol. 16, Jan. 1989, p. 17-20. refs
(Contract NGL-16-001-043)

This paper discusses the phenomenological and formal similarities between the merging of aircraft vortex trails and the merging of magnetic field lines in a plasma. High-resolution photographs are shown of smoke trails from the wing tips of an airplane. These photographs show that the two vortex trails merge together downstream of the aircraft in a way similar to the merging of oppositely directed magnetic field lines in a plasma. Although there are some differences, this correspondence is apparently related to the fact that the vorticity equation in a fluid has the same mathematical form as the magnetic field equation in an MHD plasma. In both cases the merging proceeds at a rate considerably faster than would be predicted from classical estimates of the viscosity and resistivity. The enhanced merging rate in the fluid case appears to result from turbulence that increases the diffusion rate in the merging region. Author

A89-27741#
SOURCE LOCALIZATION TECHNIQUE FOR IMPULSIVE MULTIPLE SOURCES
D. BLACODON, M. CAPLOT, and G. ELIAS (ONERA, Chatillon-sous-Bagneux, France) Journal of Aircraft (ISSN 0021-8669), vol. 26, Feb. 1989, p. 154-156. Previously cited in issue 04, p. 571, Accession no. A88-16579. refs

N89-18167*# Cornell Univ., Ithaca, NY. School of Mechanical and Aerospace Engineering.
HELICOPTER TAIL ROTOR BLADE-VORTEX INTERACTION NOISE Final Technical Report, 1 Feb. 1986 - 31 Mar. 1987
ALBERT R. GEORGE and S.-T. CHOU Mar. 1987 28 p
(Contract NAG2-379)
(NASA-CR-183178; NAS 1.26:183178) Avail: NTIS HC A03/MF A01 CSCL 20A

A study is made of helicopter tail rotor noise, particularly that due to the interactions with main rotor tip vortices. Summarized here are present analysis, the computer codes, and the results of several test cases. Amiet's unsteady thin airfoil theory is used to calculate the acoustics of blade-vortex interaction. The noise source is modelled as a force dipole resulting from an airfoil of infinite span chopping through a skewed line vortex. To analyze the interactions between helicopter tail rotor and main rotor tip vortices, we developed a two-step approach: (1) the main rotor tip vortex system is obtained through a free wake geometry calculation of the main rotor using CAMRAD code; (2) acoustic analysis takes the results from the aerodynamic interaction analysis and calculates the farfield pressure signatures for the interactions. It is found that under a wide range of helicopter flight conditions, acoustic pressure fluctuations of significant magnitude can be generated by tail rotors due to a series of interactions with main rotor tip vortices. This noise mechanism depends strongly on the helicopter flight conditions and the relative location and phasing of the main and tail rotors. fluctuations of significant magnitude can be generated by tail rotors due to a series of interactions with main rotor tip vortices. This noise mechanism depends strongly upon the helicopter flight conditions and the relative location and phasing of the main and tail rotors. Author

17

SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

A89-25513#
AIRCRAFT DESIGN EDUCATION AT NORTH CAROLINA STATE UNIVERSITY
J. N. PERKINS, R. J. VESS (North Carolina State University, Raleigh), and R. A. MITCHELTREE AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p.
(AIAA PAPER 89-0649)

This paper discusses one of the senior year design programs in Aerospace Engineering at North Carolina State University. The objectives, organization, and management of the final year group projects in aircraft design are described. Emphasis is placed on introducing some of the real world into the course by requiring the students to build and fly, by remote means, a scaled model of their design. Details of the design activities, construction techniques, and flight testing are discussed. Author

A89-26665
THE LAW: THE PILOT AND THE AIR TRAFFIC CONTROLLER - DIVISION OF RESPONSIBILITIES
HENK GEUT (Vereniging voor Nederlandse Verkeersvliegers, Amstelveen, Netherlands) Air Law (ISSN 0165-2079), vol. 13, Dec. 1988, p. 256-267. refs

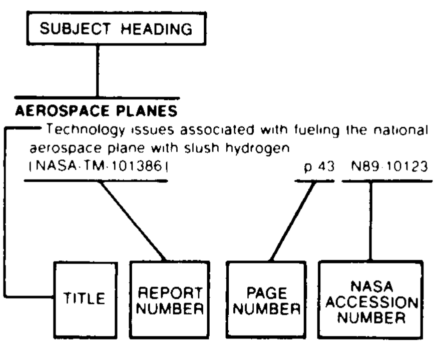
The question of whether the pilot or the air traffic controller is responsible for the operation and safety of a flight is discussed. The duties of a pilot and an air traffic controller are reviewed. It is found that the law does not give a clear division of responsibilities. Several cases are examined, showing that the responsibility depends on the circumstances of each individual case. It is concluded that there is an interrelation between the duties of the pilot and the controller and that both are responsible for the safe operation of a flight. R.B.

A89-26666
SOME CONSIDERATIONS ON THE LIABILITY OF AIR TRAFFIC CONTROL AGENCIES
KIM DOO HWAN (Soong Jun University, Seoul, Republic of Korea) Air Law (ISSN 0165-2079), vol. 13, Dec. 1988, p. 268-272.

International law concerning the liability of air traffic control agencies is reviewed. Studies by the Legal Committee of ICAO are considered. The governmental agencies which control air traffic control in several countries are examined, including France, the U.S., the UK, West Germany, Japan, and Korea. It is suggested that rules concerning the air traffic control systems of various countries should be unified. R.B.

SUBJECT INDEX

Typical Subject Index Listing



The subject heading is a key to the subject content of the document. The title is used to provide a description of the subject matter. When the title is insufficiently descriptive of document content, a title extension is added, separated from the title by three hyphens. The (NASA or AIAA) accession number and the page number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document. Under any one subject heading, the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

A

B

D

E

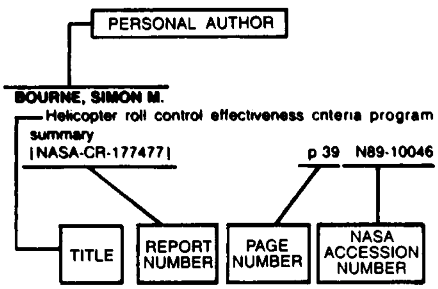
N

O

S

W

Typical Personal Author Index Listing



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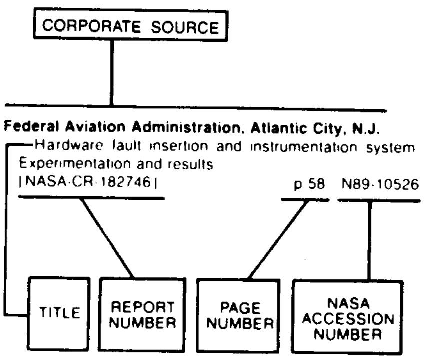

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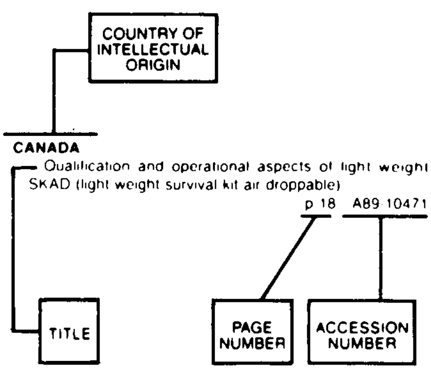

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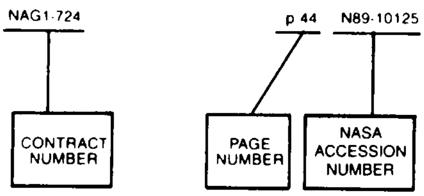

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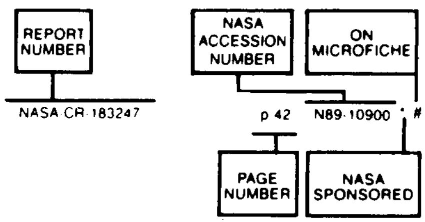

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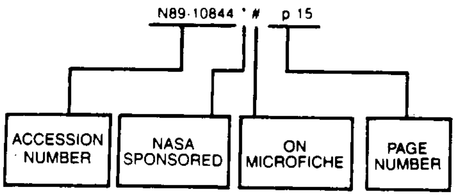

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