



## ACCESSION NUMBER RANGES

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# AERONAUTICAL ENGINEERING

## A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 227)

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 1988 in

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



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Washington, DC

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# INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 418 reports, journal articles and other documents originally announced in May 1988 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA)*.

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

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

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

An annual cumulative index will be published.

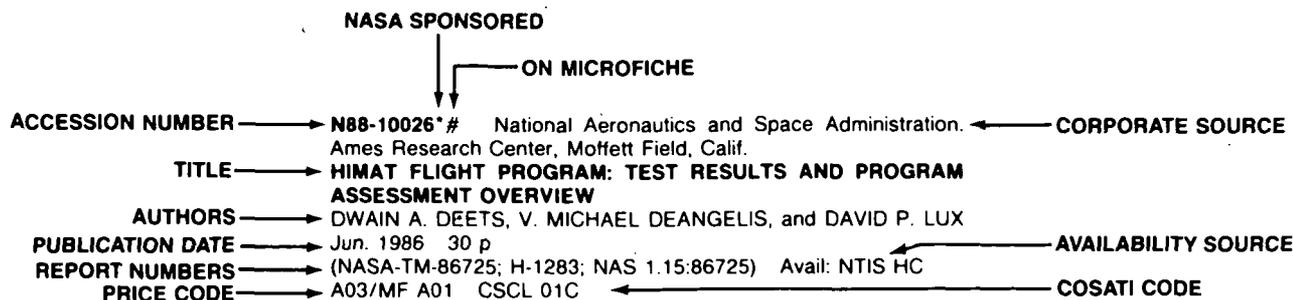
Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

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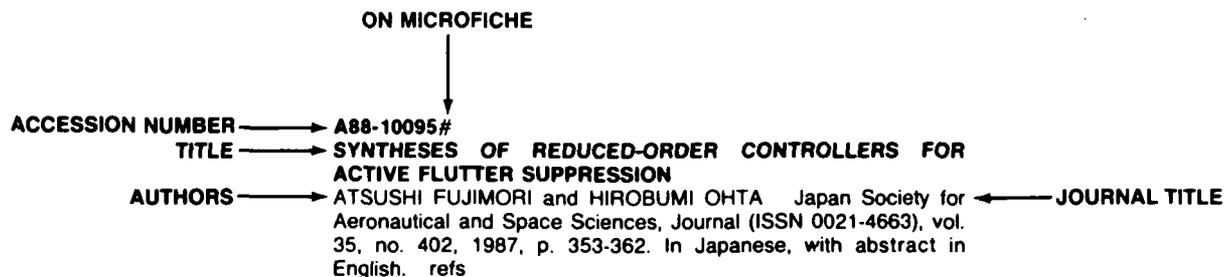
# TYPICAL REPORT CITATION AND ABSTRACT



The Highly Maneuverable Aircraft Technology (HiMAT) program consisted of design, fabrication of two subscale remotely piloted research vehicles (RPRVs), and flight test. This technical memorandum describes the vehicles and test approach. An overview of the flight test results and comparisons with the design predictions are presented. These comparisons are made on a single-discipline basis, so that aerodynamics, structures, flight controls, and propulsion controls are examined one by one. The interactions between the disciplines are then examined, with the conclusions that the integration of the various technologies contributed to total vehicle performance gains. An assessment is made of the subscale RPRV approach from the standpoint of research data quality and quantity, unmanned effects as compared with manned vehicles, complexity, and cost. It is concluded that the RPRV technique, as adopted in this program, resulted in a more complex and costly vehicle than expected but is reasonable when compared with alternate ways of obtaining comparable results.

Author

# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



Reduced-order controllers for active flutter suppression of a two-dimensional airfoil are studied using two design approaches. One is based on the generalized Hessenberg representation (GHR) in the time domain, and the other, called the Nyquist frequency approximation (NFA), is a method in the frequency domain. In the NFA method, the reduced-order controllers are designed so that the stability margin of the Nyquist plot may be increased over a specific frequency range. To illustrate and to make a comparison between the two methods, numerical simulations are carried out using a thirteenth-order controlled plant. It is to be noted that the GHR method can yield quasi-optimal controllers in the sense of minimizing quadratic performance indices. The designed controllers, however, do not have enough stability margin, and the order reduction resulting from full state controllers may not be satisfactory. On the other hand, reduced-order controllers in the NFA method can be designed with increased stability margin at the expense of the performance index. For all simulation cases, the NFA method yields second-order controllers with a better stability margin than those by the GHR method. Thus, the NFA method provides an effective method for synthesizing robust reduced-order controllers.

Author

# AERONAUTICAL ENGINEERING

*A Continuing Bibliography (Suppl. 227)*

JUNE 1988

01

## AERONAUTICS (GENERAL)

**A88-26175\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **EUROPEAN/U.S. COOPERATIVE FLIGHT TESTING - SOME FOOD FOR THOUGHT**

RONALD M. GERDES (NASA, Ames Research Center, Moffett Field, CA) Cockpit (ISSN 0742-1508), July-Sept. 1987, p. 4-9.

Increasing numbers of flight test teams are participating in cooperative European/U.S. flight test programs due to the growth in international aircraft R&D. Preparing for and participating in these overseas assignments can be complicated by such factors as language barriers, unfamiliar flight test procedures, lack of adequate flight experience and unexpected weather trends. A visiting test pilot's checklist is presented which outlines the tasks of the various phases (i.e., concept, planning, preparation, execution, analysis, and data presentation). K.K.

**A88-26646#**

### **KEEPING A SHARP TECHNOLOGY EDGE**

JAY C. LOWNDES Aerospace America (ISSN 0740-722X), vol. 26, Feb. 1988, p. 24-28.

The erosion of the U.S. share of the world aircraft market may be taken as evidence of a narrowing of technical preeminence. Attention is presently given to NASA, Federal Government and industry efforts to validate advanced technologies for expeditious commercial application. These technologies encompass advanced structural materials, advanced propulsion system thermodynamic cycles and configurations, and efforts to reduce boundary layer drag in both subsonic airliners and post-Concorde SSTs. Attention is given to the economic support required for suitable R&D. O.C.

**N88-16624#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Systems and Logistics.

### **A MODEL FOR ESTIMATING DEPOT MAINTENANCE COSTS FOR AIR FORCE FIGHTER AND ATTACK AIRCRAFT M.S. Thesis**

MICHAEL P. WAKER Sep. 1987 84 p (AD-A187097; AFIT/GSM/LSQ/87S-36) Avail: NTIS HC A05/MF A01 CSCL 05C

The model developed in this study has two cost estimating relationships (CERs) for estimating depot maintenance costs in its two categories: depot maintenance cost per Primary Authorized Aircraft (PAA); and, depot maintenance cost per flying hour. The data source used for depot maintenance costs is the Weapon Systems Cost Retrieval System (WSCRS) as developed by HQ AFLC. The CERs developed used empty weight of fighter and attack aircraft to predict the cost of depot maintenance per PAA. For depot maintenance cost per flying hour, the variables used were combat radius, thrust-to-weight ratio, and empty weight. The study found that the F-111 was a significant outlier with respect to the data set, but even when included in the data base the F-111 enhanced the values of the statistics for the model and improved the ability of the model to predict. The relationship found

for depot maintenance cost per PAA in the CER developed, was not as strong a predictor as was the CER developed for depot maintenance cost per flying hour. This conclusion agrees with previous studies that have tried to determine significant relationships between depot maintenance costs and those costs attributed to the number of PAA. GRA

**N88-16625\*#** National Aeronautics and Space Administration, Washington, D.C.

### **NASA/ARMY ROTORCRAFT TECHNOLOGY. VOLUME 1: AERODYNAMICS, AND DYNAMICS AND AEROELASTICITY**

Feb. 1988 537 p Conference held at Moffett Field, Calif., 17-19 Mar. 1987

(NASA-CP-2495-VOL-1; NAS 1.55:2495-VOL-1) Avail: NTIS HC A23/MF A01 CSCL 01B

The Conference Proceedings is a compilation of over 30 technical papers presented at this milestone event which reported on the advances in rotorcraft technical knowledge resulting from NASA, Army, and industry rotorcraft research programs over the last 5 to 10 years. The Conference brought together over 230 government, industry, and allied nation conferees to exchange technical information and hear invited technical papers by prominent NASA, Army, and industry researchers covering technology topics which included: aerodynamics, dynamics and elasticity, propulsion and drive systems, flight dynamics and control, acoustics, systems integration, and research aircraft.

**N88-16626\*#** Army Aerostructures Directorate, Hampton, Va.

### **ACCOMPLISHMENTS AT NASA LANGLEY RESEARCH CENTER IN ROTORCRAFT AERODYNAMICS TECHNOLOGY**

JOHN C. WILSON in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity p 7-33 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01B

In recent years, the development of aerodynamic technology for rotorcraft has continued successfully at NASA LaRC. Though the NASA Langley Research Center is not the lead NASA center in this area, the activity was continued due to facilities and individual capabilities which are recognized as contributing to helicopter research needs of industry and government. Noteworthy accomplishments which contribute to advancing the state of rotorcraft technology in the areas of rotor design, airfoil research, rotor aerodynamics, and rotor/fuselage interaction aerodynamics are described. Rotor designs were defined for current helicopters and evaluated in wind tunnel testing. These designs have incorporated advanced airfoils defined analytically and also proven in wind tunnel tests. A laser velocimetry system has become a productive tool for experimental definition of rotor inflow/wake and is providing data for rotorcraft aerodynamic code validation.

Author

## 01 AERONAUTICS (GENERAL)

**N88-16632\*#** National Aeronautics and Space Administration, Washington, D.C.

**NASA/ARMY ROTORCRAFT TECHNOLOGY. VOLUME 2: MATERIALS AND STRUCTURES, PROPULSION AND DRIVE SYSTEMS, FLIGHT DYNAMICS AND CONTROL, AND ACOUSTICS**

Feb. 1988 587 p Conference held at Moffett Field, Calif., 17-19 Mar. 1987

(NASA-CP-2495-VOL-2; NAS 1.55:2495-VOL-2) Avail: NTIS HC A25/MF A01 CSCL 01B

The Conference Proceedings is a compilation of over 30 technical papers presented which report on the advances in rotorcraft technical knowledge resulting from NASA, Army, and industry research programs over the last 5 to 10 years. Topics addressed in this volume include: materials and structures; propulsion and drive systems; flight dynamics and control; and acoustics.

**N88-16650\*#** National Aeronautics and Space Administration, Washington, D.C.

**NASA/ARMY ROTORCRAFT TECHNOLOGY. VOLUME 3: SYSTEMS INTEGRATION, RESEARCH AIRCRAFT, AND INDUSTRY**

Feb. 1988 387 p Conference held at Moffett Field, Calif., 17-19 Mar. 1987

(NASA-CP-2495-VOL-3; NAS 1.55:2495-VOL-3) Avail: NTIS HC A17/MF A01 CSCL 01B

This is part 3 of the conference proceedings on rotorcraft technology. This volume is divided into areas on systems integration, research aircraft, and industry. Representative titles from each area are: system analysis in rotorcraft design, the past decade; rotorcraft flight research with emphasis on rotor systems; and an overview of key technology thrusts at Bell Helicopter Textron.

**N88-17847#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.

**AIRBUS, THE SUCCESSFUL EUROPEAN COOPERATION [AIRBUS - DIE ERFOLGREICHE EUROPÄISCHE KOOPERATION]**

HARTMUT MEHDORN *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 179-182 1987 In GERMAN

(MBB-UT-005/87) Avail: NTIS HC A14/MF A01

The history of the European Airbus project is depicted. The structure, organization, responsibilities, and goals of Airbus Industry are explained. ESA

**N88-17849#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.

**PRODUCT PLANNING IN CIVIL AIRCRAFT CONSTRUCTION [PRODUKTPLANUNG IM ZIVILEN FLUGZEUGBAU]**

WERNER ZABKA *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 187-196 1987 In GERMAN

(MBB-UT-002/87; VDI-619) Avail: NTIS HC A14/MF A01

Planning in the production of civil passenger aircraft is described. The general economic boundary conditions are given. The procurement of a new aircraft is discussed from the point of view of an airline company. The risks involved in the development of a new passenger aircraft are presented on the basis of the essential planning parameters and their mutual dependencies. The influence of the development domain on the efficiency of an aircraft program, and the use of value analysis are explained. ESA

## 02

### AERODYNAMICS

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

**A88-25300#**

**OBLIQUE SHOCK/LAMINAR BOUNDARY LAYER INTERACTIONS IN HYPERSONIC FLOW**

G. R. INGER and A. A. RANGWALLA (Iowa State University of Science and Technology, Ames) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 49 p. refs (AIAA PAPER 88-0603)

This paper analyzes the weakly-hypersonic interaction of an oblique shock with an adiabatic laminar boundary layer (in 2-D) by means of a non-asymptotic triple deck approach which is essentially an extension of Lighthill's work for supersonic flow to include second order effects. The disturbance flow field is obtained analytically for a range of free stream Mach numbers and Reynolds numbers. In particular, the first and second order wall pressure and skin friction perturbations are obtained and their far upstream and downstream asymptotic behavior are deduced as a function of Mach number and Reynolds number. The relative importance of the hypersonic effects to those of the supersonic are then obtained as a function of both Mach number and Reynolds number. Also, the upstream influence distance is obtained and the onset of separation is predicted. Author

**A88-25561**

**CALCULATION OF NONPOTENTIAL FLOWS OF AN IDEAL GAS IN AXISYMMETRIC NOZZLES BY THE APPROXIMATE FACTORIZATION METHOD [RASCHET NEPOTENTIAL'NYKH TECHENII IDEAL'NOGO GAZA V OSESIMMETRICHNYKH SOPLAKH METODOM PRIBLIZHENNOI FAKTORIZATSII]**

V. G. BUTOV and S. B. KHALIMOV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 27, Dec. 1987, p. 1861-1867. In Russian. refs

The approximate factorization method is applied to the analysis of mixed stationary subsonic nonpotential flows of an ideal gas in axisymmetric nozzles. The system of equations is written in solution-referenced orthogonal coordinates and converted (by increasing its order) to a form convenient for approximate factorization. The efficiency of the approach is demonstrated for flows in nozzles of complex geometry, flow of a given vorticity at the inlet of a nozzle, and a nonadiabatic flow. V.L.

**A88-25617**

**COMPARISON OF THE AERODYNAMIC CHARACTERISTICS OF ANNULAR AND ELLIPTIC WINGS [SRAVNIENIE AERODINAMICHESKIKH KHARAKTERISTIK KOL'TSEVYKH I ELLIPTICHESKIKH KRYL'EV]**

M. D. ZHURAVLEV and S. A. MATVEENKO Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 29-31. In Russian. refs

Results of experimental studies of annular and elliptic wings of varying sweep are reported for low subsonic flow velocities. The experimental data cover several different configurations based on wings of these types. The advantages of sweptforward wings and of the canard configuration are demonstrated. V.L.

**A88-25632**

**THREE-DIMENSIONAL PROBLEM OF THE CONSTRAINED TORSION OF A THIN-WALLED ROD OF THE TRAPEZOIDAL WING TYPE [PROSTRANSTVENNAIA ZADACHA STESNENNOGO KRUCHENIIA TONKOSTENNOGO STERZHNIYA TIPA TRAPETSEIDAL'NOGO KRYLA]**

V. I. KOROL'KOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 79-82. In Russian. refs

An analytical solution is presented for the three-dimensional problem of the constrained bending of a weakly conical hollow rod, with one end of the rod fixed and a torque applied to its

other end. The results obtained confirm the conclusion of Grossman (1947) that the constraint and conicity give rise to normal stresses of opposite signs. The accuracy of the solution obtained here is verified experimentally by the photoelasticity method using models of an epoxy-based photosensitive material. V.L.

**A88-25633**  
**CALCULATION OF A WING WITH ALLOWANCE FOR FUSELAGE ELASTICITY [RASCHET KRYLA S UCHETOM UPRUGOSTI FIUZELIAZHA]**

V. V. KUZ'MIN and V. I. FIGUROVSKII Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 82-85. In Russian.

A model allowing for fuselage elasticity is proposed for wing calculations by the finite element method in displacements. In the analysis presented here, a cylindrical fuselage is considered, with the wing located at an arbitrary height; variable frame spacing and stiffness and an arbitrary number of frame elements are permitted. It is shown that, for the wing design scheme considered here, displacements increase substantially when fuselage elasticity is taken into account, whereas stresses change only slightly.

V.L.

**A88-25835**  
**LASER DOPPLER VELOCITY BIAS IN SEPARATED TURBULENT FLOWS**

H. L. PETRIE (Pennsylvania State University, State College), M. SAMIMY (Ohio State University, Columbus), and A. L. ADDY (Illinois, University, Urbana) Experiments in Fluids (ISSN 0723-4864), vol. 6, no. 2, 1988, p. 80-88. refs (Contract DAAG29-79-C-0184; DAAG29-83-K-0043)

Velocity bias effects on data obtained with a coincident two channel laser Doppler velocimeter in a highly turbulent separated supersonic flow are presented. Probability distributions of the fluctuating velocities were distorted by velocity bias in a manner consistent with theory and a two-dimensional velocity inverse weighting function bias correction produced reasonable appearing velocity probability distributions. The addition of an approximate correction term to account for the effects of the unmeasured third velocity component improved these results but had little effect on the velocity statistics. Experimental factors that could partially compensate or falsely add to the velocity bias, conditions for the bias to occur, and conditions for which the bias may also be observed and corrected for are discussed. Author

**A88-25842**  
**TIME DEPENDENT FLOW VISUALIZATION IN THE SEPARATED REGION OF AN APPENDAGE-FLAT PLATE JUNCTION**

S. C. DICKINSON (U.S. Navy, David W. Taylor Naval Ship Research and Development Center, Bethesda, MD) Experiments in Fluids (ISSN 0723-4864), vol. 6, no. 2, 1988, p. 140-143. Navy-supported research. refs

Flow visualizations of the complex 'horseshoe root' vortex secondary flow of an appendage-flat plate junction are presented, with application to the study of the flow around an aircraft wing-fuselage junction. The oil film flow visualization studies show the presence of a significant three-dimensional separated zone. Time dependent oil film techniques indicate large differences in surface shear stress on the flat plate. The oil dot flow visualizations reveal the upstream reversed flow near the leading edge, in addition to the outwardly directed surface streamlines under the vortex alongside of the appendage. R.R.

**A88-25988#**  
**STRONG COUPLING BETWEEN INVISCID FLUID AND BOUNDARY LAYER FOR AIRFOILS WITH SHARP LEADING EDGE. I - 2-D INCOMPRESSIBLE STEADY CASE**

J. J. ANGELINI and C. SOIZE (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aerospaciale (English Edition) (ISSN 0379-380X), no. 4, 1987, p. 19-36. refs

The strong coupling between inviscid fluid and two-dimensional boundary layer in cascade aeroelasticity problems is considered. The upper surface boundary layer separated at the leading edge and reattached before the trailing edge is taken as a significant

situation. In this first part, the incompressible steady case is studied. The aim is to develop the mathematical and physical model using experiments made on a flat plate with sharp leading edge with four degrees of incidence at a Reynolds number of 400,000. The assumptions and the construction of the physical and mathematical model are given along with the numerical analysis, and the experiments are compared with numerical results. Author

**A88-26120**  
**DISTRIBUTED GAS INJECTION INTO HYPERSONIC FLOW [RASPREDELENNYI VDUV GAZA V GIPERZVUKOVOI POTOK]**  
 I. I. LIPATOV Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Nov.-Dec. 1987, p. 57-61. In Russian. refs

The effect of evenly distributed injection on flow in a laminar boundary layer is investigated for the case of strong hypersonic interaction. Results of the numerical integration of the boundary value problem are presented which make it possible to determine the dependence of the aerodynamic characteristics on the injection intensity, surface temperature, and bottom pressure gradient. The characteristic features distinguishing the case investigated from the case of weak interaction in the boundary layer are examined. V.L.

**A88-26129**  
**NUMERICAL SOLUTION OF THE PROBLEM OF SUPERSONIC GAS FLOW FROM A NARROW SLOT IN HODOGRAPH VARIABLES [K CHISLENNOMU RESHENIU ZADACHI O SVERKHZVUKOVOM ISTECHENII GAZA IZ PLOSKOI SHCHELI V PEREMENNYKH GODOGRAFA]**

IU. S. KOSOLAPOV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 28, Jan. 1988, p. 137-141. In Russian. refs

The paper presents a modified version of a method for calculating, in the hodograph plane, stationary subsonic and transonic flows of an ideal gas in converging plane and axisymmetric nozzles with a straight-line generatrix. The modified version proposed here is shown to be more accurate than the original method, making it possible to obtain a numerical solution with second-order accuracy. The advantages of the proposed version of the method are demonstrated for the case of supersonic gas flow from a plane slot. V.L.

**A88-26163**  
**EXCESS STREAMWISE VORTICITY AND ITS ROLE IN SECONDARY FLOW**

P. W. JAMES (Plymouth Polytechnic, England) Institution of Mechanical Engineers, Proceedings, Part C - Mechanical Engineering Science (ISSN 0263-7154), vol. 201, no. C6, 1987, p. 413-420. refs

The purpose of this paper is, first, to show how the concept of excess secondary vorticity arises naturally from attempts to recover three-dimensional flow details lost in passage-averaging the equations governing the flow through gas turbines. An equation for the growth of excess streamwise vorticity is then derived. This equation, which allows for streamwise entropy gradients through a prescribed loss term, could be integrated numerically through a blade-row to provide the excess vorticity at the exit to a blade-row. The second part of the paper concentrates on the approximate methods of Smith (1955) and Came and Marsh (1974) for estimating this quantity and demonstrates their relationship to each other and to the concept of excess streamwise vorticity. Finally the relevance of the results to the design of blading for gas turbines, from the point of view of secondary flow, is discussed. Author

**A88-26358#**  
**QUASI-CONICAL AERODYNAMIC LOADINGS DUE TO KINKED PLANFORM WINGS**

KYOKO NITTA, SHIGENORI ANDO, and SETSUYA KINUGAWA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 407, 1987, p. 586-595. In Japanese, with abstract in English. refs

Aerodynamic loadings over kinked-planform wings are investigated using lifting-surface theories. In using conventional

mode methods, kinked edges of the planform should be rounded in some way. The effects of roundings on loadings are investigated through BIS-QS, which is a discrete method developed in the authors' laboratory. Another discrete method, DLM, is used supplementarily. Two kinds of roundings are used. It is found that the influence of roundings remains spanwise considerably far from the rounded region. Conventional mode methods are thus less efficient than discrete methods for investigating kinked-planform wings. Modified aerodynamic loading (MAL) is introduced to be kept free from the conventional square-foot edge-singularities. It is noteworthy that quasi-conical distributions of MAL appear near kinks. Thus the well known peculiar loadings of swept-back, or forward-swept wings can be explained essentially and naturally. This quasi-conical MAL would serve for rapid convergence of mode methods in lifting-surface theory. Author

A88-26359#

**AERODYNAMIC CHARACTERISTICS OF THE WEIS-FOGH MECHANISM. II - NUMERICAL COMPUTATIONS BY THE DISCRETE VORTEX METHOD**

MICHIHISA TSUTAHARA and TAKEYOSHI KIMURA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 407, 1987, p. 596-604. In Japanese, with abstract in English. refs

Aerodynamic characteristics of the Weis-Fogh (1973) mechanism, which is a lift-generating mechanism of hovering flight of small insects, were studied by the discrete-vortex method. Two flat wings were approximated by a finite number of bound vortices, and the unsteady force due to the change of the strengths of these vortices was estimated by a contour of integration including newly introduced nascent vortices. A sufficient lift is generated in all the stages of the wing motion. Especially at the final stage of the closing motion, the moment for closing the wing becomes very large while the lift remains moderate. At the same stage, a jet is produced between the two wings, and a region of high-speed flow also appears in the back side of each wing. Author

A88-26388

**AN EXPERIMENTAL INVESTIGATION ON AERODYNAMIC INTERBLADE INTERACTIONS OF A VIBRATING CASCADE IN TRANSONIC FLOW**

YOJI HANAMURA and KAZUO YAMAGUCHI (Tokyo, University, Japan) JSME International Journal (ISSN 0913-185X), vol. 30, Dec. 1987, p. 1919-1927.

The aerodynamic interblade interaction of a cascade blade row in a transonic flow is investigated in a Freon gas wind tunnel. A one-blade oscillation method is introduced which experimentally clarifies some previously hidden aspects of the conventional all-blade oscillation method. The unsteady moment induced at the center of the vibrating blade itself lags behind the blade displacement, implying that the flutter of one blade only in a cascade does not occur. The time lag increases with the increment of Mach number and reduced frequency. In a highly staggered cascade, the effects of the center vibrating blade becomes less on the upstream neighboring blades than on the downstream neighboring blades. The amplitude of an unsteady moment becomes smaller and its phase lag against the displacement of the center vibrating blade becomes larger at blades situated farther upstream. C.D.

A88-26421

**WING TIP SAILS - PROGRESS TO DATE AND FUTURE DEVELOPMENTS**

J. J. SPILLMAN (Cranfield Institute of Technology, England) Aeronautical Journal (ISSN 0001-9240), vol. 91, Dec. 1987, p. 445-453. refs

An account is given of the accumulating evidence (derived from wind tunnel research and full scale aircraft flight tests) that the swirling flow about the tips of lifting wings can be redirected by small 'sail' airfoils to reduce overall lift-dependent drag. Variable incidence sails can be effectively used to furnish roll power for maneuvering. Sails can reduce aircraft drag in all flight regimes to the extent of fuel savings estimated at \$225/year per 1000 lbs of

takeoff weight, per 1000 hours of annual utilization; in the case of a 300,000 lb airliner operating for 3000 hours, this represents a fuel saving of over \$200,000/year. O.C.

A88-26422

**THE TIP FLOW OF A PART SPAN SLOTTED FLAP**

A. C. WILLMER (British Aerospace, PLC, London, England), R. V. BARRETT, and J. D. COLEMAN (Bristol, University, England) Aeronautical Journal (ISSN 0001-9240), vol. 91, Dec. 1987, p. 453-469.

An experimental study into the overall influence of the end region of a flap on the flow of a high lift wing has attempted to furnish a body of data on this aspect of the overall three-dimensional problem posed by high lift device-incorporating wing systems. Extensive pressure surveys and minituft flow visualization records were obtained, together with detailed boundary layer and wake surveys. It is hoped that these data will aid the formulation of mathematical models for high lift configurations. O.C.

A88-26423

**A FIRST ORDER THEORY FOR NEWTONIAN FLOW OVER TWO-DIMENSIONAL AIRFOILS**

HAMDI T. HEMDAN (King Saud University, Riyadh, Saudi Arabia) Aeronautical Journal (ISSN 0001-9240), vol. 91, Dec. 1987, p. 471-478. Research supported by King Saud University. refs

A simple closed-form formula for the coefficient of surface pressure,  $C_p$ , is given in this paper. The formula is based on first and second approximations of the full problem, and can be used for the Newtonian flow past two-dimensional thin airfoils at small angles of attack and with attached shock waves. It thus extends Cole's (1957) zero-order theory to the effects of nonzero ( $\gamma - 1$ ) and finite values of freestream Mach number where  $\gamma$  is the ratio of the specific heats of the gas. The results are compared with other approximate methods and the agreement is found to be generally good. Author

A88-26424

**INVISCID THEORY OF TWO-DIMENSIONAL AEROFOIL/SPOILER CONFIGURATIONS AT LOW SPEED. V - STEADY AND OSCILLATORY AEROFOIL-SPOILER-FLAP CHARACTERISTICS**

H. B. TOU and G. J. HANCOCK (Queen Mary College, London, England) Aeronautical Journal (ISSN 0001-9240), vol. 91, Dec. 1987, p. 479-498. refs

An inviscid model for a steady two-dimensional airfoil/spoiler at low speeds is applied to an airfoil/spoiler/plain-flap configuration. The model is extended to an airfoil/spoiler/slotted-flap configuration. The flow through a slotted flap can result in either attached flow or separated flow about the flap. The location of the separation point on the flap has to be assumed; it is taken empirically to fit experimental data. The inviscid model is extended to the airfoil/spoiler/slotted-flap configuration with the spoiler oscillating in small amplitude simple harmonic motion about a mean spoiler angle. Although both the steady and unsteady models for the airfoil/spoiler/flap configuration are crude, the results look encouraging. Author

A88-26433

**IMPROVED RELAXATION SCHEMES FOR TRANSONIC POTENTIAL CALCULATIONS**

M. HAFEZ (California, University, Davis) and D. LOVELL (Flow Research, Inc., Kent, WA) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 8, Jan. 1988, p. 1-16. refs

A block relaxation scheme, grouped in a red-black ordering, is applied to transonic aerofoil calculations using body-fitted coordinates. The scheme is simple and easily vectorizable. Detailed comparisons with the approximate factorization method (AF2) are presented and it is shown that the new scheme is competitive in all cases considered. Transonic results, of engineering accuracy, on an O-type grid of 149 x 30 points, are usually obtained within 200 iterations (about 40s on a Cyber 175). Author

A88-26434

**COMPUTATION OF THREE-DIMENSIONAL TRANSONIC FLOWS USING TWO STREAM FUNCTIONS**

A. SHERIF (Cairo University, Egypt) and M. HAFEZ (California, University, Davis) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 8, Jan. 1988, p. 17-29. refs

A computational method for three-dimensional flows is presented in terms of two stream functions, which may be considered as two components of a generalized vector potential. An iterative scheme is developed such that only a sequence of two-dimensional-like problems, for each function, is solved. The convergence of the iterative scheme is studied based on von Neumann linear analysis. For transonic flow calculation, numerical methods used for potential flows are readily applied, namely artificial density and Zebra relaxation. Results of transonic flow calculations around a wing are presented. Author

A88-26435\* California Univ., Davis.

**ENTROPY AND VORTICITY CORRECTIONS FOR TRANSONIC FLOWS**

M. HAFEZ (California, University, Davis) and D. LOVELL (Flow Research, Inc., Kent, WA) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 8, Jan. 1988, p. 31-53. NASA-supported research. refs

Different models for inviscid transonic flows are examined. The common assumptions that the flow is isentropic and irrotational are critically evaluated. Entropy and vorticity correction procedures for potential and stream function formulations are presented, together with the details of the treatment of shocks and wakes, and drag and lift calculations. The non-uniqueness problem of the potential formulation is studied using different artificial viscosity forms. Numerical results are compared with Euler solutions. Author

A88-26584#

**NUMERICAL CALCULATION OF 3-D TURBULENT FLOW IN A STRAIGHT COMPRESSOR CASCADE WITH CIRCULAR-ARC BLADES**

DEYONG JIAO and HONGWEI YANG (Harbin Institute of Technology, People's Republic of China) Journal of Engineering Thermophysics (ISSN 0253-231X), vol. 8, Nov. 1987, p. 329-335. In Chinese, with abstract in English. refs

In this paper, the 'parabolic method' is used to calculate three-dimensional incompressible turbulent flow in a straight compressor cascade with circular-arc blades adopting k-epsilon turbulence model. The comparison with the quasi-laminar calculating results and experimental data shows that the k-epsilon turbulence model will be appropriate for the calculation of turbulent flow in the cascade. Author

A88-26586#

**STREAM FUNCTION SOLUTION OF TRANSONIC FLOW ALONG AN ARBITRARY TWISTED S1 STREAM SURFACE**

XIAOLU ZHAO and LISEN QIN (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) Journal of Engineering Thermophysics (ISSN 0253-231X), vol. 8, Nov. 1987, p. 340-342. In Chinese, with abstract in English. refs

The effects of the fully three-dimensional flow in the transonic turbo-machine's passage are stronger than in a subsonic one. In this case, the full three-dimensional solution may be more exact than the quasi-three-dimensional one. Based on a stream surface coordinate system, in which a coordinate surface coincides with the arbitrary twisted S1 stream surface, a principal stream function equation governing the transonic flow has been established. The mixed type equation can be solved by a traditional artificial compressibility method. The standard conservative differences were used to discretized the obtained equation, and a constant coefficients matrix decomposition method has been used to speed up the calculation. In terms of the integration velocity gradient equation, the velocity distribution can be determined first, then the densities are updated. Sample calculations are presented to illustrate the method's capabilities. Author

A88-26587#

**THE EFFECT OF THE BOUNDARY LAYER ON TRANSONIC CASCADE FLOW**

YAONAN HUA and BAOGUO WANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) Journal of Engineering Thermophysics (ISSN 0253-231X), vol. 8, Nov. 1987, p. 343-345. In Chinese, with abstract in English. refs

A computational method to take account of viscosity in transonic cascade flow is presented. The stream function method was used to calculate the inviscid blade-to-blade transonic flow. On the assumption that the viscous effect only occurs in boundary layer on the blade surface, the reference enthalpy method was used to calculate the characteristic parameters of the compressible boundary layer. The inviscid-viscous interaction procedure was used to calculate the entire blade-to-blade flow field. The effect of the boundary layer on the computation results of inviscid flow was investigated. The results show that the effect of the boundary layer on the inviscid flow is considerable. The calculation results of the inviscid-viscous interaction are closer to the experimental data than the inviscid calculation. The present method can be used to improve the computation results of inviscid flow. It is an effective and convenient method in engineering practice. Author

A88-26629#

**STUDY OF PERFORMANCE OF ROTATING STALL IN BLADE ROW**

ZHIWEI LIU, JUNJIANG ZHU, and ZHUNSHENG WANG (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power, vol. 3, Jan. 1988, p. 18-22, 88, 89. In Chinese, with abstract in English. refs

The tendency of the performances in rotating stall to vary with the stagger angles and the solidities is observed. Blockage ratio, the performance loss, and the hysteresis in stall rise with the increase of the stagger angles and the solidities. Both blockage ratio and performance loss in stall for a stage are larger than those for an isolated rotor, but the hysteresis effect of the stage is weakened due to the presence of the stator. The flow model (with an active cell structure) is discussed and evaluated on the basis of the experimental data. The results show that the features of the active-cell model should involve two aspects: (1) the mass interchange between the stall and unstall flow regions as well as between the stall cells from the outlet to the inlet of the blade row, and (2) the momentum interchange in the tangential direction of the rotor between the fluid in the stall cell and the rotor. Author

A88-26630#

**A COMPUTATIONAL METHOD OF EXCITING FORCES GENERATED BY NOZZLE WAKES ON TURBINE BLADES**

LING LIU and QINGJI MENG (Xian Jiaotong University, Xian, People's Republic of China) Journal of Aerospace Power, vol. 3, Jan. 1988, p. 23-26, 89. In Chinese, with abstract in English. refs

A computational method has been developed to solve the problem of two-dimensional compressible unsteady flow passing through the rotating blade row of a turbine. This work aims at determining the exciting forces generated by nozzle wakes on the blades. The numerical results obtained show that the distribution of the exciting forces is different from that of the nozzle wakes. Author

A88-26631#

**AN ANALYSIS SYSTEM FOR TRANSONIC FLOW IN CASCADE**

CHUNJUN JI and XINHAI ZHOU (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power, vol. 3, Jan. 1988, p. 27-30, 89, 90. In Chinese, with abstract in English. refs

A central-difference algorithm is developed for the analysis of inviscid blade-to-blade flow and coupled inviscid/boundary-layer flow in a transonic turbine cascade. A relaxed linear interpolation procedure for the y direction is combined with the opposed-difference scheme of Denton (1974) for the

## 02 AERODYNAMICS

quasi-streamline direction. The stability of the method for all relaxation coefficients greater than 1 is demonstrated; a procedure for coupling the inviscid and boundary-layer flows is given; and results from sample computations are presented in graphs and shown to be in good agreement with published experimental data.  
T.K.

**A88-26640#**

**A CONTOUR LINE PLOTTING SYSTEM WITH POLAR COORDINATES FOR AEROENGINE INLET FLOW FIELD**  
ZHANXIAN WANG (Flight Test Research Centre, People's Republic of China) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 67-69, 94. In Chinese, with abstract in English.

**A88-26643#**

**3D-COMPUTATIONAL MESH GENERATION AROUND A PROPELLER BY ELLIPTIC DIFFERENTIAL EQUATION SYSTEM**  
MAKOTO KOBAYAKAWA and ICHIRO HATANO (Kyoto University, Japan) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 81-86. refs

In this paper, an analytic method is applied for the generation of a three-dimensional mesh system for the Navier-Stokes equations around an ATP propfan. One of the advantages of this method is that mesh lines have strong differentiability. The differential equation used is Poisson type, and the right-hand side is called the control function. This function is able to control the degree of meshline clustering. Here, the form of the control function was contrived to cluster near the solid surfaces. By this method, several mesh lines are laid in the boundary layer above the blade surfaces.  
Author

**A88-26696**

**AERODYNAMIC CALCULATION OF THIN BODIES IN A RAREFIED GAS [AERODINAMICHESKII RASCHET TONKIKH TEL V RAZREZHENNOM GAZE]**  
V. S. NARITSA Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia (ISSN 0024-0850), Oct. 1987, p. 46-50. In Russian. refs

An approximation is proposed for the dependence of local transfer coefficients on the local Reynolds number, with allowance made for the nonmonotonic change of the aerodynamic characteristics. This approximation is then used to obtain formulas for calculating the aerodynamic coefficients of thin bodies, such as semiinfinite and triangular plates and a cone. By using regression analysis, it is shown that, in the transition region, the dependence of local transfer coefficients on the Reynolds number is determined by a single parameter, which should be determined from experimental data. A comparison is made with experimental data.  
V.L.

**A88-26731#**

**GEOMETRY/GRID GENERATION IN  $N + 1$  EASY STEPS**  
B. K. SONI, M. D. MCCLURE (Sverdrup Technology, Inc., Arnold Air Force Station, TN), and C. WAYNE MASTIN (Mississippi State University, Mississippi State) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 83-94.

Progress concerning efforts designed to generate 'optimal' three-dimensional computational grids for real world engineering problems related to propulsion ground testing is presented. This progress has been brought about through enhancements incorporated into a procedure which uses several techniques either separately or in combination to quickly and economically generate three-dimensional computational grids for arbitrary geometries. Improvements in grid generation strategies for complex geometries have been made along with the development of grid refinement algorithms which are used to make an existing grid smoother and more nearly orthogonal. Examples of three-dimensional grids are provided to illustrate the success of these methods. Author

**A88-26743**

**GENERATION OF PATCHED MULTIPLE-REGION GRIDS USING ELLIPTIC EQUATIONS**

D. M. SCHUSTER (Lockheed-Georgia Co., Marietta) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 259-270. refs

This paper deals with the numerical generation of two-dimensional grids, in multiple regions, using elliptic grid generation equations. The method involves the patching together of simple two-dimensional grids about components of complicated geometries into one large composite grid about the complete geometry. A number of solution strategies have been used to obtain global smoothness of these multiple-region grids, and the relative merits of each of these methods is discussed. The particular application addressed in this paper is the generation of grids about multiple-component airfoil high-lift systems for Navier-Stokes computations. However, the method is general, and it can be applied to a number of problems requiring the analysis of complicated or multiple component geometries. Author

**A88-26745**

**GENERATION OF BODY-FITTED GRIDS AROUND AIRFOILS USING MULTIGRID METHOD**

R. K. JAIN (Gesellschaft fuer Mathematik und Datenverarbeitung mbH, Sankt Augustin, Federal Republic of Germany) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 305-317. BMFT-supported research. refs

To generate a body-fitted grid about an airfoil, a system of partial differential equations is solved using a multigrid technique. Full approximation scheme has been used with the starting solution obtained by full multigrid (FMG) algorithm. Gauss-Seidel successive line relaxation is used as a smoother in finer grids and as a solver in the coarsest grid. Implementation of the boundary condition on the cut is done implicitly when using horizontal line relaxation. Pure injection and full weighting are used for the restriction of the solution and the residuals, respectively. Prolongation uses linear interpolation. Cubic interpolation is used when the final solution is transferred from coarser to finer grids in the FMG algorithm. V- and W-cycles with various relaxation steps have been analyzed. Best results were obtained using V-cycle with one relaxation step each before restriction and after prolongation, and it required less than 15 work units (WUs) for an accuracy of 0.00001. An asymptotic convergence rate of 0.67/WU was attained. Author

**A88-26747**

**A BLOCK STRUCTURED MESH GENERATION TECHNIQUE FOR AERODYNAMIC GEOMETRIES**

J. SHAW, C. R. FORSEY, N. P. WEATHERILL, and K. E. ROSE (Aircraft Research Association, Ltd., Bedford, England) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 329-340. Research supported by the Ministry of Defense Procurement Executive and British Aerospace, PLC. refs

A method is described for calculating the flowfield around aerodynamic geometries, based upon a block structured grid generation technique, coupled with an Euler flow algorithm. The flow domain is subdivided into a number of nonoverlapping blocks and grids generated either by the solution of a set of partial differential equations, or by transfinite interpolation. Details of the surface and field grid generators are given and techniques to control the position of grid points are highlighted. Examples are shown of grids on and around aircraft geometries together with flow calculations on block structured grids. Author

A88-26751

**ALGEBRAIC GRID GENERATION FOR ANNULAR NOZZLE FLOWFIELD PREDICTION**

B. N. WANG and J. D. HOFFMAN (Purdue University, West Lafayette, IN) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 399-409. refs

A two-dimensional algebraic grid generation procedure is presented for annular nozzle flow-field prediction. The grid distribution on the physical boundaries is determined by two piecewise polynomials. The grid distribution within the physical domain is determined from the boundary grid points by a quadratic connection function. The grid generation procedure is used with a numerical method of characteristics algorithm to calculate inviscid trisonic flow fields in annular propulsive nozzles. An example is presented to illustrate the grid generation procedure. Results of a nozzle flow-field analysis are presented and compared with experimental data to verify the overall numerical procedure.

Author

A88-26753

**APPLICATION OF A FEM MOVING NODE ADAPTIVE METHOD TO ACCURATE SHOCK CAPTURING**

B. PALMERIO (Nice, Universite, France) and A. DERVIEUX (Institut National de Recherche en Informatique et en Automatique, Valbonne, France) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 425-433.

A 'spring method' is applied to mesh adaptation for the calculation of compressible steady Euler flows. Two-dimensional triangulations are used in combination with an upwind Finite Element scheme. Several examples of shocked transonic flow calculations are presented.

Author

A88-26796#

**SIDEWALL EFFECT FOR TRANSONIC AIRFOIL TESTING**

YAOXI SU Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 6, Jan. 1988, p. 63-71. In Chinese, with abstract in English. refs

The mechanism of the sidewall effect for airfoil testing is investigated based on the results of oil flow visualization, and a systematic description of the mechanism in both subcritical and supercritical flow conditions is given. Five types of oil flow patterns are identified, and features characteristic of supercritical flow conditions are stated and described. The origin of all the sidewall effects observed experimentally can be traced back to the displacement effect of the sidewall boundary layer. The two-dimensional wind tunnel with solid sidewall is entirely improper for transonic airfoil testing due to the strong influence of oblique shocks. Wind tunnels of larger width may reduce the sidewall effect, but even for tunnels with width of 3.4 chord lengths, there is still an evident effect in the middle section for some test conditions. The proper application of suction provides a promising answer to the problem, since it both reduces and compensates for the displacement effect.

C.D.

A88-27715\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**AN EXPLICIT RUNGE-KUTTA METHOD FOR UNSTEADY ROTOR/STATOR INTERACTION**

PHILIP C. E. JORGENSON and RODRICK V. CHIMA (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 15 p. refs (AIAA PAPER 88-0049)

A quasi-three-dimensional rotor/stator analysis has been developed for blade-to-blade flows in turbomachinery. The analysis solves the unsteady Euler or thin-layer Navier-Stokes equations in a body-fitted coordinate system. It accounts for the effects of rotation, radius change, and stream-surface thickness. The Baldwin-Lomax eddy-viscosity model is used for turbulent flows. The equations are integrated in time using a four-stage Runge-Kutta

scheme with a constant timestep. Results are shown for the first stage of the Space Shuttle Main Engine high pressure fuel turbopump. Euler and Navier-Stokes results are compared on the scaled single- and multi-passage machine. The method is relatively fast and the quasi-three-dimensional formulation is applicable to a wide range of turbomachinery geometries.

Author

A88-27717\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**NUMERICAL SIMULATION OF HYPERSONIC INLET FLOWS WITH EQUILIBRIUM OR FINITE RATE CHEMISTRY**

SHENG-TAO YU, KWANG-CHUNG HSIEH, JIAN-SHUN SHUEN (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH), and BONNIE J. MCBRIDE (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 14 p. refs (AIAA PAPER 88-0273)

An efficient numerical program incorporated with comprehensive high temperature gas property models has been developed to simulate hypersonic inlet flows. The computer program employs an implicit lower-upper time marching scheme to solve the two-dimensional Navier-Stokes equations with variable thermodynamic and transport properties. Both finite-rate and local-equilibrium approaches are adopted in the chemical reaction model for dissociation and ionization of the inlet air. In the finite rate approach, eleven species equations coupled with fluid dynamic equations are solved simultaneously. In the local-equilibrium approach, instead of solving species equations, an efficient chemical equilibrium package has been developed and incorporated into the flow code to obtain chemical compositions directly. Gas properties for the reaction products species are calculated by methods of statistical mechanics and fit to a polynomial form for  $C(p)$ . In the present study, since the chemical reaction time is comparable to the flow residence time, the local-equilibrium model underpredicts the temperature in the shock layer. Significant differences of predicted chemical compositions in shock layer between finite rate and local-equilibrium approaches have been observed.

Author

A88-27884\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**THEORETICAL ANALYSIS OF AIRCRAFT AFTERBODY FLOW**

GEORGE S. DEIWERT, ALISON E. ANDREWS (NASA, Ames Research Center, Moffett Field, CA), and KAZUHIRO NAKAHASHI (National Aerospace Laboratory, Tokyo, Japan) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Nov.-Dec. 1987, p. 496-503. refs

Computational methods solving the thin shear layer formulation of the compressible, Reynolds-averaged Navier-Stokes equations are presently used to investigate the strongly interactive flow field about aircraft afterbodies. Solutions for a variety of axisymmetric afterbody and nozzle geometries are solved by means of a time-dependent implicit numerical algorithm for both subsonic and supersonic external flows, and the results obtained are compared with experimental data. A novel adaptive-grid technique is used to resolve flow regimes having large gradients, as well as to improve the accuracy and efficiency of the computational scheme.

O.C.

A88-28033#

**VORTEX/SEPARATED BOUNDARY-LAYER INTERACTIONS AT TRANSONIC MACH NUMBERS**

RABINDRA D. MEHTA (Stanford University, CA) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988, p. 15-26. refs

An experimental study has been completed on the effect of a single longitudinal vortex on a separated, transonic, turbulent boundary layer. The vortex was generated by a half-delta wing mounted at the upstream end of an axisymmetric 'bump' model. A flow visualization study was conducted using vapor screen and surface oilflow techniques. In addition surface pressures were measured and mean flow and turbulence data obtained using a two-component laser velocimeter. At precritical Mach numbers, the vortex delayed or eliminated boundary-layer separation on the downwash side and enhanced it on the upwash side, thus

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converting a nominally two-dimensional separation into a three-dimensional one. At the postcritical Mach number, the effect of the vortex was to reduce the size and extent of the shock-induced boundary-layer separation throughout the region of interaction. The boundary-layer turbulence in both cases was found to reorganize accordingly, although in a rather complex manner. The onset of three-dimensionality in the separation line produced by the vortex resulted in secondary vortices (foci), the sign and number being strongly dependent on the freestream Mach number. Author

**A88-28034#**

**INFLUENCE OF NOZZLE ASYMMETRY ON SUPERSONIC JETS**  
R. W. WLEZIEN and V. KIBENS (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988, p. 27-33. Research sponsored by the McDonnell Douglas Independent Research and Development Program. Previously cited in issue 07, p. 832, Accession no. A86-19787. refs

**A88-28050#**

**COMMENT ON 'COMPUTATION OF THE POTENTIAL FLOW OVER AIRFOILS WITH CUSPED OR THIN TRAILING EDGES'**  
H. N. V. DUTT (National Aeronautical Laboratory, Bangalore, India) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988, p. 122, 123.

**A88-28356**

**THERMODYNAMIC NONEQUILIBRIUM OF A FAR HYPERSONIC WAKE [O TERMODINAMICHESKOI NERAVNOVESNOSTI DAL'NEGO GIPERZYUKOVOGO SLEDA]**

IU. P. SAVEL'EV and M. M. STEPANOV (Leningradskii Mekhanicheskii Institut, Leningrad, USSR) Zhurnal Tekhnicheskoi Fiziki (ISSN 0044-4642), vol. 57, Nov. 1987, p. 2178-2183. In Russian. refs

The flow of a low-temperature plasma of a far hypersonic wake is studied theoretically with allowance for nonequilibrium chemical reactions as well as the possible absence of thermodynamic equilibrium. The investigation is based on a numerical analysis of simplified parabolic Navier-Stokes equations for a multicomponent mixture of reacting gases. Numerical results indicate the range of the greatest effect of thermodynamic nonequilibrium on the far-wake parameters. B.J.

**N88-16630\*#** Army Aviation Systems Command, Moffett Field, Calif.

**COMPREHENSIVE ROTORCRAFT ANALYSIS METHODS**

WENDELL B. STEPHENS and EDWARD E. AUSTIN (Army Research and Technology Labs., Fort Eustis, Va.) In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity p 312-352 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01A

The development and application of comprehensive rotorcraft analysis methods in the field of rotorcraft technology are described. These large scale analyses and the resulting computer programs are intended to treat the complex aeromechanical phenomena that describe the behavior of rotorcraft. They may be used to predict rotor aerodynamics, acoustic, performance, stability and control, handling qualities, loads and vibrations, structures, dynamics, and aeroelastic stability characteristics for a variety of applications including research, preliminary and detail design, and evaluation and treatment of field problems. The principal comprehensive methods developed or under development in recent years and generally available to the rotorcraft community because of US Army Aviation Research and Technology Activity (ARTA) sponsorship of all or part of the software systems are the Rotorcraft Flight Simulation (C81), Dynamic System Coupler (DYSCO), Coupled Rotor/Airframe Vibration Analysis Program (SIMVIB), Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics (CAMRAD), General Rotorcraft Aeromechanical Stability Program (GRASP), and Second Generation Comprehensive Helicopter Analysis System (2GCHAS). Author

**N88-16664#** Brown Univ., Providence, R. I. Div. of Applied Mathematics.

**NEW TECHNIQUES IN COMPUTATIONAL AERODYNAMICS Final Report, 1 Jun. 1983 - 28 Feb. 1987**

LAWRENCE SIROVICH 6 Aug. 1987 95 p

(Contract AF-AFOSR-0336-83)

(AD-A186719; AFOSR-87-1419TR) Avail: NTIS HC A05/MF A01 CSCL 20D

A wide range of problems in gas dynamics have been considered. Advances in subsonic, transonic, and supersonic gas dynamics have been made. The emphasis has been made on computational procedures both numerical and algebraic. This work has a strong basis in analytical methods, and goal has been to produce computational efficient codes which made optimal use of analytically known results. GRA

**N88-16666#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Experimentelle Stroemungsmechanik.

**EXPERIMENTAL INVESTIGATION OF SHOCK-INDUCED DISTURBANCES ON TRANSONIC AIRFOILS Ph.D. Thesis - Goettingen Univ., Fed. Republic of Germany**

DIETER BASLER Jul. 1987 128 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1097)

(DFVLR-FB-87-28; ISSN-0171-1342; ETN-88-91450) Avail: NTIS HC A07/MF A01; DFVLR, Cologne, Fed. Republic of Germany DM 38

The mechanism of buffeting was investigated in a wind tunnel on a transonic airfoil. A holographic high speed real time interferometer was developed to observe and analyze the entire flow field surrounding the airfoil. The information from interferograms was compared with results from hot film and pressure measurements. The results show that the shock oscillation can be described by an interaction of the shock with the boundary layer and the flow conditions at the trailing edge of the airfoil. The observed buffet frequencies are higher for an initially laminar boundary layer than for a turbulent boundary layer. Buffer frequency decreases with increasing Reynolds number in the case of a turbulent boundary layer. ESA

**N88-16667#** Royal Aircraft Establishment, Farnborough (England).

**THE AERODYNAMIC PERFORMANCE OF PROPELLERS SUITABLE FOR UNMANNED AIRCRAFT (UMAS)**

W. J. G. TREBLE Jan. 1987 25 p

(RAE-TM-AERO-2094; BR102328; ETN-88-91530) Avail: NTIS HC A03/MF A01

The aerodynamic performance of 13 cheap fixed-pitch 0.512 m diameter pusher-propellers suitable for powering unmanned aircraft for low speed missions (i.e., less than 50 m/sec) was investigated. Ten of them were twin-bladed and three of them had four blades. Thrust and torque at rotational speeds between 3000 and 9000 rpm in the 1.5 m acoustic tunnel at airspeeds from 10 to 50 m/sec were measured. As expected, propellers with coarser blade settings require more power and produce more thrust than those with finer pitch, and peak efficiency is delayed to higher values of the advance ratio (J). The peak efficiency is between 70 and 80 percent measured efficiency over the normal operating range (J=0.4 to 0.6) is 80 to 85 percent of the ideal efficiency, for a propeller of a different design performance is degraded by a further 10 percent. ESA

**N88-16668\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**COMPUTATIONAL UNSTEADY AERODYNAMICS FOR AEROELASTIC ANALYSIS**

WOODROW WHITLOW, JR. Dec. 1987 29 p

(NASA-TM-100523; NAS 1.15:100523) Avail: NTIS HC A03/MF A01 CSCL 01A

This report summarizes the status of computational unsteady aerodynamics methods for aeroelastic analysis and makes recommendations for future research activities. The flight conditions

for which various types of flows exist are described and the aeroelastic phenomena that can occur in those flight regimes are discussed. Some important aeroelastic problems of current interest are described, and the aerodynamic methods needed to analyze them are presented. The capabilities and limitations of existing unsteady aerodynamics methods are discussed. Computer resources required to perform aeroelastic analysis of various flight vehicle configurations are presented. Recommendations for future research are made, and schedules for completion of proposed research tasks are presented. Author

**N88-16670#** Association Aeronautique et Astronautique de France, Paris.

**EFFECT OF A MODEL SUPPORT STRUT ON MEASUREMENT OF AERODYNAMIC LONGITUDINAL AND LATERAL COEFFICIENTS**

M. QUEMARD, M. VANDEKREEKE, and M. VERRIERE Nov. 1986 32 p In FRENCH Sponsored by Direction des Recherches, Etudes et Techniques, Paris, France Prepared in cooperation with ONERA, Paris, France and Centre d'Essais Aeronautique de Toulouse, France (PB87-170288; NOTE-TECHNIQUE-86-09; ISBN-2-7170-0857-8) Avail: NTIS HC E04/MF E04 CSCL 01A

Lateral stability tests were run in wind tunnels on civilian airplane models mounted on a single strut. The model was balanced atop a vertical strut tied in with the devices regulating the angles of attack and sideslip. Significant discrepancies in lateral stability were noted during testing of the ATR 42 models in the two wind tunnels. It was shown that the very visible interaction of the ATR 42 strut with the landing gear fairing was responsible and that the effect was proportional to the relative thickness of the strut. Ground effects are studied by lowering the model toward the floor with a telescoping mask. Measurements also furnished the figures needed to correct the absolute values of the lift and pitching moment coefficients. Author

**N88-16671#** Association Aeronautique et Astronautique de France, Paris.

**TESTING OF A SCHEMATIC TRANSPORT PLANE MODEL IN SEVERAL EUROPEAN WINDTUNNELS**

V. SCHMITT Nov. 1986 30 p In FRENCH Presented at the 23rd Colloque d'Aerodynamique Appliquee, Modane, France, 12-14 Nov. 1986 Sponsored by Direction des Recherches, Etudes et Techniques, Paris, France Prepared in cooperation with Office National d'Etudes et de Recherches Aerospatiales, Paris, France (PB87-170270; NOTE-TECHNIQUE-86-08; ISBN-2-7170-0856-X) Avail: NTIS HC E04/MF E04 CSCL 01A

An international program was carried out to improve design methods for three dimensional configurations and to increase confidence in experimental data. The selected configuration was the DFVLR-F4 wing body incorporating a high aspect ratio supercritical wing and an Airbus type fuselage. For the experimental part of the exercise, a single model was tested in the major European wind tunnels. The transonic test consisted mainly of global force and moment measurements and measurement of pressure distributions on the wing and fuselage. The results were analyzed and compared. Author

**N88-16672#** Association Aeronautique et Astronautique de France, Paris.

**DESCRIPTION OF TESTS RUN IN THE T2 CRYOGENIC WIND TUNNEL**

A. SERAUDIE, A. BLANCHARD, and J. B. DOR Nov. 1986 51 p Sponsored by Direction des Recherches, Etudes et Techniques, Paris, France Prepared in cooperation with ONERA, Paris, France and Centre d'Etudes et de Recherches, Toulouse, France (PB87-170296; NOTE-TECHNIQUE-86-07; ISBN-2-7170-0855-1) Avail: NTIS HC E04/MF E04 CSCL 01A

Research done on the testing techniques and measurement methods to be used in the T2 pressurized cryogenic wind tunnel is described. It was found that the model temperature must be established before measuring the gust. Several rounds of cryogenic tests provided valuable experience in conducting cold flow

measurements. Cross checking was done to validate the tests. However, some experimental snags related to high unit Reynolds numbers were encountered during natural transition tests. It was found necessary to take the level of flow turbulence into account and to improve the condition of the model surfaces to maintain a laminar state in the boundary layers of most of the airfoils. Author

**N88-16674\*#** Florida Univ., Gainesville. Dept. of Engineering Sciences.

**A JET IN A CROSSFLOW Final Report, 1 Jan. 1978 - 31 Jul. 1987**

RICHARD L. FEARN 3 Mar. 1988 8 p (Contract NSG-2288) (NASA-CR-182469; NAS 1.26:182469) Avail: NTIS HC A02/MF A01 CSCL 01A

In the transition from hover to wingborn flight, V/STOL aircraft rely on the direct thrust of lift jets to supplement wing generated lift. The lifting jets interact with the flow over the aerodynamic surface to produce a complex flow around the aircraft. The simplest configuration which retains the essential characteristics of the jet/aerodynamic-surface interaction problem is a subsonic round jet exhausting perpendicularly through a large flat plate into a uniform crossflow. This configuration was studied extensively, both by experiment and by analysis. As a result, a fairly complete experiment data base exists for comparison with the numerical calculations. Research publications and presentations in this area are included. Each citation is followed by an abstract of the work. B.G.

**N88-16675\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**MACH NUMBER EFFECTS ON TRANSONIC AEROELASTIC FORCES AND FLUTTER CHARACTERISTICS**

ROSS W. MOHR, JOHN T. BATINA, and HENRY T. Y. YANG (Purdue Univ., West Lafayette, Ind.) Feb. 1988 13 p Proposed for presentation at the AIAA/ASME/ASCE/AHS/ASC 29th Structures, Structural Dynamics and Materials Conference, Williamsburg, Va. (NASA-TM-100547; NAS 1.15:100547; AIAA-88-2304) Avail: NTIS HC A03/MF A01 CSCL 01A

Transonic aeroelastic stability analysis and flutter calculations are presented for a generic transport-type wing based on the use of the CAP-TSD (Computational Aeroelasticity Program - Transonic Small Disturbance) finite-difference code. The CAP-TSD code was recently developed for transonic unsteady aerodynamic and aeroelastic analysis of complete aircraft configurations. A binary aeroelastic system consisting of simple bending and torsion modes was used to study aeroelastic behavior at transonic speeds. Generalized aerodynamic forces are presented for a wide range of Mach number and reduced frequency. Aeroelastic characteristics are presented for variations in freestream Mach number, mass ratio, and bending-torsion frequency ratio. Flutter boundaries are presented which have two transonic dips in flutter speed. The first dip is the usual transonic dip involving a bending-dominated flutter mode. The second dip is characterized by a single degree-of-freedom torsion oscillation. These aeroelastic results are physically interpreted and shown to be related to the steady state shock location and changes in generalized aerodynamic forces due to freestream Mach number. Author

**N88-16677#** Aeronautical Research Labs., Melbourne (Australia).

**A NOTE ON THE AERODYNAMIC DESIGN OF THIN PARALLEL-SIDED AEROFOIL SECTIONS**

N. POLLOCK Sep. 1987 28 p (ARL-AERO-TM-388; AR-004-551) Avail: NTIS HC A03/MF A01

There are many situations where parallel-sided airfoil sections with leading and trailing edge fairings of limited chordwise extent have advantages over conventional sections. The design of these unconventional sections was investigated using two potential flow plus boundary layer computer programs. Guidelines for the

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selection of the leading and trailing edge fairing shapes are presented. Author

**N88-16678\*#** Bolt, Beranek, and Newman, Inc., Cambridge, Mass.

**AN EXPERIMENTAL INVESTIGATION OF THE CHOPPING OF HELICOPTER MAIN ROTOR TIP VORTICES BY THE TAIL ROTOR. PART 2: HIGH SPEED PHOTOGRAPHIC STUDY Final Report, Sep. 1985 - Aug. 1987**

CHARLES M. CARY 8 Sep. 1987 62 p

(Contract NAS2-12256)

(NASA-CR-177457; NAS 1.26:177457; TM-977) Avail: NTIS HC A04/MF A01 CSCL 01A

The interaction of a free vortex and a rotor was recorded photographically using oil smoke and stroboscopic illumination. The incident vortex is normal to the plane of the rotor and crosses the rotor plane. This idealized aerodynamic experiment most nearly corresponds to helicopter flight conditions in which a tip vortex from the main rotor is incident upon the tail rotor while hovering. The high speed photographs reveal important features not observed using conventional photography where the image is the time average of varying instantaneous images. Most prominent is the strong interaction between the rotor tip vortex system and the incident vortex, resulting in the roll-up of the incident vortex around the (stronger) tip vortices and the resulting rapid destabilization of the deformed incident vortex. The viscous interaction is clearly shown also. Other forms of instabilities or wave-like behavior may be apparent from further analysis of the photographs. Author

**N88-16679\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**CFD VALIDATION EXPERIMENTS FOR INTERNAL FLOWS**

LOUIS A. POVINELLI 1988 22 p Proposed for presentation at the Symposium on Validation of Computational Fluid Dynamics, Lisbon, Portugal, 2-5 May 1988; sponsored by AGARD (NASA-TM-100797; E-3973; NAS 1.15:100797) Avail: NTIS HC A03/MF A01 CSCL 01A

Computational Fluid Dynamics (CFD) validation experiments at NASA Lewis Research Center are described. The material presented summarizes the research in three areas: Inlets, Ducts and Nozzles; Turbomachinery; and Chemically Reacting Flows. The specific validation activities are concerned with shock-boundary layer interactions, vortex generator effects, large low speed centrifugal compressor measurements, transonic fan shock structure, rotor/stator kinetic energy distributions, stator wake shedding characteristics, boundary layer transition, multiphase flow and reacting shear layers. These experiments are intended to provide CFD validation data for the internal flow fields within aerospace propulsion system components. Author

**N88-16680\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**LOADS AND AEROELASTICITY DIVISION RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS FOR FY 1987 AND PLANS FOR FY 1988**

S. C. DIXON and JAMES E. GARDNER Jan. 1988 143 p (NASA-TM-100534; NAS 1.15:100534) Avail: NTIS HC A07/MF A01 CSCL 01A

The purpose of this paper is to present the Loads and Aeroelasticity Division's research accomplishments for FY87 and research plans for FY88. The work under each Branch (technical area) is described in terms of highlights of accomplishments during the past year and highlights of plans for the current year as they relate to five year plans for each technical area. This information will be useful in program coordination with other government organizations and industry in areas of mutual interest. Author

**N88-17579** Princeton Univ., N. J.

**SOLUTION OF THE THREE-DIMENSIONAL NAVIER-STOKES EQUATIONS FOR TRANSONIC FLOW USING A MULTIGRID METHOD Ph.D. Thesis**

MOHAN JAYARAM 1987 132 p

Avail: Univ. Microfilms Order No. DA8722569

Solutions are obtained for steady, transonic flow over airplane wings by solving the three dimensional Reynolds averaged Navier-Stokes equations. Both laminar and turbulent flows, both attached and separated, are addressed. Emphasis is placed on efficiency and accuracy. The three dimensional Navier-Stokes equations are discretized by a finite volume technique. This offers flexibility in treating arbitrary geometries. A central differencing procedure is used to approximate spatial derivatives thereby ensuring second order accuracy. The resulting set of ordinary differential equations is integrated in time to reach a steady state using an explicit hybrid multistage scheme. Author

**N88-17580** Stanford Univ., Calif.

**CONTROL OF VORTICAL SEPARATION ON CONICAL BODIES Ph.D. Thesis**

NIKOS JOHN MOURTOS 1987 200 p

Avail: Univ. Microfilms Order No. DA8723056

In a variety of aeronautical applications, the flow around conical bodies at incidence is of interest. For such conical bodies, starting at moderate angles of attack, the flow separates from the lee side, forming two vortices. Although the vortex lift contribution is highly desirable, as the angle of attack increases, the vortex system becomes asymmetric, and eventually the vortices breakdown. This causes problems with stability in all directions. Thus, some control of the separation process is necessary if the vortex lift is to be exploited at higher angles of attack. The theoretical model which is used in this analysis has three parts. First, the single line vortex model is used within the framework of slender body theory to compute the outer inviscid field for specified separation lines. Next, the three-dimensional boundary layer is represented by a momentum equation for the cross flow, analogous to that for a plane boundary layer. Thirdly, control of separation is achieved by blowing tangentially from a slot located along a cone generator. For very small blowing coefficients, the separation can be postponed or suppressed completely. Dissert. Abstr.

**N88-17581\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**APPLICATION OF EMPIRICAL AND LINEAR METHODS TO VSTOL POWERED-LIFT AERODYNAMICS**

RICHARD MARGASON and RICHARD KUHN (Kuhn, Richard E., Valencia, Calif ) Feb. 1988 34 p

(NASA-TM-100048; A-88038; NAS 1.15:100048) Avail: NTIS HC A03/MF A01 CSCL 01A

Available prediction methods applied to problems of aero/propulsion interactions for short takeoff and vertical landing (STOVL) aircraft are critically reviewed and an assessment of their strengths and weaknesses provided. The first two problems deal with aerodynamic performance effects during hover: (1) out-of-ground effect, and (2) in-ground effect. The first can be evaluated for some multijet cases; however, the second problem is very difficult to evaluate for multijets. The ground-environment effects due to wall jets and fountain flows directly affect hover performance. In a related problem: (3) hot-gas ingestion affects the engine operation. Both of these problems as well as jet noise affect the ability of people to work near the aircraft and the ability of the aircraft to operate near the ground. Additional problems are: (4) the power-augmented lift due to jet-flap effects (both in- and out-of-ground effects), and (5) the direct jet-lift effects during short takeoff and landing (STOL) operations. The final problem: (6) is the aerodynamic/propulsion interactions in transition between hover and wing-borne flight. Areas where modern CFD methods can provide improvements to current computational capabilities are identified. Author

**N88-17583\*#** Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.

**BURST VORTEX/BOUNDARY LAYER INTERACTION Progress Report, 1 Sep. 1987 - 29 Feb. 1988**

P. BRADSHAW and M. NAASERI 14 Mar. 1988 27 p

(Contract NAGW-581)

(NASA-CR-182510; NAS 1.26:182510) Avail: NTIS HC A03/MF A01 CSCL 01A

Several configurations of delta wing vortex generator and boundary layer test plate were tested, and two final ones selected. Sample measurements and flow visualizations in the candidate configurations, together with more detailed measurements in one of the two final arrangements, which were selected so that a pure vortex bursts repeatedly and then interacts, in as simple fashion as possible, with a simple turbulent boundary layer, are included. It is concluded that different intensities of bursting or breakdown, like different strengths of shock wave or hydraulic jump, can be produced by minor changes of configuration. The weaker breakdowns do not produce flow reversal. The initial measurements were done with a fairly weak, but repeatable, breakdown. Basic measurements on the second final arrangement, with a stronger breakdown, are in progress. Author

**N88-17585\*#** Kuhn (Richard E.), Newport News, Va.

**RECOMMENDATIONS FOR GROUND EFFECTS RESEARCH FOR V/STOL AND STOL AIRCRAFT AND ASSOCIATED EQUIPMENT FOR LARGE SCALE TESTING**

RICHARD E. KUHN Mar. 1986 110 p

(Contract NAS2-11912)

(NASA-CR-177429; NAS 1.26:177429) Avail: NTIS HC A06/MF A01 CSCL 01A

The current understanding of the effects of ground proximity on V/STOL and STOL aircraft is reviewed. Areas covered include (1) single jet suckdown in hover, (2) fountain effects on multijet configurations, (3) STOL ground effects including the effect of the ground vortex flow field, (4) downwash at the tail, and (5) hot gas ingestion in both hover and STOL operation. The equipment needed for large scale testing to extend the state of the art is reviewed and developments in three areas are recommended as follows: (1) improve methods for simulating the engine exhaust and inlet flows; (2) develop a model support system that can simulate realistic rates of climb and descent as well as steady height operation; and (3) develop a blowing BLC ground board as an alternative to a moving belt ground board to properly simulate the flow on the ground. Author

**N88-17586\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**PROCEEDINGS OF THE CIRCULATION-CONTROL WORKSHOP, 1986**

JACK N. NIELSEN, comp. May 1987 591 p Workshop held at Moffett Field, Calif., 19-21 Feb. 1986 Original contains color illustrations

(NASA-CP-2432; A-86314; NAS 1.55:2432) Avail: NTIS HC A25/MF A01 CSCL 01A

A Circulation Control Workshop was held at NASA Ames by representatives of academia, industry, and government. A total of 32 papers were given in six technical sessions covering turbulence, circulation control airfoil theory, circulation control airfoil wing experiments, circulation control rotor theory, x-wing technology, fixed wing technology, and other concepts. The last session of the workshop was devoted to circulation control research planning.

**N88-17591\*#** Lockheed-Georgia Co., Marietta. Advanced Flight Sciences Dept.

**EVALUATION OF A RESEARCH CIRCULATION CONTROL AIRFOIL USING NAVIER-STOKES METHODS**

GEORGE D. SHREWSBURY In NASA. Ames Research Center

Proceedings of the Circulation-Control Workshop, 1986 p 115-134 May 1987 Previously announced in IAA as A87-22754

Avail: NTIS HC A25/MF A01 CSCL 01A

The compressible Reynolds time averaged Navier-Stokes equations were used to obtain solutions for flows about a two dimensional circulation control airfoil. The governing equations were written in conservation form for a body-fitted coordinate system and solved using an Alternating Direction Implicit (ADI) procedure. A modified algebraic eddy viscosity model was used to define the turbulent characteristics of the flow, including the wall jet flow over the Coanda surface at the trailing edge. Numerical results are compared to experimental data obtained for a research circulation control airfoil geometry. Excellent agreement with the experimental results was obtained. Author

**N88-17592\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**NAVIER-STOKES COMPUTATIONS FOR CIRCULATION CONTROL AIRFOILS**

THOMAS H. PULLIAM, DENNIS C. JESPERSEN, and TIMOTHY

J. BARTH In its Proceedings of the Circulation-Control Workshop, 1986 p 135-163 May 1987 Previously announced as

N86-30995

Avail: NTIS HC A25/MF A01 CSCL 01A

Navier-Stokes computations of subsonic to transonic flow past airfoils with augmented lift due to rearward jet blowing over a curved trailing edge are presented. The approach uses a spiral grid topology. Solutions are obtained using a Navier-Stokes code which employs an implicit finite difference method, an algebraic turbulence model, and developments which improve stability, convergence, and accuracy. Results are compared against experiments for no jet blowing and moderate jet pressures and demonstrate the capability to compute these complicated flows. Author

**N88-17593\*#** Analytical Methods, Inc., Redmond, Wash.

**WALL JET ANALYSIS FOR CIRCULATION CONTROL AERODYNAMICS. PART 2: ZONAL MODELING CONCEPTS FOR WALL JET/POTENTIAL FLOW COUPLING**

FRANK A. DVORAK and SANFORD M. DASH (Science Applications International Corp., Princeton, N.J.) In NASA. Ames

Research Center Proceedings of the Circulation-Control Workshop, 1986 p 165-181 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

Work currently in progress to update an existing transonic circulation control airfoil analysis method is described. Existing methods suffer from two deficiencies: the inability to predict the shock structure of the underexpanded supersonic jets; and the insensitivity of the calculation to small changes in the Coanda surface geometry. A method developed for the analysis of jet exhaust plumes in supersonic flow is being modified for the case of the underexpanded wall jet. In the subsonic case, the same wall jet model was modified to include the calculation of the normal pressure gradient. This model is currently being coupled with the transonic circulation control airfoil analysis. Author

**N88-17594\*#** Stanford Univ., Calif.

**THE FURTHER DEVELOPMENT OF CIRCULATION CONTROL AIRFOILS**

N. J. WOOD In NASA. Ames Research Center Proceedings of

the Circulation-Control Workshop, 1986 p 183-196 May 1987 Avail: NTIS HC A25/MF A01 CSCL 01A

The performance trends of circulation control airfoils are reviewed and observations are made as to where improvements in performance and expansion of the flight envelope may be feasible. A new analytically defined family of airfoils is suggested, all of which maintain the fore and aft symmetry required for stopped rotor application. It is important to recognize that any improvements

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in section capabilities may not be totally applicable to the present vehicle operation. It remains for the designers of the rotor system to reappraise the three dimensional operating environment in view of the different airfoil operating characteristics and for the airfoil definitions to be flexible while maintaining satisfactory levels of performance. Author

**N88-17595\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **ON THE EFFECT OF LEADING EDGE BLOWING ON CIRCULATION CONTROL AIRFOIL AERODYNAMICS**

B. G. MCLACHLAN *In its* Proceedings of the Circulation-Control Workshop, 1986 p 199-208 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

In the present context the term circulation control is used to denote a method of lift generation that utilizes tangential jet blowing over the upper surface of a rounded trailing edge airfoil to determine the location of the boundary layer separation points, thus setting an effective Kutta condition. At present little information exists on the flow structure generated by circulation control airfoils under leading edge blowing. Consequently, no theoretical methods exist to predict airfoil performance under such conditions. An experimental study of the flow field generated by a two dimensional circulation control airfoil under steady leading and trailing edge blowing was undertaken. The objective was to fundamentally understand the overall flow structure generated and its relation to airfoil performance. Flow visualization was performed to define the overall flow field structure. Measurements of the airfoil forces were also made to provide a correlation of the observed flow field structure to airfoil performance. Preliminary results are presented, specifically on the effect on the flow field structure of leading edge blowing, alone and in conjunction with trailing edge blowing. Author

**N88-17596\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **PRESSURE DISTRIBUTIONS AND OIL-FLOW PATTERNS FOR A SWEEP CIRCULATION-CONTROL WING**

EARL R. KEENER, DWIGHT T. SANDERFER, and NORMAN J. WOOD (Stanford Univ., Calif.) *In its* Proceedings of the Circulation-Control Workshop, 1986 p 209-238 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

Pressure distributions and photographs of oil flow patterns are presented for a circulation control wing. The model was an aspect ratio four semispan wing mounted on the side wall of the NASA Ames Transonic Wind Tunnel. The airfoil was a 20 percent thick ellipse, modified with circular leading and trailing edges of 4 percent radius, and had a 25.4 cm constant chord. This configuration does not represent a specific wing design, but is generic. A full span, tangential, rearward blowing, circulation control slot was incorporated ahead of the trailing edge on the upper surface. The wing was tested at Mach numbers from 0.3 to 0.75 at sweep angle of 0 to 45 deg with internal to external pressure ratios of 1.0 to 3.0. Lift and pitching moment coefficients were obtained from measured pressure distributions at five span stations. When the conventional corrections resulting from sweep angle are applied to the lift and moment of circulation control sections, no additional corrections are necessary to account for changes in blowing efficiency. This is demonstrated for an aft sweep angle of 45 deg. An empirical technique for estimating the downwash distribution of a swept wing was validated. Author

**N88-17597\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **BOUNDARY-LAYER AND WAKE MEASUREMENTS ON A SWEEP, CIRCULATION-CONTROL WING**

FRANK W. SPAID (McDonnell-Douglas Research Labs., St. Louis, Mo.) and EARL R. KEENER *In its* Proceedings of the Circulation-Control Workshop, 1986 p 239-266 May 1987

Previously announced in IAA as A87-22449

Avail: NTIS HC A25/MF A01 CSCL 01A

Wind tunnel measurements of boundary layer and wake velocity profiles and surface static pressure distributions are presented for

a swept, circulation control wing. The model is an aspect ratio four semispan wing mounted on the tunnel side wall as a sweep angle of 45 deg. A full span, tangential, rearward blowing, circulation control slot is located ahead of the trailing edge on the upper surface. Flow surveys were obtained at mid-semispan at freestream Mach numbers of 0.425 and 0.70. Boundary layer profiles measured on the forward portions of the wing are approximately streamwise and two dimensional. The flow in the vicinity of the jet exit and in the near wake is highly three dimensional. The jet flow near the slot on the Coanda surface is directed normal to the slot. Near wake surveys show large outboard flows at the center of the wake. At Mach 0.425 and a 5 deg angle of attack, a range of jet blowing rates was found for which an abrupt transition from incipient separation to attached flow occurs in the boundary layer upstream of the slot. The variation in the lower surface separation location with blowing rate was determined from the boundary layer measurements at Mach 0.425. Author

**N88-17598\*#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.

### **WIND TUNNEL STUDIES OF CIRCULATION CONTROL ELLIPTICAL AIRFOILS**

M. E. FRANKE and J. K. HARVELL *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 267-287 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

Effects of blown jets on the lift and drag of cambered elliptical airfoils are described. Performance changes due to a splitter plate attached to the lower surface of an elliptical airfoil near the trailing edge with and without blowing are indicated. Lift and drag characteristics of airfoils with two blown jets are compared with airfoils with single blowing jets. Airfoil designs that vary the location of a second jet relative to a fixed jet are described. Author

### **N88-17600\*#** Maryland Univ., College Park. **FLAP-LAG-TORSION AEROELASTIC STABILITY OF A CIRCULATION CONTROL ROTOR IN FORWARD FLIGHT**

INDERJIT CHOPRA and CHANG-HO HONG *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 315-352 May 1987 Sponsored in part by David Taylor Naval Ship Research and Develop Center (Contract N0016785-M-4464)

Avail: NTIS HC A25/MF A01 CSCL 01A

The aeroelastic stability of a circulation control rotor blade undergoing three degrees of motion (flap, lag, and torsion) is investigated in forward flight. Quasi-steady strip theory is used to evaluate the aerodynamics forces; and the airfoil characteristics are from data tables. The propulsive and the auxiliary power trims are calculated from vehicle and rotor equilibrium equations through the numerical integration of element forces in azimuth as well as in radial directions. The nonlinear time dependent periodic blade response is calculated using an iterative procedure based on Floquet theory. The periodic perturbation equations are solved for stability using Floquet transition matrix theory. The effects of several parameters on blade stability are examined, including advance ratio, collective pitch, thrust level, shaft tilt, structural stiffness variation, and propulsive and auxiliary power trims. Author

**N88-17602\*#** Naval Ship Research and Development Center, Bethesda, Md.

### **ANALYSIS OF A FIXED-PITCH X-WING ROTOR EMPLOYING LOWER SURFACE BLOWING**

ALAN W. SCHWARTZ and ERNEST O. ROGERS *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 363-380 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

Lower surface blowing (LSB) is investigated as an alternative to the variable blade pitch requirement for the X-wing Circulation Control (CC) rotor concept. Addition trailing edge blowing slots on the lower surfaces of CC airfoils provide a bidirectional lift capability that effectively doubles the control range. The operational requirements of this rotor system are detailed and compared to the projected performance attributes of LSB airfoils. Analysis shows

that, aerodynamically, LSB supplies a fixed pitch rotor system with the equivalent lift efficiency and rotor control of present CC rotor designs that employ variable blade pitch. Aerodynamic demands of bidirectional lift production are predicted to be within the capabilities of current CC airfoil design methodology. Emphasis in this analysis is given to the high speed rotary wing flight regime unique to stoppable rotor aircraft. The impact of a fixed pitch restriction in hover and low speed flight is briefly discussed.

Author

**N88-17603\*# Sikorsky Aircraft, Stratford, Conn.  
PREDICTION OF AEROELASTIC RESPONSE OF A MODEL  
X-WING ROTOR**

ROBERT DOPHER and JAMES E. DUH *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 383-398 May 1987 Previously announced in IAA as A88-20000

Avail: NTIS HC A25/MF A01 CSCL 01A

The rotorcraft dynamics analysis was used to predict the aeroelastic responses of a representative X-wing model with a 10 ft diameter rotor. The aeroelastic methodology used and the tests and assumptions involved are reviewed. Results are reported on the findings concerning control power and higher harmonic control in hover, transition flight, vibratory loads at forward speed, and responses in conversion. It is concluded that the analysis can give satisfactory predictions of X-wing behavior.

E.R.

**N88-17604\*# Sikorsky Aircraft, Stratford, Conn.  
X-WING POTENTIAL FOR NAVY APPLICATIONS**

ARTHUR W. LINDEN and JAMES C. BIGGERS (Naval Ship Research and Development Center, Bethesda, Md.) *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 399-425 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

The X-wing provides a VTOL aircraft which has a low disc loading hover capability, similar to a conventional helicopter, combined with a high subsonic cruise speed capability. As a result, it hovers with low fuel flow rates which make extended hover duration missions practical. Its low hover power requirements also permit hovering and low speed flight on only one engine in a high speed twin engine aircraft design. The NASA DARPA Sikorsky RSRA X-wing program developed flightworthy X-wing hardware. All design activity and the majority of its component fabrication is completed. A design study was performed on an X-wing concept demonstrator aircraft which is based on the RSRA X-wing components, combined with two MTE engines and a new fuselage.

Author

**N88-17605\*# National Aeronautics and Space Administration.  
Ames Research Center, Moffett Field, Calif.  
REDUCTION OF TILT ROTOR DOWNLOAD USING  
CIRCULATION CONTROL**

FORT F. FELKER, JEFFREY S. LIGHT, and ROBERT E. FAYE (California Polytechnic State Univ., San Luis Obispo.) *In* its Proceedings of the Circulation-Control Workshop, 1986 p 429-447 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

The effect of boundary layer control blowing on the download of a wing in the wake of a hovering rotor was measured in a small scale experiment. The objective was to evaluate the potential of boundary layer control blowing for reducing tilt rotor download. Variations were made in rotor thrust coefficient, blowing pressure ratio, and blowing slot height. The effect of these parameter variations on the wing download and wing surface pressures is presented. The boundary layer control blowing caused reductions in the wing download of 25 to 55 percent.

Author

**N88-17606\*# Grumman Aerospace Corp., Bethpage, N.Y.  
AN AERODYNAMIC COMPARISON OF BLOWN AND  
MECHANICAL HIGH LIFT AIRFOILS**

JOHN E. CARR *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 449-477 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

Short takeoff and landing (STOL) performance utilizing a circulation control airfoil was successfully demonstrated on the A-6 CCW (circulation control wing). Controlled flight at speeds as slow as 67 knots was demonstrated. Takeoff ground run and liftoff speed reductions in excess of 40 and 20 percent respectively were achieved. Landing ground roll and approach speeds were similarly reduced. The technology demonstrated was intended to be useable on modern high performance aircraft. STOL performance would be achieved through the combination of a 2-D vectored nozzle and a circulation control type of high lift system. The primary objective of this demonstration was to attain A-6 CCW magnitude reductions in takeoff and landing flight speed and ground distance requirements using practical bleed flow rates from a modern turbofan engine for the blown flap system. Also, cruise performance could not be reduced by the wing high lift system. The A-6 was again selected as the optimum demonstration vehicle. The procedure and findings of the study to select the optimum high lift wing design are documented. Some findings of a supercritical airfoil and a comparison of 2-D and 3-D results are also described.

Author

**N88-17607\*# Naval Ship Research and Development Center,  
Bethesda, Md.  
FIXED WING CCW AERODYNAMICS WITH AND WITHOUT  
SUPPLEMENTARY THRUST DEFLECTION**

J. H. NICHOLS and M. J. HARRIS *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 479-489 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01A

The concept of circulation control was successfully demonstrated in flight using an A-6 aircraft. Circulation control can provide an aircraft with STOL performance of heavy lift capability. For ship based Naval aircraft the lower takeoff and landing velocities result in reduced deck gear and wind over the deck requirements. Circulation control airfoils can be mechanically less complex and lightweight compared to multi-element high lift airfoils.

Author

**N88-17610\*# West Virginia Univ., Morgantown. Dept. of  
Mechanical and Aerospace Engineering.**

**CIRCULATION CONTROL STOL AIRCRAFT DESIGN ASPECTS**  
JOHN L. LOTH *In* NASA. Ames Research Center, Proceedings of the Circulation-Control Workshop, 1986 p 569-588 May 1987 (Contract MDA-53-108444630)

Avail: NTIS HC A25/MF A01 CSCL 01A

Since Davidson patented Circulation Control Airfoils in 1960, there have been only 2 aircraft designed and flown with circulation control (CC). Designing with CC is complex for the following reasons: the relation between lift increase and blowing momentum is nonlinear; for good cruise performance one must change the wing geometry in flight from a round to a sharp trailing edge. The bleed air from the propulsion engines or an auxiliary compressor, must be used efficiently. In designing with CC, the propulsion and control aspects are just as important as aerodynamics. These design aspects were examined and linearized equations are presented in order to facilitate a preliminary analysis of the performance potential of CC. The thrust and lift requirements for takeoff make the calculated runway length very sensitive to the bleed air ratio. Thrust vectoring improves performance and can offset nose down pitching moments. The choice of blowing jet to free stream velocity ratio determines the efficiency of applying bleed air power.

Author

## 02 AERODYNAMICS

**N88-17611#** Naval Postgraduate School, Monterey, Calif.  
**INVESTIGATION OF DYNAMIC STALL USING LDV (LASER DOPPLER VELOCIMETRY): MEAN FLOW STUDIES M.S. Thesis**

RICHARD RANDOLPH RYLES Sep. 1987 80 p Sponsored in part by Army Research Office and AFOSR (AD-A187629) Avail: NTIS HC A05/MF A01 CSCL 20D

This thesis lays the foundation for the dynamic stall investigation being conducted at the Fluid Mechanics Laboratory at NASA-Ames Research Center. Using existing optical and electrical equipment, a new dedicated Micro-VAX computer and Labstar software, an Indraft transonic wind tunnel and able technicians to make the proper interface hardware, the project came together in a new test facility at the Fluid Mechanics Laboratory. The goal of the thesis was to obtain both qualitative and quantitative information about the wake profiles of an airfoil in steady state operations at varying angles of attack and tunnel conditions. To accomplish this task, schlieren photography was used to obtain a qualitative picture of the flow field. With this information, a two component Laser Doppler Velocimeter was set up to accurately measure the velocity profiles that correspond to the schlieren photographs. Once this preliminary work is completed, the same apparatus will be used to further investigate the unsteady dynamic stall phenomenon. GRA

**N88-17612\*#** Kansas Univ. Center for Research, Inc., Lawrence. Flight Research Lab.

**CALCULATION OF AERODYNAMIC CHARACTERISTICS OF AIRPLANE CONFIGURATIONS AT HIGH ANGLES OF ATTACK Final Report**

J. B. TSENG and C. EDWARD LAN Sep. 1987 115 p (Contract NAG1-635) (NASA-CR-182541; NAS 1.26:182541; CRINC-FRL-730-1) Avail: NTIS HC A06/MF A01 CSCL 01A

Calculation of the longitudinal and lateral-directional aerodynamic characteristics of airplanes by the VORSTAB code is examined. The numerical predictions are based on the potential flow theory with the corrections of high angle-of-attack phenomena, i.e., vortex flow and boundary layer separation effects. To account for the vortex flow effect, vortex lift, vortex action point, augmented vortex lift, and vortex breakdown effect through the method of suction analogy are included. The effect of boundary layer separation is obtained by matching the nonlinear section data with the 3-D lift characteristics iteratively. Through correlation with results for nine fighter configurations, it is concluded that reasonably accurate prediction of longitudinal and static lateral-directional aerodynamics can be obtained with the VORSTAB code up to an angle of attack at which wake interference and forebody vortex effect are not important. Possible reasons for discrepancy at high angles of attack are discussed. Author

**N88-17613#** National Aerospace Lab., Tokyo (Japan).  
**LIFTING-SURFACE THEORY OF OSCILLATING PROPELLERS IN COMPRESSIBLE FLOW**

TERUO ICHIKAWA Aug. 1987 25 p In JAPANESE; ENGLISH summary (NAL-TR-943; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Linear simultaneous integral equations are derived for computing aerodynamic loads of oscillating propellers in a compressible flow. It is shown that the integral over the boundary surface at infinity in Green's formula vanishes by virtue of conditions at infinity which must be satisfied by the acceleration potential and the fundamental solution of the adjoint governing equation. A study is also made on the Mach cone in supersonic sections regarded as a characteristic surface belonging to the steady case governing differential equation. This makes it possible to distinguish subsonic and supersonic trailing edges. Author

**N88-17614\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**A TRANSONIC-SMALL-DISTURBANCE WING DESIGN METHODOLOGY**

PAMELA S. PHILLIPS, EDGAR G. WAGGONER, and RICHARD L. CAMPBELL Mar. 1988 32 p (NASA-TP-2806; L-16393; NAS 1.60:2806) Avail: NTIS HC A03/MF A01 CSCL 01A

An automated transonic design code has been developed which modifies an initial airfoil or wing in order to generate a specified pressure distribution. The design method uses an iterative approach that alternates between a potential-flow analysis and a design algorithm that relates changes in surface pressure to changes in geometry. The analysis code solves an extended small-disturbance potential-flow equation and can model a fuselage, pylons, nacelles, and a winglet in addition to the wing. A two-dimensional option is available for airfoil analysis and design. Several two- and three-dimensional test cases illustrate the capabilities of the design code. Author

**N88-17615\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**SUPERSONIC AERODYNAMICS OF DELTA WINGS**

RICHARD M. WOOD Mar. 1988 106 p (NASA-TP-2771; L-16212; NAS 1.60:2771) Avail: NTIS HC A06/MF A01 CSCL 01A

Through the empirical correlation of experimental data and theoretical analysis, a set of graphs has been developed which summarize the inviscid aerodynamics of delta wings at supersonic speeds. The various graphs which detail the aerodynamic performance of delta wings at both zero-lift and lifting conditions were then employed to define a preliminary wing design approach in which both the low-lift and high-lift design criteria were combined to define a feasible design space. Author

## 03

### AIR TRANSPORTATION AND SAFETY

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

**A88-27640#**  
**DESIGN DEFICIENCY - PROBABLE CAUSE OF FATAL AIRCRAFT ACCIDENT**

P. TYAGI Aviation Medicine, vol. 30, June 1986, p. 38-40.

This paper describes an aircraft accident where a design deficiency was the probable primary cause. In the case described, an accident occurred immediately after take off, when the sleeve of the pilot, whose hand moved blindly to select flap switches, inadvertently pulled up the HP cock handle, causing the engine to flame out. The pilot landed successfully on a lake, unstrapped himself, disconnected the oxygen tube, and removed his oxygen mask, but has drowned in weed-infested water. As a result of an investigation, suitable modifications to provide a safety guard for the HP cock handle, when in fully down position, were recommended together with the use of an inflatable vest while flying and a provision of rope ladder and other flotation gear, since the only forced-landing area for take off emergencies was close to the lake. I.S.

**N88-16635\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**HELICOPTER CRASHWORTHINESS RESEARCH PROGRAM**

GARY L. FARLEY, RICHARD L. BOITNOTT (Army Research and Technology Labs., Fort Eustis, Va.), and HUEY D. CARDEN *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 606-655 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 01C

Results are presented from the U.S. Army-Aerostructures Directorate/NASA-Langley Research Center joint research program on helicopter crashworthiness. Through the on-going research program an in-depth understanding was developed on the cause/effect relationships between material and architectural variables and the energy-absorption capability of composite material and structure. Composite materials were found to be efficient energy absorbers. Graphite/epoxy subfloor structures were more efficient energy absorbers than comparable structures fabricated from Kevlar or aluminum. An accurate method predicting the energy-absorption capability of beams was developed. Author

**N88-16641\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**NASA'S ROTORCRAFT ICING RESEARCH PROGRAM**

ROBERT J. SHAW, JOHN J. REINMANN, and THOMAS L. MILLER (Sverdrup Technology, Inc., Cleveland, Ohio.) *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 802-832 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 01C

The objective of the NASA aircraft icing research program is to develop and make available icing technology to support the needs and requirements of industry for all weather aircraft designs. While a majority of the technology being developed is viewed to be generic (i.e., appropriate to all vehicle classes), vehicle specific emphasis is being placed on the helicopter due to its unique icing problems. In particular, some of the considerations for rotorcraft icing are indicated. The NASA icing research program emphasizes technology development in two key areas: ice protection concepts and icing simulation (analytical and experimental). The NASA research efforts related to rotorcraft icing in these two technology areas will be reviewed. Author

**N88-16682#** Federal Aviation Administration, Oklahoma City, Okla. Civil Aeromedical Inst.

**SUDDEN IN-FLIGHT INCAPACITATION IN GENERAL AVIATION Final Report**

CHARLES F. BOOZE, JR. Aug. 1987 12 p  
(AD-A187044; DOT/FAA/AM-87/7) Avail: NTIS HC A03/MF A01 CSCL 06E

Incapacitation in the general aviation flight environment is a matter of utmost concern to the Federal Aviation Administration since the likelihood of accident is greater due to lack of redundant pilot skills in most instances. The purpose of this study was to appraise the adequacy of medical standards in minimizing the risk of sudden incapacitation. This study considers NTSB data and postcrash medical data received by the Medical Statistical Section of the Civil Aeromedical Institute (CAMI), Oklahoma City, Oklahoma, during the time period from 1975 to the present and other related literature to estimate the probability of incapacitation in general aviation. The occurrence of incapacitation for obvious medical reasons is less than would be expected based on general population morbidity/mortality data; however, the need for continued vigilance in certification and education regarding flying with known or suspected medical problems is emphasized. GRA

**N88-16683#** National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.

**VERIFICATION OF OBSTACLE ACCOUNTABILITY AREAS USING A SIMPLE MATHEMATICAL MODEL. PART 1: DESCRIPTION OF GENERAL MODEL AND APPLICATION FOR A SPECIFIC CASE**

G. MOEK 2 May 1985 54 p  
(Contract RB-RLD-1985-2.1/VZ)  
(NLR-TR-85069-U; ETN-88-90184) Avail: NTIS HC A04/MF A01

A probabilistic model for the lateral displacement of an aircraft after the occurrence of an engine failure during take-off is described. A lateral boundary is calculated, for any point of time after the engine failure, such that the probability of being within the (two sided) lateral boundary meets a specified value. Probability distributions for the three model parameters are considered. The model is elaborated for a specific set of probability distributions. The resulting lateral boundaries are compared with the present ICAO annex 6 obstacle accountability area. The duration of the (deterministic) first phase, when in the range of 10 to 15 sec does not significantly influence the magnitude of the computed boundary. The magnitude of the angle between flight direction and runway center line and the aircraft speed, however, have a considerable effect on the magnitude of the boundary. ESA

**N88-16684** Civil Aviation Authority, London (England). Safety Data and Analysis Unit.

**ANALYSIS OF BIRD STRIKES TO UK REGISTERED AIRCRAFT 1985 (CIVIL AIRCRAFT OVER 5700 KG MAXIMUM WEIGHT)**

J. THORPE Sep. 1987 20 p  
(CAA-PAPER-87012; ISBN-0-86039-323-2; ISSN-0269-4956; ETN-88-91517) Avail: Issuing Activity

Bird strikes reported throughout the world in 1985 by UK airlines were analyzed. The analysis includes strike rates for aircraft types and operators based on aircraft movements. It also covers aerodromes, bird species, and effect of strike. Strike rate in 1985 is slightly less than in 1984. Gulls (*Larus* spp.) were involved in 39 percent of incidents where the bird species were identified. The major effect was damage to 20 engines, and there were 5 cases in which more than 1 engine on an aircraft suffered ingestion. ESA

**N88-17616\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**AIRBORNE WIND SHEAR DETECTION AND WARNING SYSTEMS: FIRST COMBINED MANUFACTURERS' AND TECHNOLOGISTS' CONFERENCE**

AMOS A. SPADY, JR., comp., ROLAND L. BOWLES, comp., and HERBERT SCHLICKENMAIER, comp. (Federal Aviation Administration, Washington, D.C.) Jan. 1988 558 p Conference held in Hampton, Va., 22-23 Oct. 1987  
(NASA-CP-10006; NAS 1.55:10006; DOT/FAA/PS-88/7) Avail: NTIS HC A24/MF A01 CSCL 01C

The purpose of the meeting was to transfer significant, ongoing results gained during the first year of the joint NASA/FAA Airborne Wind Shear Program to the technical industry and to pose problems of current concern to the combined group. It also provided a forum for manufacturers to review forward-looking technology concepts and for technologists to gain an understanding of FAA certification requirements and the problems encountered by the manufacturers during the development of airborne equipment.

**N88-17618\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**RESPONSE OF WIND SHEAR WARNING SYSTEMS TO TURBULENCE WITH IMPLICATION OF NUISANCE ALERTS**

ROLAND L. BOWLES *In its* Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 67-86 Jan. 1988  
Avail: NTIS HC A24/MF A01 CSCL 01C

The objective was to predict the inherent turbulence response characteristics of candidate wind shear warning system concepts and to assess the potential for nuisance alerts. Information on

### 03 AIR TRANSPORTATION AND SAFETY

the detection system and associated signal processing, physical and mathematical models, wind shear factor root mean square turbulence response and the standard deviation of the wind shear factor due to turbulence is given in vugraph form. R.J.F.

**N88-17619\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

#### **INVESTIGATION OF THE INFLUENCE OF WIND SHEAR ON THE AERODYNAMIC CHARACTERISTICS OF AIRCRAFT USING A VORTEX-LATTICE METHOD**

DAN D. VICROY *In its* Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 91-136 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

The objective was to investigate and characterize the aerodynamic effect of shear flow through a series of sensitivity studies of the wind velocity gradients and wing planform geometry parameters. The wind shear effect was computed using a modified vortex-lattice computer program and characterized through the formulation of wind shear aerodynamic coefficients. The magnitude of the aerodynamic effect was demonstrated by computing the resultant change in the aerodynamics of a conventional wing and tail combination on a fixed flight path through a simulated microburst. The results of the study indicate that a significant amount of the control authority of an airplane may be required to counteract the wind shear induced forces and moments in the microburst environment. Author

**N88-17620\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

#### **WINDSHEAR WARNING AEROSPATIALE APPROACH**

J. L. BONAFE *In its* Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 137-163 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Vugraphs and transcribed remarks of a presentation on Aerospace's approach to windshear warning systems are given. Information is given on low altitude wind shear probability, wind shear warning models and warning system false alarms. R.J.F.

**N88-17621\*#** Sundstrand Data Control, Inc., Redmond, Wash.  
**WINDSHEAR DETECTION EFFECT OF STATIC AIR TEMPERATURE BIAS**

HOWARD GLOVER *In NASA*. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 165-175 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Data in vugraph form is given on vertical winds, atmospheric temperature bias output and simulation with and without temperature bias. A block diagram of a windshear detection algorithm is given. R.J.F.

**N88-17622\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

#### **AIRBORNE DOPPLER RADAR TECHNOLOGY FOR WIND SHEAR DETECTION**

*In its* Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 177-181 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

The objectives of the Airborne Doppler Radar Technology Development Program, the technical approach and program status are given in vugraph form. R.J.F.

**N88-17628\*#** Turbulence Prediction Systems, Boulder, Colo.

#### **INFRARED LOW-LEVEL WIND SHEAR WORK**

PAT ADAMSON *In NASA*. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 283-321 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Results of field experiments for the detection of clear air disturbance and low level wind shear utilizing an infrared airborne system are given in vugraph form. The hits, misses and nuisance alarms scores are given. Information is given on the infrared spatial resolution technique. The popular index of aircraft hazard ( $F = WX$  over  $g - VN$  over  $AS$ ) is developed for a remote temperature sensor. R.J.F.

**N88-17629\*#** Delco Systems Operations, Milwaukee, Wis.

#### **FORWARD LOOKING WIND SHEAR DETECTION Status Report, 22 Oct. 1987**

*In NASA*. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 323-334 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Information on forward looking wind shear detection is presented in vugraph form. Information is given on system concept development, signal characterization, the field test program, typical radiance fluctuations vs time and radiometric temperatures vs azimuth headings. R.J.F.

**N88-17630\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

#### **SIMULATOR INVESTIGATION OF WIND SHEAR RECOVERY TECHNIQUES M.S. Thesis - George Washington Univ.**

DAVID A. HINTON *In its* Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 335-363 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

The objective was the development of practical flight procedures and guidance for near-optimal trajectories during inadvertent wind shear encounters following takeoff. The approach was to conduct preliminary development of candidate strategies using batch simulation of the point mass B737-100 performance model and to evaluate candidate guidance strategies in piloted, real time, six degrees of freedom simulation. R.J.F.

**N88-17631\*#** Boeing Commercial Airplane Co., Seattle, Wash. Flight Deck Research.

#### **CREW INTERFACE WITH WINDSHEAR SYSTEMS**

DAVE CARBAUGH *In NASA*. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 365-397 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

A review is given of the areas within Boeing that are working on the NASA contract to conduct windshear studies. A synopsis is given of the work that Boeing Flight Deck Research is doing. A short review of nuisance and alerts is given in light of upcoming forward look technology. R.J.F.

**N88-17633\*#** National Center for Atmospheric Research, Boulder, Colo. Atmospheric Technology Div.

#### **THE ADVANCED LOW-LEVEL WINDSHEAR ALERT SYSTEM OPERATIONAL DEMONSTRATION RESULTS, SUMMER, 1987, DENVER STAPLETON INTERNATIONAL AIRPORT**

JAMES MOORE *In NASA*. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 481-506 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Operational results of the Advanced Low-Level Windshear Alert System operational demonstration results are presented in vugraph form and are followed by a transcribed question and answer session. R.J.F.

**N88-17635\*#** National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.

**ARE WINDSHEAR TRAINING AID RECOMMENDATIONS APPROPRIATE FOR OTHER THAN LARGE JET TRANSPORTS? PILOT PROCEDURES: SHEAR MODELS**

R. S. BRAY *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 517-524 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Information is given in vugraph form on pilot procedures in windshear, typical winds in a downburst, a downburst encounter at takeoff by a large jet transport and a light turboprop twin, and a comparison of pitch algorithms in an approach encounter with downburst shear. It is observed that the light turboprop appears no less tolerant of a downburst encounter than the large jet.

R.J.F.

**N88-17636\*#** Federal Aviation Administration, Seattle, Wash.

**AIRWORTHINESS CONSIDERATIONS**

RAY STOER *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 525-531 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 01C

Guidance is provided for the airworthiness approval of both annunciation only and annunciation with guidance airborne windshear warning systems. Characteristics of a comprehensive certification plan, the criticality of certain system failure cases for windshear warning with and without escape guidance, software based systems, and probability analysis are among the topics covered.

R.J.F.

**N88-17638#** National Transportation Safety Board, Washington, D. C. Bureau of Safety Program.

**ANNUAL REVIEW OF AIRCRAFT ACCIDENT DATA: US AIR CARRIER OPERATIONS CALENDAR YEAR 1985**

27 Nov. 1987 121 p  
(PB88-135843; NTSB/ARC-87/03) Avail: NTIS HC A06/MF A01 CSCL 01C

The record of aviation accidents involving revenue operations of U.S. Air Carriers including Commuter Air Carriers and On Demand Air Taxis for calendar year 1985 is presented. The report is divided into three major sections according to federal regulations under which the flight was conducted: 14 CFR 121, 125, 127, Scheduled 14 CFR 135, or Nonscheduled 14 CFR 135. In each section of the report tables are presented to describe the losses and characteristics of the 1985 accidents to enable comparison with prior years.

Author

**N88-17639#** National Transportation Safety Board, Washington, D. C. Bureau of Accident Investigation.

**AIRCRAFT ACCIDENT/INCIDENT, NEWARK, NEW JERSEY, NOVEMBER 13, 1986 Summary Report**

30 Dec. 1987 14 p  
(NTSB/AAR-87/04-SUMM) Avail: NTIS HC A03/MF A01

A summary is presented of an aircraft accident investigated by the National Transportation Safety Board. The accident location and date is Newark, New Jersey, November 13, 1986. Author

**AIRCRAFT COMMUNICATIONS AND NAVIGATION**

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

**A88-25755**

**RAY ANALYSIS OF A CLASS OF HYBRID CYLINDRICAL AIRCRAFT WINGS**

R. M. JHA, S. A. BOKHARI, V. SUDHAKAR, and P. R. MAHAPATRA (Indian Institute of Science, Bangalore, India) Electronics Letters (ISSN 0013-5194), vol. 24, Jan. 7, 1988, p. 21, 22.

With the growing trend toward the utilization of higher frequencies of the electromagnetic spectrum, aircraft wings have become electrically large scatterers, and their curvature and thickness can no longer be ignored in the mutual coupling calculations between antennas located over them. A realistic hybrid quadric cylinder model is developed here for an aircraft wing of finite thickness. A surface ray treatment in closed form is used, permitting direct evaluation of mutual coupling between antennas located arbitrarily on the wing.

C.D.

**A88-27363**

**TRACKING AIRCRAFT BY ACOUSTIC SENSORS - MULTIPLE HYPOTHESIS APPROACH APPLIED TO POSSIBLY UNRESOLVED MEASUREMENTS**

SHOZO MORI, KUO-CHU CHANG, and CHEE-YEE CHONG (Advanced Decision Systems, Mountain View, CA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1099-1105. refs (Contract MDA903-86-C-0011)

Poor resolution of acoustic sensors frequently lead to merged measurements for closely spaced targets. This paper considers tracking low-altitude aircraft by a network of acoustic sensors. Merging measurement outputs from sensors are probabilistically analyzed. A multiple hypothesis approach is then used to derive an algorithm for tracking the targets. The likelihood functions used in hypothesis evaluation are derived assuming two-way merging and a simulated example is used to illustrate the algorithm.

Author

**A88-27412**

**DISTRIBUTED MIXED SENSOR AIRCRAFT TRACKING**

RICHARD T. LACOSS (MIT, Lexington, MA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1827-1830. DARPA-sponsored research.

A combination of geographically distributed, small acoustic arrays, and imaging sensors can be used to detect passively and track low-flying aircraft. Detection and tracking algorithms developed to illustrate this concept have been developed and demonstrated in real-time using an experimental test bed. This paper describes the algorithms, the test bed system, and the experimental results.

C.D.

**A88-27413**

**TRACKING MULTIPLE AIR TARGETS WITH DISTRIBUTED ACOUSTIC SENSORS**

CHEE-YEE CHONG, KUO-CHU CHANG, and SHOZO MORI (Advanced Decision Systems, Mountain View, CA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1831-1836. refs (Contract ARPA ORDER 4272-07; MDA903-86-C-0011)

The tracking of multiple air targets by a network of distributed acoustic sensor/processor nodes is considered. Since each sensor measures only the acoustic azimuths of the targets, cooperation among nodes in the distributed sensor network (DSN) is needed. A multiple-hypothesis approach to distributed tracking is used. Each

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sensor/processor forms hypotheses consisting of local azimuth and azimuth rate tracks for targets. When the nodes communicate, hypotheses consisting of global position and velocity tracks are then formed. Simulation results for a network of several nodes are presented to illustrate the algorithms. Author

**A88-27587#**

### **AVSAT - A NEW GLOBAL SATELLITE SYSTEM FOR AIRCRAFT COMMUNICATIONS**

DONALD K. DEMENT (Aeronautical Radio, Inc., Annapolis, MD) IN: AIAA International Communication Satellite Systems Conference, 12th, Arlington, VA, Mar. 13-17, 1988, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 526-534. refs (AIAA PAPER 88-0846)

A global aeronautical satellite communications system is now a practical and needed development. It will enable improved operations worldwide for both commercial and private aircraft and provide new services for their crew and passengers. Leading members of industry and regulatory bodies worldwide have joined forces to define such a global system. Plans call for initiation of a thin-route data operation in 1989, upgrading to establish voice communications via shared spot-beam transponders launched on other satellites, and deploying six dedicated multichannel satellites by 1994. The needs, users, and characteristics of such a system are described, and steps to achieve its operational deployment are shown to be under way. Author

**A88-27599#**

### **WORLD-WIDE AERONAUTICAL SATELLITE COMMUNICATIONS**

PETER WOOD and KEITH SMITH (International Maritime Satellite Organization, London, England) IN: AIAA International Communication Satellite Systems Conference, 12th, Arlington, VA, Mar. 13-17, 1988, Technical Papers . Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 603-611. (AIAA PAPER 88-0865)

The aeronautical industry's interest in satellite communications goes back more than twenty-five years. Many tests and demonstrations have confirmed the feasibility of using satellites for both voice and data communications with aircraft. However, for most of this time, the high costs associated with the introduction of a satellite communication system dedicated to aeronautical services have presented the introduction of an operational system. In contrast, satellite communications for maritime services have been in general use for many years, and have proved to be commercially successful. The introduction of new, higher capacity, satellites capable of serving both maritime and aeronautical users now make it possible for operational aeronautical satellite services to be introduced. Within the next year, communications for air traffic services, aeronautical operational and administrative communications, and public correspondence (telephone) will be available on a world-wide basis. Author

**N88-16686#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Hauptabteilung Verkehrsforschung.

### **ADDITIONAL INVESTIGATIONS IN LANDING PROCESS OF AIRCRAFT: TEST DISTRIBUTIONS**

HANNS-JUERGEN PETERS Jun. 1987 76 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1099) (DFVLR-MITT-87-13; ISSN-0176-7739; ETN-88-91452) Avail: NTIS HC A05/MF A01; DFVLR, Cologne, Fed. Republic of Germany DM 25.50

The landing times for the 10 German civil airports, without waiting times due to aircraft allocations to holding areas, were investigated using a simulation model for the landing process. Test distributions were developed. Results are synthetic landing time distributions with waiting times, the adaptation of which to the empirical landing time distribution was evaluated using the Chi-square test. Further improvements of the adaptation of the simulated distribution to the empirical one can be obtained by

structural changes of the test distribution, e.g., by limitation of the maximum landing time. ESA

**N88-16687\*#** Ohio State Univ., Columbus. Dept. of Electrical Engineering.

### **A STUDY OF THE TCAS 2 COLLISION AVOIDANCE SYSTEM MOUNTED ON A BOEING 737 AIRCRAFT**

B. GRANDCHAMP, W. D. BURNSIDE, and R. G. ROJAS Dec. 1987 175 p (Contract NSG-1498) (NASA-CR-182457; NAS 1.26:182457; TR-716199-10) Avail: NTIS HC A08/MF A01 CSCL 17G

The purpose of this report is to determine the effects of scattering from major aircraft structures on the TCAS 2 collision avoidance system mounted on a Boeing 737. It is found that the major source of scattering for angles of observation above the horizon is the vertical stabilizer and that its effect may be greatly reduced by mounting the TCAS 2 array close to the nose of the aircraft. In addition, by mounting the array close to the nose, the effects of fuselage blockage on the array patterns at elevation angles below the horizon may be greatly reduced in the forward direction. Author

**N88-16688\*#** Douglas Aircraft Co., Inc., Long Beach, Calif.

### **CREW PROCEDURES FOR MICROWAVE LANDING SYSTEM OPERATIONS**

LELAND G. SUMMERS Nov. 1987 49 p (Contract NAS1-18028) (NASA-CR-178359; NAS 1.26:178359) Avail: NTIS HC A03/MF A01 CSCL 17G

The objective of this study was to identify crew procedures involved in Microwave Landing System (MLS) operations and to obtain a preliminary assessment of crew workload. The crew procedures were identified for three different complements of airborne equipment coupled to an autopilot. Using these three equipment complements, crew tasks were identified for MLS approaches and precision departures and compared to an ILS approach and a normal departure. Workload comparisons between the approaches and departures were made by using a task-timeline analysis program that obtained workload indexes, i.e., the ratio of time required to complete the tasks to the time available. The results showed an increase in workload for the MLS scenario for one of the equipment complements. However, even this workload was within the capacity of two crew members. Author

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

Includes aircraft simulation technology.

**A88-25792**

### **FOKKER 50 MARKS A FRESH START**

JACQUES CLOSTERMANN Interavia (ISSN 0020-5168), vol. 43, Jan. 1988, p. 39-43.

The Fokker 50 is a commuter airliner carrying 50 passengers at 32-in pitch; it is powered by two PW125 turboprops of 2250 shp at takeoff, which drive six-blade propellers. The noise level is noted to be exceptionally low, averaging 77 dB over three-quarters of the passenger cabin, and has been achieved through the use of vibration-absorbing panels and careful synchronization of propeller frequencies. The flight deck is arranged according to the 'dark cockpit' principle, so that all indicator lights are off when all is well. If the engine-control computer fails, the engines can be controlled manually without limitations. O.C.

A88-25793

**THINKING BIG IN RPVS - AN AFFORDABLE GIANT AMONG THE MINIS**

BRIAN WANSTALL Interavia (ISSN 0020-5168), vol. 43, Jan. 1988, p. 53, 54.

The TRA Model 410 Unmanned Air Vehicle attempts to furnish RPV users with a broader range of capabilities for all-weather surveillance than the more highly specialized mini-RPVs currently in use. The 410's 160-hp piston engine yields 190 kt top speed, and the airframe accommodates an 0.68-cu m payload bay. The 410 is able to stay on station for 8 hr at 1000 km from base while carrying a 135-kg multisensor payload; it may alternatively orbit for 19 hr at 30,000 ft over any area of interest. Navigational accuracy will be ensured by the use of GPS. The wings of the 410 fold back for stowage and carriage. O.C.

A88-25794

**BULLSEYE FOR SKYEYE - THE RPV WITH PARAFOL, SKID AND SALES**

BRIAN WANSTALL Interavia (ISSN 0020-5168), vol. 43, Jan. 1988, p. 57-59.

Skyeye is a large reconnaissance RPV whose planform is a modification (with wingtip extensions) of the Aquila RPV wing; to this wing are mated a deeper, squarer cross-section fuselage than that of the Aquila, with a twin-boom/tailplane empennage, that renders Skyeye more accommodating of payload volumes and less center-of-gravity-sensitive. Skyeye has a retractable, shock-absorbent skid allowing it to land off a steep approach without flaring on sand, dirt, grass, or hard surfaces. A recently-incorporated novel feature is a parafoil for controlled spot-landings in very difficult or confined terrain. O.C.

A88-25809

**XT-4 - POTENT WITH POTENTIAL**

PETER MIDDLETON and JANICE LOWE Flight International (ISSN 0015-3710), vol. 133, Jan. 2, 1988, p. 17-21.

The Japanese XT-4 aircraft built solely for the training of pilots is the highest performance subsonic trainer now flying. Airframe integrity proved by static and fatigue tests as well as good high-angle-of-attack and spin characteristics predicted from free-flight model tests and vertical wind-tunnel trials are described. Design policy and engine technology, low stalling speeds, and reduction of the laxes to vestigial proportions are discussed. Other specifications of the XT-4 aircraft include a ceiling of more than 50,000 ft, 3,680-lb thrust, a bypass ratio of 0.9, a sea-level static specific fuel consumption of 0.68 lb/hr lb, and digital avionics. Quoted range, in clear configuration with its full 1,600 kg of internal fuel, is over 700 nmi. The aircraft costs are in the range of \$18 million per unit. A.S.

A88-26415

**THE BOEING HELICOPTER MODEL 360 ADVANCED TECHNOLOGY HELICOPTER**

KEN GRINA Vertiflite (ISSN 0042-4455), vol. 34, Jan.-Feb. 1988, p. 29-33.

The Model 360 transport helicopter incorporates all-composite primary fuselage structure, elastomeric rotor bearings and dampers, very smooth aerodynamic surfaces (by comparison with metallic airframes), state-of-the-art digital avionics and displays, and advanced flight controls. Nomex honeycomb paneling is used throughout the fuselage structure to minimize weights, costs, and parts counts, while maximizing damage resistance and ease of repair. The use of such technology in future rotorcraft will result in 35-percent higher cruise speeds, 20-percent lower structural weights, a 50-percent reduction in maintenance costs, and a 70-percent improvement in dynamic system component fatigue. O.C.

A88-26644#

**FLIGHT TESTING KEEPS PACE**

SHAHID SIDDIQI (Aviation Advanced Technology Applications, Orlando, FL) and ROY ROBSON (McDonnell Douglas Corp., Saint Louis, MO) Aerospace America (ISSN 0740-722X), vol. 26, Feb. 1988, p. 14-16, 19.

The flight test requirements of laminar flow airframes, propfan engines, and high agility marginal stability control systems are primary drivers for flight test technology and methodology evolution. Typifying the state-of-the-art is a high speed data-acquisition system gathering noise and vibration data during ultrahigh bypass turbofan engine testing on an MD-80 test aircraft; the system employs 256 channels, and is capable of 1.6 million samples/sec. In conjunction with advanced ground data processing, the system has reduced the time for dynamic data reduction from the 6-8 weeks typical of analog recording and processing to two days. O.C.

A88-26645#

**SQUEEZING THE TEST CYCLE**

ORVILLE WRIGHT, JR. (IBM, Federal Systems Div., Bethesda, MD) Aerospace America (ISSN 0740-722X), vol. 26, Feb. 1988, p. 17-19.

A development history is presented for aircraft flight testing methods, in order to furnish perspective for an account of contemporary practices. Since the mid-1970s, 'single-site' testing has allowed company pilots to demonstrate a given aircraft's flight envelope, while military crews fly a combined flight test program to prove specification compliance and operational effectiveness. As the testing cycle has been thus shortened, flight testing has come to stress reliability and maintainability; avionics testing has also become a primary challenge. O.C.

A88-26647#

**CONTROL MUSCLE FOR AGILE AIRCRAFT**

RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 26, Feb. 1988, p. 32-35.

An evaluation is made of the design features, development and implementation status, and performance characteristics of the 8000-psi pressure/nonflammable hydraulic fluid actuators, electromechanical actuators (EMAs), and electrohydrostatic actuators that will be incorporated into next-generation combat aircraft. The USAF hopes that the 8000-psi hydraulics technology will be sufficiently advanced for integration into the forthcoming Advanced Tactical Fighter, which requires such control features to fully realize relaxed stability maneuvering. All three types of actuators are highly responsive to computer-controlled command inputs. O.C.

A88-26749\* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**ELLIPTIC GENERATION OF COMPOSITE THREE-DIMENSIONAL GRIDS ABOUT REALISTIC AIRCRAFT**

REESE L. SORENSON (NASA, Ames Research Center, Moffett Field, CA) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 353-371. refs

An elliptic method for generating composite grids about realistic aircraft is presented. A body-conforming grid is first generated about the entire aircraft by the solution of Poisson's differential equation. This grid has relatively coarse spacing, and it covers the entire physical domain. At boundary surfaces, cell size is controlled and cell skewness is nearly eliminated by inhomogeneous terms, which are found automatically by the program. Certain regions of the grid in which high gradients are expected, and which map into rectangular solids in the computational domain, are then designated for zonal refinement. Spacing in the zonal grids is reduced by adding points with a simple, algebraic scheme. Details of the grid-generation method are presented along with results of the present application, a wing/body configuration based on the F-16 fighter aircraft. Author

Author

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

**A88-26875**

### **F-16 FLIGHT TESTS WITH THE F110 ENGINE - LESSONS LEARNED**

GARALD K. ROBINSON (USAF, Washington, DC) Cockpit (ISSN 0742-1508), Oct.-Dec. 1987, p. 5-21. refs

The F-16C aircraft and the F110 engine are described. The flight test plan objectives such as primary operating mode (PRI) control throttle transients (dry and afterburner), secondary control mode (SEC) transients and transfers, and PRI and SEC airstarts are discussed. The various organizations that participated in the test program, the significant problems and challenges encountered during the course of testing, and the constraints imposed on the test program are considered. A summary of the lessons learned is presented so other test programs may benefit from them. It is concluded that the engine has a substantial increase in thrust that provides quicker acceleration and higher top speeds than previously achievable, and without paying a fuel-consumption penalty; the normal and emergency procedures are much simpler, and there are no restrictions on normal-throttle operation or the use of afterburner anywhere in the flight envelope. A.S.

**A88-26893**

### **FINITE ELEMENT ANALYSIS FOR SHOCK ABSORBERS OF PILOT SEATS**

SHOUMEI WANG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) Computers and Structures (ISSN 0045-7949), vol. 28, no. 2, 1988, p. 217-222.

The mechanical response of a pilot-seat shock absorber and support structure is investigated analytically by means of a nonlinear FEM. The shock absorbers and their sliding motion along the seat rail are treated using a truss element with a nonlinear history-dependent material model and a nonlinear three-node beam, respectively, and the nonlinearity due to the moving node is described by specialized shape functions. Numerical results for a sample problem are presented in tables and graphs and briefly characterized. T.K.

**A88-27496**

### **AGILE FALCON AND HORNET 2000**

BILL SWEETMAN Interavia (ISSN 0020-5168), vol. 43, Feb. 1988, p. 161-164.

The Agile Falcon (based on the 1991-production Block 50 F-16C/D but with a new wing) and proposals for updating of the F-18 Super Hornet are discussed, with an emphasis on the cost/technology advantages these updated aircraft will have over advanced fighters being developed in Europe. The baseline configuration for Agile Falcon includes an 1100-module electronically scanning radar which can be produced for about the same price as the APG-68 radar. The engine for the F-16 will probably be a derivative of the current F100 or F110 developed under the Improved Performance Engine program. No final decisions have been made regarding the F-18, but four new configurations are being studied: (1) a baseline version with 10-percent improved thrust, (2) a heavier, longer-range version, (3) a more maneuverable stretched version of (2), and (4) a radical design with cranked-arrow wing, foreplanes, and new vertical stabilizers. T.K.

**A88-28251\*#** Stanford Univ., Calif.

### **OPTIMAL LANDING OF A HELICOPTER IN AUTOROTATION**

ALLAN Y. LEE, ARTHUR E. BRYSON, JR., and WILLIAM S. HINDSON (Stanford University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Jan.-Feb. 1988, p. 7-12. Previously cited in issue 23, p. 3399, Accession no. A86-47705. refs

(Contract NCC2-106)

**A88-28252#**

### **INTERIOR TRANSITION LAYERS IN FLIGHT-PATH OPTIMIZATION**

MARK D. ARDEMA (Santa Clara, University, CA) and L. YANG (Sterling Software, Inc., Palo Alto, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Jan.-Feb. 1988, p. 13-18. Previously cited in issue 23, p. 3402, Accession no. A86-48576. refs

**N88-16627\*#** Army Aviation Systems Command, Moffett Field, Calif.

### **THE DEVELOPMENT OF CFD METHODS FOR ROTOR APPLICATIONS**

F. X. CARADONNA and W. J. MCCROSKEY /in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity p 34-65 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01C

The optimum design of the advancing helicopter rotor for high-speed forward flight always involves a tradeoff between transonic and stall limitations. However, the preoccupation of the rotor industry was primarily concerned with stall until well into the 1970s. This emphasis on stall resulted from the prevalent use of low-solidity rotors with rather outdated airfoil sections. The use of cambered airfoil sections and higher-solidity rotors substantially reduced stall and revealed the advancing transonic flow to be a more persistent limitation to high-speed rotor performance. Work in this area was spurred not only by operational necessity but also by the development of a tool for the prediction of these flows (the method of computational fluid dynamics). The development of computational fluid dynamics for these rotor problems was a major Army and NASA achievement. This work is now being extended to other rotor flow problems. The developments are outlined. Author

**N88-16629\*#** Army Aviation Systems Command, Moffett Field, Calif.

### **A REVIEW OF RESEARCH IN ROTOR LOADS**

WILLIAM G. BOUSMAN and WAYNE R. MANTAY (Army Aerostructures Directorate, Hampton, Va.) /in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity p 180-311 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01C

The research accomplished in the area of rotor loads over the last 13 to 14 years is reviewed. The start of the period examined is defined by the 1973 AGARD Milan conference and the 1974 hypothetical rotor comparison. The major emphasis of the review is research performed by the U.S. Army and NASA at their laboratories and/or by the industry under government contract. For the purpose of this review, two main topics are addressed: rotor loads prediction and means of rotor loads reduction. A limited discussion of research in gust loads and maneuver loads is included. In the area of rotor loads predictions, the major problem areas are reviewed including dynamic stall, wake induced flows, blade tip effects, fuselage induced effects, blade structural modeling, hub impedance, and solution methods. It is concluded that the capability to predict rotor loads has not significantly improved in this time frame. Future progress will require more extensive correlation of measurements and predictions to better understand the causes of the problems, and a recognition that differences between theory and measurement have multiple sources, yet must be treated as a whole. There is a need for high-quality data to support future research in rotor loads, but the resulting data base must not be seen as an end in itself. It will be useful only if it is integrated into firm long-range plans for the use of the data. Author

**N88-16636\*#** Army Research and Technology Labs., Fort Eustis, Va. Aviation Applied Technology Directorate.

**ADVANCED COMPOSITE AIRFRAME PROGRAM: TODAY'S TECHNOLOGY**

DANNY E. GOOD and L. THOMAS MAZZA *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 656-678 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 01C

The Advanced Composite Airframe Program (ACAP) was undertaken to demonstrate the advantages of the application of advanced composite materials and structural design concepts to the airframe structure on helicopters designed to stringent military requirements. The primary goals of the program were the reduction of airframe production costs and airframe weight by 17 and 22 percent respectively. The ACAP effort consisted of a preliminary design phase, detail design, and design support testing, full-scale fabrication, laboratory testing, and a ground/flight test demonstration. Since the completion of the flight test demonstration programs follow-on efforts were initiated to more fully evaluate a variety of military characteristics of the composite airframe structures developed under the original ACAP advanced development contracts. An overview of the ACAP program is provided and some of the design features, design support testing, manufacturing approaches, and the results of the flight test evaluation, as well as, an overview of Militarization Test and Evaluation efforts are described. Author

**N88-16652\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**SYSTEM ANALYSIS IN ROTORCRAFT DESIGN: THE PAST DECADE**

THOMAS L. GALLOWAY *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1154-1166 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

Rapid advances in the technology of electronic digital computers and the need for an integrated synthesis approach in developing future rotorcraft programs has led to increased emphasis on system analysis techniques in rotorcraft design. The task in systems analysis is to deal with complex, interdependent, and conflicting requirements in a structured manner so rational and objective decisions can be made. Whether the results are wisdom or rubbish depends upon the validity and sometimes more importantly, the consistency of the inputs, the correctness of the analysis, and a sensible choice of measures of effectiveness to draw conclusions. In rotorcraft design this means combining design requirements, technology assessment, sensitivity analysis and reviews techniques currently in use by NASA and Army organizations in developing research programs and vehicle specifications for rotorcraft. These procedures span simple graphical approaches to comprehensive analysis on large mainframe computers. Examples of recent applications to military and civil missions are highlighted. Author

**N88-16656\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**ROTORCRAFT FLIGHT RESEARCH WITH EMPHASIS ON ROTOR SYSTEMS**

WILLIAM J. SNYDER *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1235-1273 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

Over fifty years of contributions by NASA and the Army through rotor systems flight research were examined with an emphasis on the last 25 years. During this time, the helicopter has gone from an abnormality that did a few useful things to a vehicle that is a necessity to life in this country and a major part of all military forces in the world. Major data acquisition programs like the H-34 and White Cobra have been undertaken that have increased the understanding of the aerodynamic behavior of the rotor system. Specialized programs like the Ogee tip on the UH-1 and the flight tests of the hingeless rotor helicopters, the XH-13 and XH-51N, contributed greatly to the understanding of these technologies.

The extensive airfoil test program also undertaken on the White Cobra provided valuable data on advanced airfoil configurations.

Author

**N88-16657\*#** Textron Bell Helicopter, Fort Worth, Tex.

**AN OVERVIEW OF KEY TECHNOLOGY THRUSTS AT BELL HELICOPTER TEXTRON**

JAMES H. HARSE, JING G. YEN, and RODNEY S. TAYLOR *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1279-1340 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

Insight is provided into several key technologies at Bell. Specific topics include the results of ongoing research and development in advanced rotors, methodology development, and new configurations. The discussion on advanced rotors highlight developments on the composite, bearingless rotor, including the development and testing of full scale flight hardware as well as some of the design support analyses and verification testing. The discussion on methodology development concentrates on analytical development in aeromechanics, including correlation studies and design application. New configurations, presents the results of some advanced configuration studies including hardware development. Author

**N88-16658\*#** Boeing Vertol Co., Philadelphia, Pa.

**ROTORCRAFT TECHNOLOGY AT BOEING VERTOL: RECENT ADVANCES**

JOHN SHAW, LEO DADONE, and ROBERT WIESNER *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1341-1394 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

An overview is presented of key accomplishments in the rotorcraft development at Boeing Vertol. Projects of particular significance: high speed rotor development and the Model 360 Advanced Technology Helicopter. Areas addressed in the overview are: advanced rotors with reduced noise and vibration, 3-D aerodynamic modeling, flight control and avionics, active control, automated diagnostics and prognostics, composite structures, and drive systems. Author

**N88-16659\*#** Sikorsky Aircraft, Stratford, Conn.

**RECENT SIKORSKY R AND D PROGRESS**

*In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1395-1449 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

The recent activities and progress in four specific areas of Sikorsky's research and development program are summarized. Since the beginning of the S-76 design in 1974, Sikorsky has been aggressively developing the technology for using composite materials in helicopter design. Four specific topics are covered: advanced cockpit/controller efforts, fly-by-wire controls on RSRA/X-Wing, vibration control via higher harmonic control, and main rotor aerodynamic improvements. Author

**N88-16660\*#** McDonnell-Douglas Helicopter Co., Mesa, Ariz.

**MCDONNELL DOUGLAS HELICOPTER COMPANY INDEPENDENT RESEARCH AND DEVELOPMENT: PREPARING FOR THE FUTURE**

ALLEN C. HAGGERTY *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1450-1481 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01C

During the 1970's and 80's, research has produced the technology that is seen in aircraft such as the LHX and future models. The technology is discussed that is reaching maturity and moving into the application stage of future programs. Technology is discussed in six major areas: advanced concepts, analysis techniques, structures, systems, simulation, and research and development facilities. The partnership of McDonnell Douglas

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Helicopter Co. and the government in developing these technologies is illustrated in several programs. Author

**N88-16689#** Naval Postgraduate School, Monterey, Calif.  
**A PILOTTED SIMULATION INVESTIGATING HANDLING QUALITIES AND PERFORMANCE REQUIREMENTS OF A SINGLE-PILOT HELICOPTER IN AIR COMBAT EMPLOYING A HELMET-DRIVEN TURRETED GUN M.S. Thesis**

JEFFREY N. WILLIAMS Sep. 1987 113 p  
(AD-A186878) Avail: NTIS HC A06/MF A01 CSCL 01B

The development, implementation, and results of a pilot-in-the-loop fixed-base simulation investigating yaw-axis handling qualities and vehicle maneuverability requirements for the task of single-pilot helicopter air combat at terrain-flight altitudes are presented. Experimental variables included yaw-axis natural frequency and damping. Weapon system type was also varied to include a full- and limited-traverse turret driven by a helmet-mounted sight and a fixed-forward gun. Results indicated that a high yaw natural frequency ( $\omega_n = 1.5$  to  $2.0$  rad/sec) and high yaw damping ( $\zeta$  approx. 1.4) were desirable for Level 1 handling qualities. Pilot ratings generally decreased and the effect of the yaw dynamic characteristics became more pronounced and the weapon system became more restrictive. Other analyses discussed are the vehicle maneuver envelope usage, turret envelope usage, tracking performance, and pilot commentary. GRA

**N88-16690#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Systems and Logistics.  
**A COST AND BENEFIT ANALYSIS OF HYDRAULIC FLUID SYSTEMS FOR THE NEXT GENERATION OF TACTICAL AIRCRAFT M.S. Thesis**

MICHAEL P. MAHONY Sep. 1987 79 p  
(AD-A186911; AFIT/GSM/LSY/87S-18) Avail: NTIS HC A05/MF A01 CSCL 11H

This study analyzed the life cycle costs, cost of fires, and benefits of using a new nonflammable hydraulic fluid (CTFE) in future tactical aircraft versus a fire retardant fluid (Mil-H-83282) currently used, assuming a future hydraulic systems pressure of 8000 psi. A McDonnell Douglas Corporation study compared Mil-H-83282 and CTFE at 8000 psi showing weight as the primary difference. Therefore, this weight difference, the fluid price difference, and the fuel consumption of an F-15 were used to determine the life cycle cost difference between the two systems. Since the added weight was slight, only the additional fuel consumption to fly the extra weight was significant. The added life cycle costs for using CTFE was estimated at \$11.4 million in FY87 dollars. Since CTFE will prevent hydraulic fires, an estimate of Mil-H-83282 fire costs was attempted. The differences in the benefits were primarily in the survivability and capability of the aircraft. Taking these differences together CTFE is slightly better than Mil-H-83282 in peacetime. This difference becomes more pronounced in wartime. Finally, a sensitivity analysis was conducted, concluding that CTFE was a viable alternative at 8000 psi. GRA

**N88-16691#** Analytical Methods, Inc., Redmond, Wash.  
**PREDICTING DYNAMIC SEPARATION CHARACTERISTICS OF GENERAL CONFIGURATIONS Final Report, Apr. 1984 - Jul. 1987**

B. MASKEW and F. A. DVORAK Jul. 1987 48 p  
(Contract F49620-82-C-0033)  
(AD-A186689; AMI-8706; AFOSR-87-1418TR) Avail: NTIS HC A03/MF A01 CSCL 01A

A procedure has been developed for treating the dynamic interaction between a separated wake and a surface undergoing an unsteady motion. The basis of the method is an unsteady (time-stepping) panel method coupled with unsteady integral boundary layer codes. Pilot codes have been developed for both two and three dimensional conditions. Results presented here are mainly from the two-dimensional code in which the various routines for controlling the dynamic wake model have been developed. Some viscous/inviscid three-dimensional results are shown. The

long term objective is to treat complete aircraft configurations through high angle-of-attack maneuvers. GRA

**N88-16692#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.

**HELICOPTERS AS TEST CARRIERS FOR AVIONICS SYSTEMS (HETAS) Final Report [HETAS: HUBSCHRAUBER ALS ERPROBUNGSTRAEGER FUER AVIONIK-SYSTEME]**

K. BENDER, E. DANNEBERG, R. DIERKE, G. HAEHNLEIN, G. MANSFELD, and J. TERSTEEGEN 9 Oct. 1985 28 p In GERMAN  
(DFVLR-IB-112-85/18; LVL-8302-I-2; ETN-88-91013) Avail: NTIS HC A03/MF A01

The HETAS integrated test bed for avionics systems in human engineering, digital control engineering, and sensors is presented. The flight test system, including helicopter test carrier, systems concept, and integrated flight test system, is described. The ground test system, including helicopter simulation, cockpit, and redundant fly-by-wire system are described. ESA

**N88-16694\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**A FLIGHT-TEST METHODOLOGY FOR IDENTIFICATION OF AN AERODYNAMIC MODEL FOR A V/STOL AIRCRAFT**

RALPH E. BACH, JR. and B. DAVID MCNALLY Mar. 1988 12 p Submitted for publication  
(NASA-TM-100067; A-88095; NAS 1.15:100067) Avail: NTIS HC A03/MF A01 CSCL 01C

Described is a flight test methodology for developing a data base to be used to identify an aerodynamic model of a vertical and short takeoff and landing (V/STOL) fighter aircraft. The aircraft serves as a test bed at Ames for ongoing research in advanced V/STOL control and display concepts. The flight envelope to be modeled includes hover, transition to conventional flight, and back to hover, STOL operation, and normal cruise. Although the aerodynamic model is highly nonlinear, it has been formulated to be linear in the parameters to be identified. Motivation for the flight test methodology advocated in this paper is based on the choice of a linear least-squares method for model identification. The paper covers elements of the methodology from maneuver design to the completed data base. Major emphasis is placed on the use of state estimation with tracking data to ensure consistency among maneuver variables prior to their entry into the data base. The design and processing of a typical maneuver is illustrated. Author

**N88-16696#** Oak Ridge National Lab., Tenn.  
**ANALYSIS OF TASKS FOR DYNAMIC MAN/MACHINE LOAD BALANCING IN ADVANCED HELICOPTERS**

C. C. JORGENSEN Oct. 1987 33 p  
(Contract DE-AC05-84OR-21400)  
(DE88-003735; ORNL/TM-10558; CESAR-87/44) Avail: NTIS HC A03/MF A01

This report considers task allocation requirements imposed by advanced helicopter designs incorporating mixes of human pilots and intelligent machines. Specifically, it develops an analogy between load balancing using distributed non-homogeneous multiprocessors and human team functions. A taxonomy is presented which can be used to identify task combinations likely to cause overload for dynamic scheduling and process allocation mechanisms. Designer criteria are given for function decomposition, separation of control from data, and communication handling for dynamic tasks. Possible effects of n-p complete scheduling problems are noted and a class of combinatorial optimization methods are examined. DOE

**N88-17069#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Flight Dynamics Lab.

**A NEW LOOK AT THE USE OF LINEAR METHODS TO PREDICT AIRCRAFT DYNAMIC RESPONSE TO TAXI OVER BOMB DAMAGED AND REPAIRED AIRFIELDS**

JAMES J. OLSEN *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 4: Structural Dynamics and Modal Test and Analysis p 65-82 Jan. 1987  
Avail: NTIS HC A07/MF A01 CSCL 01C

The dynamic response of an aircraft that taxis over two arbitrary disturbances, under the assumption that the aircraft can be represented as a linear, one degree-of-freedom system is discussed. That analysis produces the concept of the BUMP MULTIPLIER which explicitly and simply determines whether a second discrete disturbance will amplify or attenuate the response from the first disturbance. The BUMP MULTIPLIER also simplifies the understanding and presentation of the results. While the assumptions are very severe, the resulting formulas can be very useful in gaining physical insight, as guides to more elaborate nonlinear calculations, and in planning test programs. Author

**N88-17252\*#** Texas Instruments, Inc., Dallas.  
**ROBOTIC AIR VEHICLE. BLENDING ARTIFICIAL INTELLIGENCE WITH CONVENTIONAL SOFTWARE**

CHRISTA MCNULTY, JOYCE GRAHAM, and PAUL ROEWER *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 335-340 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 01C

The Robotic Air Vehicle (RAV) system is described. The program's objectives were to design, implement, and demonstrate cooperating expert systems for piloting robotic air vehicles. The development of this system merges conventional programming used in passive navigation with Artificial Intelligence techniques such as voice recognition, spatial reasoning, and expert systems. The individual components of the RAV system are discussed as well as their interactions with each other and how they operate as a system. Author

**N88-17433#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Flugmechanik.

**FLIGHT TEST TECHNIQUE, ILLUSTRATED BY ADVANCED TECHNOLOGIES TESTING AIRCRAFT SYSTEM (ATTAS) [FLUGVERSUCHSTECHNIK AM BEISPIEL ATTAS]**

PETER HAMEL and HEINZ WINTER *In its* Scientific Colloquium in Honor of Prof. Dr. Rer. Nat. Hermann L. Jordan p 9-36 Jun. 1987 *In* GERMAN

Avail: NTIS HC A07/MF A01; DFVLR, Cologne, Fed. Republic of Germany DM 29

The systems techniques of the flying simulator ATTAS are described. The flexibility of the simulator is obtained by the installation of an electro-optical control system, in parallel with mechanical, conventional control. Software flexibility is obtained by a complex onboard computer system. The ATTAS has electrically manipulable control surfaces. Hardware, such as computers and avionics systems can easily be connected to the onboard data processing system. The technological applications of ATTAS, such as systems identification, the flying simulation technique, active flight control system, man-machine systems, sensor-avionics systems, air traffic management, and pilot qualification are presented. ESA

**N88-17608\*#** Lockheed-Georgia Co., Marietta. Advanced Flight Sciences Dept.

**DEVELOPMENT OF CIRCULATION CONTROL TECHNOLOGY FOR POWERED-LIFT STOL AIRCRAFT**

ROBERT J. ENGLAR *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 491-537 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01C

The flow entraining capabilities of the Circulation Control Wing high lift system were employed to provide an even stronger STOL

potential when synergistically combined with upper surface mounted engines. The resulting configurations generate very high supercirculation lift in addition to a vertical component of the pneumatically deflected engine thrust. A series of small scale wind tunnel tests and full scale static thrust deflection tests are discussed which provide a sufficient data base performance. These tests results show thrust deflections of greater than 90 deg produced pneumatically by nonmoving aerodynamic surfaces, and the ability to maintain constant high lift while varying the propulsive force from high thrust recovery required for short takeoff to high drag generation required for short low speed landings. Author

**N88-17609\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**A POTENTIAL FLIGHT EVALUATION OF AN UPPER-SURFACE-BLOWING/CIRCULATION-CONTROL-WING CONCEPT**

DENNIS W. RIDDLE and JOSEPH C. EPEL *In its* Proceedings of the Circulation-Control Workshop, 1986 p 539-567 May 1987  
Avail: NTIS HC A25/MF A01 CSCL 01C

The technology data base for powered lift aircraft design has advanced over the last 15 years. NASA's Quiet Short Haul Research Aircraft (QSRA) has provided a flight verification of upper surface blowing (USB) technology. The A-6 Circulation Control Wing flight demonstration aircraft has provide data for circulation control wing (CCW) technology. Recent small scale wind tunnel model tests and full scale static flow turning test have shown the potential of combining USB with CCW technology. A flight research program is deemed necessary to fully explore the performance and control aspects of CCW jet substitution for the mechanical USB Coanda flap. The required hardware design would also address questions about the development of flight weight ducts and CCW jets and the engine bleed-air capabilities vs requirements. NASA's QSRA would be an optimum flight research vehicle for modification to the USB/CCW configuration. The existing QSRA data base, the design simplicity of the QSRA wing trailing edge controls, availability of engine bleed-air, and the low risk, low cost potential of the suggested program is discussed. Author

**N88-17641#** Essex Corp., Alexandria, Va.

**HELICOPTER EXTERNAL VISION REQUIREMENTS AND VISUAL DISPLAY CHARACTERISTICS: A REPORT/BIBLIOGRAPHY, REVISION A Final Report**

STEVEN HALE Oct. 1987 28 p  
(Contract DAAK11-85-C-0031; DA PROJ. 1L1-62716-AH-70)  
(AD-A187075; EFR-010-REV-A; HEL-TN-6-87-REV-A) Avail:  
NTIS HC A03/MF A01 CSCL 01C

A literature review was conducted to examine helicopter external vision requirements and related visual display characteristics. Several articles are summarized in annotated bibliography format. A subsequent discussion section addresses the information contained in those articles as well as relevant information contained in other documents. Suggestions are made for future research. GRA

**N88-17642#** International Technical Associates Ltd., Drexel Hill, Pa.

**ROTORCRAFT WEIGHT TRENDS IN LIGHT OF STRUCTURAL MATERIAL CHARACTERISTICS Final Report, 6 Sep. 1984 - 31 May 1987**

W. Z. STEPNIIEWSKI 1987 113 p  
(Contract DAAJ09-84-M-0706)  
(AD-A186576; AVSCOM-TR-87-A-10) Avail: NTIS HC A06/MF A01 CSCL 01C

Variations in weight of rotorcraft and their major components due to the use of advanced materials are examined. The impact of new materials on component weights is illustrated by historical weight trends. The influences of structural material characteristics on relative weight levels of major rotorcraft components and the weight effectiveness for both static and fatigue-type loadings are reviewed. Cursor expressions are developed to permit estimation of how the strength effectiveness values or structural materials affect the relative weights of components. Special constraints which

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could limit the possible weight reductions achievable are considered briefly. A survey of advanced structural materials is also included.

GRA

**N88-17643** Stanford Univ., Calif.  
**FREQUENCY-RESPONSE IDENTIFICATION OF XV-15 TILT-ROTOR AIRCRAFT DYNAMICS** Ph.D. Thesis  
MARK B. TISCHLER 1987 191 p  
Avail: Univ. Microfilms Order No. DA8723101

The timely design and development of the next generation of tilt-rotor aircraft (JVX) depend heavily on the in-depth understanding of existing XV-15 dynamics and the availability of fully validated simulation models. The objectives of this study include the following: documentation and evaluation of XV-15 bare-airframe dynamics; comparison of aircraft and simulation responses; and development of a validated transfer function description of the XV-15 needed for future studies. A nonparametric frequency response approach is used which does not depend on assumed model order or structure. Transfer function representations are subsequently derived which fit the frequency-responses in the bandwidth of greatest concern for piloted handling-qualities and control-system applications. Flight tests on the XV-15 aircraft and piloted-simulation for four flight conditions from hover to cruise were planned and executed. Improved test techniques and pilot-training procedures were devised. Analytical software tools were developed which allow the identification of high-resolution spectral responses and the derivation and validation of multi-input/multi-output transfer function models. These techniques were applied in an extensive evaluation of the open-loop flight dynamics of the XV-15 aircraft and simulation mathematical models. Deficiencies were exposed and documented. A new, fully validated transfer function model was then derived for hover and cruise flight conditions. Dissert. Abstr.

**N88-17644\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**X-29A FORWARD-SWEPT-WING FLIGHT RESEARCH PROGRAM STATUS**

GARY A. TRIPPENSEE and DAVID P. LUX Nov. 1987 11 p  
Presented at the SAE International Pacific Air and Space Technology Conference, Melbourne, Australia, 13-17 Nov. 1987 (NASA-TM-100413; H-1432; NAS 1.15:100413) Avail: NTIS HC A03/MF A01 CSCL 01C

The X-29A aircraft is a fascinating combination of integrated technologies incorporated into a unique research aircraft. The X-29A program is multiple agency program with management and other responsibilities divided among NASA, DARPA, the U.S. Air Force, and the Grumman Corporation. An overview of the recently completed X-29A flight research program, objectives achieved, and a discussion of its future is presented. Also discussed are the flight test approach expanding the envelope, typical flight maneuvers performed, X-29A program accomplishments, lessons learned for the Number One aircraft, and future plans with the Number Two aircraft. A schedule for both aircraft is presented. A description of the unique technologies incorporated into the X-29A aircraft is given, along with descriptions of the onboard instrumentation system. The X-29A aircraft research program has proven highly successful. Using high fly rates from a very reliable experimental aircraft, the program has consistently met or exceeded its design and research goals. Author

**N88-17645\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**TRANSPORT DELAY COMPENSATION FOR COMPUTER-GENERATED IMAGERY SYSTEMS**  
RICHARD E. MCFARLAND Jan. 1988 29 p  
(NASA-TM-100084; A-87385; NAS 1.15:100084) Avail: NTIS HC A03/MF A01 CSCL 01C

In the problem of pure transport delay in a low-pass system, a trade-off exists with respect to performance within and beyond a frequency bandwidth. When activity beyond the band is attenuated because of other considerations, this trade-off may be used to improve the performance within the band. Specifically, transport delay in computer-generated imagery systems is reduced to a

manageable problem by recognizing frequency limits in vehicle activity and manual-control capacity. Based on these limits, a compensation algorithm has been developed for use in aircraft simulation at NASA Ames Research Center. For direct measurement of transport delays, a beam-splitter experiment is presented that accounts for the complete flight simulation environment. Values determined by this experiment are appropriate for use in the compensation algorithm. The algorithm extends the bandwidth of high-frequency flight simulation to well beyond that of normal pilot inputs. Within this bandwidth, the visual scene presentation manifests negligible gain distortion and phase lag. After a year of utilization, two minor exceptions to universal simulation applicability have been identified and subsequently resolved. Author

**N88-17646\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**USING FREQUENCY-DOMAIN METHODS TO IDENTIFY XV-15 AEROELASTIC MODES**  
C. W. ACREE, JR. and MARK B. TISCHLER (Army Aviation Research and Development Command, Moffett Field, Calif.) Nov. 1987 25 p  
(NASA-TM-100033; A-87364; NAS 1.15:100033; USAAVSCOM-TR-87-A-17) Avail: NTIS HC A03/MF A01 CSCL 01C

The XV-15 Tilt-Rotor wing has six major aeroelastic modes that are close in frequency. To precisely excite individual modes during flight test, dual flaperon exciters with automatic frequency-sweep controls were installed. The resulting structural data were analyzed in the frequency domain (Fourier transformed) with cross spectral and transfer function methods. Modal frequencies and damping were determined by performing curve fits to transfer function magnitude and phase data and to cross spectral magnitude data. Results are given for the XV-15 with its original metal rotor blades. Frequency and damping values are also compared with earlier predictions. Author

**N88-17822#** Entwicklungsring Sud, Munich (West Germany). Projektabteilung.  
**DEVELOPMENT OF VERTICAL TAKEOFF AIRCRAFT WITH TURBOJET ENGINES IN GERMANY [DIE ENTWICKLUNG VON SENKRECHTSTARTFLUGZEUGEN MIT TURBINENSTRAHLTRIEBWERKEN IN DEUTSCHLAND]**  
KARL SCHWAERZLER /in MBB GmbH, Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 33-40 1987 In GERMAN  
Avail: NTIS HC A14/MF A01

The history of the development of vertical takeoff aircraft with turbojet engines in Germany is depicted. The different engine arrangements used in VTOL aircraft are described. The different designs for the tilting of the engine nacelle are discussed. The thrust control and stabilization of VTOL aircraft are explained, and test methods are described. The effects of the soil on VTOL aircraft are outlined. The test aircraft X1 and the aircraft VJ101C are described. ESA

**N88-17823#** Entwicklungsring Sud, Munich (West Germany). Projektabteilung.  
**VARIABLE SWEEP WINGS [VARIABLE PFEILUNG DES FLUEGELS]**  
HELMUT LANGFELDER /in MBB GmbH, Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 41-46 1987 In GERMAN Presented at the 6th Europaeischen Luftfahrtkongress, Munich, Fed. Republic of Germany, 1-4 Sep. 1965  
Avail: NTIS HC A14/MF A01

The adaptation of the aircraft form to the use of variable sweep wings is treated. The use of variable sweep wings results in a possible increase of the aerodynamic lift for takeoff and landing,

and a simultaneous optimization of the maximum flight range at all speeds, and hence in a substantial improvement of the payload-range characteristics. Variable sweep wings also allow an improved maneuverability at low speed and a remarkable flight comfort. Although variable sweep wings are heavier, the aircraft can be smaller and more efficient. ESA

**N88-17824#** Deutsche Airbus G.m.b.H., Munich (West Germany). Technische Geschaeftsfuehrung.  
**THE EUROPEAN AIRBUS A-300 [DER EUROPAEISCHE AIRBUS A 300]**

HANS WOCKE *In* MBB GmbH Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 47-50 1987 In GERMAN Presented at the WGLR/DGRR-Jahrestagung, Karlsruhe, Fed. Republic of Germany, Oct. 1967  
Avail: NTIS HC A14/MF A01

The aims of the European Airbus are given. The main characteristics of the A-300 aircraft are discussed. The main requirements which determine the aircraft are presented. The operational data of the A-300 aircraft are given. ESA

**N88-17825#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Projektteilung.  
**SPECIAL FLIGHT MECHANICAL FEATURES OF THE BEARINGLESS HELICOPTER ROTOR [FLUGMECHANISCHE BESONDERHEITEN DES GELENKLOSEN HUBSCHRAUBER-ROTORS]**

GUENTER REICHERT *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 51-58 1987 In GERMAN Presented at the 6th WGLR Europaeischen Luftfahrtkongress, Munich, Fed. Republic of Germany, 1-4 Sep. 1965  
(MBB-FM-315/O) Avail: NTIS HC A14/MF A01

Features of a bearingless helicopter rotor resulting from the fact that substantially higher moments can be reached than with a normal rotor, thereby changing the flight characteristics, i.e., control as well as stability characteristics, are discussed. The control time behavior is substantially improved by the higher damping, and, simultaneously, control efficiency is enhanced. Rotor gust sensitivity is increased by the introduction of a bearingless blade connection, imposing extreme care in the design of the stiffness of blade connection and rotor blades. ESA

**N88-17839#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Abteilung Technologie-Entwicklungen.  
**MODERN MATERIALS FOR LIGHT CONSTRUCTIONS [MODERNE WERKSTOFFE FUER DEN LEICHTBAU]**

JUERGEN BRANDT, HELMUT KELLERER, and PETER J. WINKLER *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 131-134 1987 In GERMAN  
(MBB-Z-136/86) Avail: NTIS HC A14/MF A01

Materials and materials technologies for the light construction of primary aircraft structural members are discussed. The cost criteria for the use of light materials are outlined. Materials characteristics used to evaluate applicability of each material are discussed. The properties and possible applications of fiber reinforced composites, fiber reinforced metals, and light alloys are presented. ESA

**N88-17842#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.

**PURPOSES AND TASKS OF HIGH-PERFORMANCE AIRCRAFT CONSTRUCTION [ZIELE UND AUFGABEN DES HOCHLEISTUNGSFLUGZEUGBAUS]**

OSKAR FRIEDRICH *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 147-150 1987 In GERMAN  
(MBB/LK-S/PUB/296) Avail: NTIS HC A14/MF A01

The purposes of the German aircraft industry in high-grade components are outlined. Program planning concerning life time increase and combat value enhancement is presented. The requirements for the European fighter aircraft (JF90 or EFA) are given. The challenges for Germany in the fields of manned spacecraft systems and spacecraft, and cooperation programs with third-party countries are discussed. ESA

**N88-17844#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Helicopter and Military Aircraft Group.

**FLIGHT TESTING OF FIGHTER AIRCRAFT**

ARNIM KNAUS *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 157-166 1987  
(MBB/LKE-62/S/PUB/292) Avail: NTIS HC A14/MF A01

The categories of flight test are overviewed. A typical full scale flight development plan, onboard data acquisition system, flight test data production and data flow, flight test control room, and performance data analysis software network are presented. The test procedure and sequential course of flight trials, and the characteristics of fighter aircraft testing are discussed. The basic ground test prior to flight test, in-flight thrust/drag determination, flutter testing, flying qualities, integrated avionics testing, weapons trials, and operational aspects are explained. ESA

**N88-17848#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.

**THE INTELLIGENT WING. AERODYNAMIC DEVELOPMENT DIRECTION FOR FUTURE PASSENGER AIRCRAFT [DER INTELLIGENTE TRAGFLUEGEL - AERODYNAMISCHE ENTWICKLUNGSRICHTUNGEN FUER ZUKUENFTIGE VERKEHRSFLUGZEUGE]**

REINHARD HILBIG and JOACHIM SZODRUCH *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 183-186 1987 In GERMAN  
(MBB-UT-006/87) Avail: NTIS HC A14/MF A01

The status of aerodynamic technology is presented. The development potentials for passenger and transport aircraft are described. Aerodynamic solutions, leading to the realization of technologies which open the way to the forecast potential of large-aircraft construction, are illustrated by the wing with controlled flow and the transonic laminar wing. The examples demonstrate the necessity of medium and long range research programs and of longer term industrial strategies. ESA

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**N88-17850#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.

### **THE APPLICATION OF MODERN AEROELASTIC DEVELOPMENTS FOR FUTURE PROJECTS [DIE ANWENDUNG MODERNER AEROELASTISCHER ENTWICKLUNGEN FUER ZUKUNFTIGE PROJEKTE]**

HELMUT ZIMMERMANN and JENS HINRICHSEN *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 197-202 1987 In GERMAN

(MBB-UT-007/87) Avail: NTIS HC A14/MF A01

The use of aeroelastic techniques and testing methods in aircraft construction is outlined. The history of aeroelasticity in aircraft construction is depicted. The aeroelastic treatment of the bending-torsion flutter of a wing is discussed. Aids for flutter optimization are explained. Aeroelastic problems in wing boxes made of carbon fiber reinforced plastics are presented. Flutter margin augmentation systems are outlined. Transonic aerodynamic forces in aerodynamics are treated. ESA

**N88-17853#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Helicopter and Military Aircraft Group.

### **HELICOPTER ACTIVITIES IN GERMANY**

VOLKER VONTEIN *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 213-224 1987 Presented at the 12th European Rotorcraft Forum, Garmisch-Partenkirchen, Fed. Republic of Germany, 22-25 Sep. 1986 Previously announced in IAA as A87-43401

(MBB-UD-487/86) Avail: NTIS HC A14/MF A01

The history of German helicopter technology is depicted. The update of the BO 105 and BK117 programs is given. Statistical information about all types of helicopters operating in Germany and the related infrastructure is presented. The most important technology programs covering rotor technology, vibration suppression, advanced composite airframes, avionics/cockpits, and flight control are presented. The most important future helicopter projects with German participation, such as the PAH2, NH90, and ALH are described. ESA

**N88-17854#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.

### **TESTING OF A TAIL ROTOR SYSTEM IN A FIBER COMPOSITE TYPE OF CONSTRUCTION [ERPROBUNG EINES HECKROTORSYSTEMES IN FASERVERBUNDBAUWEISE]**

VALENTI KLOEPEL and BERNHARD ENENKEL *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 225-234 1987 In GERMAN Presented at the BMFT-Status-Seminar, Munich, Fed. Republic of Germany, Apr. 1986

(MBB-UD-472/86) Avail: NTIS HC A14/MF A01

An experimental version of a fiber composite, bearingless helicopter tail rotor was developed and tested, to improve aerodynamic efficiency, simplicity of construction, weight, and costs. A four-blade, bearingless, smooth rotation rotor was chosen. The design is based on a glass fiber torsion element that takes the impact and rotation bending as well as angular acceleration of the blades. The dynamic characteristics, mechanical and aeroelastic stability phenomena, as well as the loading and strain levels were determined. The test stand and test program are described. The test results were used to determine the dynamic loading due to a precession motion, and to simulate the ground resonance conditions required to verify aeromechanical stability. ESA

**N88-17863#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Wehrtechnik.

### **AERODYNAMIC ASPECTS OF THE CONFIGURATIONAL SYSTEMS LAYOUT OF A DISPENSER [AERODYNAMISCHE GESICHTSPUNKTE DER KONFIGURATIVEN SYSTEMAUSLEGUNG EINES DISPENSERS]**

HORST SCHNEIDER *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 289-292 1987 In GERMAN

(MBB-UA-1047/87) Avail: NTIS HC A14/MF A01

Details of the configurational development of a dispenser system are treated. The design was based on experience in dispenser development and on preliminary investigations, taking into account geometrical compatibility requirements. The different investigated fin forms are presented. The aerodynamic stability behavior of the investigated fuselage-wing-fin configurations is discussed. ESA

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### AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

**A88-25366**

#### **SIMPLIFYING FLIGHT TEST**

JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 8, Jan. 1988, p. 20-25.

State-of-the-art computers, sensors, and data-transmission systems facilitate the extraction of enormous amounts of test data from a single instrumented flight. Attention is presently given to an integrated airborne data acquisition/ground-based data analysis flight test system in which all test process steps, from data acquisition to data analysis, are directly controlled by the test engineers. The system operates more simply, weighs and costs less, and requires less sophisticated technical support than existing systems. The flight test software employed proceeds through two phases: one down to the flight test database, and the other to final test results. O.C.

**A88-25367**

#### **VIBRATION MONITORING - A KEY CONTRIBUTION TO FLIGHT SAFETY**

Aerospace Engineering (ISSN 0736-2536), vol. 8, Jan. 1988, p. 27-30.

An airborne vibration monitoring (AVM) system encompasses such key elements as an accelerometer, interconnecting cable, processing electronics, and displays. An accelerometer mounted on a bearing housing will furnish a frequency spectrum closely related to the vibration of the rotating shaft. MTBFs of more than 200,000 hours are obtainable for engine fan bearing accelerometers. The value of AVM system data reflecting the health of an engine or other rotating component is noted to be a function of its filtering technique's sophistication. O.C.

**A88-26247**

#### **STATE ESTIMATION OF MANOEUVRING TARGETS FROM NOISY RADAR MEASUREMENTS**

K. V. RAMACHANDRA (Electronics and Radar Development Establishment, Radar 'C', Div., Bangalore, India) IEE Proceedings, Part F - Communications, Radar and Signal Processing (ISSN 0143-7070), vol. 135, pt. F, no. 1, Feb. 1988, p. 82-84. refs

Analytical results for tracking maneuvering targets from noisy radar measurements are presented. A three-dimensional mathematical model based on the Kalman filtering technique is discussed for the tracking of a maneuvering aircraft using noisy measurements obtained from a three-dimensional radar. The measurement uncertainties and the maneuver characteristics are assumed to be known in polar co-ordinates, and are also assumed

to be white Gaussian with zero mean and constant variance. These are coupled to the cartesian co-ordinate system selected for tracking operation. The elements of the covariance and Kalman gain matrices are expressed in terms of those which apply for tracking in polar co-ordinates. The steady-state results are expressed in compact form by appropriately partitioning the covariance matrices. The numerical computations of the steady-state filter parameters of the model are in excellent agreement with those obtained from the recursive Kalman filter matrix equations. Hence these results are of practical interest in developing trackers for tracking maneuvering aircraft and to eliminate the real-time execution of the complete filter equations.

Author

**A88-26648**

**MEASURING AIRCRAFT FLUID QUANTITIES**

JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 8, Feb. 1988, p. 12-15.

The accurate measurement of aircraft fuel, oil, and hydraulic fluid levels in a way that compensates for fluid displacement during aircraft maneuvers is being accomplished by means of gaging systems in which electronic circuitry is integral to the fluid-measurement probes. Gage capacitance can then be measured locally, rather than transmitted in the form of weak signals through long cables in a high-noise environment, as formerly done. Wiring can accordingly dispense with shielding. Also noted are systems for the measurement of such conductive fluids as the phosphate ester hydraulic fluids employed in many commercial aircraft.

O.C.

**A88-26670**

**A FAULT-TOLERANT MULTISENSOR NAVIGATION SYSTEM DESIGN**

BRIAN D. BRUMBACK (General Dynamics Corp., Fort Worth, TX) and MANDYAM D. SRINATH (Southern Methodist University, Dallas, TX) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. AES-23, Nov. 1987, p. 738-756. refs

The problem of soft-failure tolerant estimation in navigation systems composed of multiple inertial measurement clusters and one or more reference sensors is addressed. A new approach is presented that achieves containment of failed sensor data, and isolates the historic good data provided by the unfailed sensors. Multiple (local) estimates are computed where the estimates are conditioned on different subsets of the sensors. A statistical overlap test is used to determine the validity of the local estimates, and a failed sensor can be identified from analysis of the invalid local estimates. After the time of detection, the most accurate estimate based on all but the failed sensor, is identified. The results are applied to a dual-inertial/Doppler radar navigation system and simulation results are presented.

Author

**A88-27329**

**INTEGRATED CONTROLS DESIGN AND SIMULATION**

RICHARD DEAN COLGREN (Lockheed-California Co., Burbank) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 561-565. refs

A workstation is proposed which integrates the design, analysis, and simulation methods employed in flight control system synthesis. The method involves the interface of aerodynamic, propulsion, and structural models. Results are transferred to a flight simulator and to the dynamic structural model. An executive is employed to implement the modular workstation, internally handling most of the input/output operations to minimize data management. The method allows new techniques to be easily implemented as executives or as additional modules.

R.R.

**A88-27399**

**MODERN CONTROL METHODS APPLIED TO A LINE-OF-SIGHT STABILIZATION AND TRACKING SYSTEM**

DAVID HAESSIG, JR. and JAMES DECOTIIS (Singer Co., Kearfoot Div., Little Falls, NJ) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1491-1498. Research supported by the Singer Co. and Texas Instruments, Inc.

Modern control methods are used to develop compensators for a precise optical positioning system designed to track a commanded line-of-sight (LOS) position while rejecting the vibrational environment of an F-16 fighter aircraft, the vehicle upon which the device will be mounted. The physical system being controlled consists of two gimbals that effect large changes in the LOS position, and a mirror assembly that is used, because of its fast dynamic response (but limited range of motion), to reduce LOS jitter (i.e. angular disturbances above 5 HZ that cause blurring). Compensators are designed that include models of the motion to reject and of the motion to track. These models become part of each compensator and enable them to distinguish aircraft vibration from aircraft maneuvers, rejecting the former and tracking the latter. The vibrational disturbance that must be rejected has a magnitude of 560 microrads rms, which is magnified by the optical system to 1400 microrads of LOS motion. Simulation of closed-loop performance with a nonlinear dynamic model of the system demonstrated that LOS jitter is reduced to about 130 microrads rms. A tradeoff between stabilization and tracking is demonstrated. Compensator robustness to unmodelled disturbances is increased using the Loop-Transfer-Recovery technique.

Author

**A88-27478**

**PERFORMANCE OF OPTICAL SENSORS IN HYPERSONIC FLIGHT**

WILLIAM J. TROPF, MICHAEL E. THOMAS, TERRY J. HARRIS, and STEVEN A. LUTZ (Johns Hopkins University, Laurel, MD) Johns Hopkins APL Technical Digest (ISSN 0270-5214), vol. 8, Oct.-Dec. 1987, p. 370-385. refs

The high pressure and temperature, radiation, and heat transfer to sensor windows associated with hypersonic flow alter the resolution, focus, and boresight of sensors by generating sharp gas density gradients, shock interactions, turbulence, and active coolant mixing effects. It is presently shown that flow calculations can be coupled with ray-tracing programs to estimate optical aberrations and boresight shifts in hypersonic conditions. More complex flow conditions, such as shock-shock interactions, must be examined experimentally. Attention is given to the effects of aerodynamic convective heat transfer on sensors. As flight speed increases, the active cooling of windows will be needed to operate sensors effectively.

O.C.

**A88-27639#**

**INFLIGHT THERMAL DATA RECORDING FROM IAF AIRCRAFT**

N. S. BABOO, P. BANDOPADHYAY, P. K. BANERJEE, and M. B. DIKSHIT Aviation Medicine, vol. 30, June 1986, p. 33-37. refs

This paper describes the results of measurements of inflight thermal data, by a modified commercial digital heat stress monitor, obtained for several types of aircraft. The system was successfully employed in Chetak helicopter, Chitra (HS-748), Kiran, and Trishul and Shamsher trainers, for which it obtaining temperatures during the start-up, taxiing, take off, start-climb, flight, landing, and switch off phases of the flight. The results indicated the maximum cabin temperature to be at the ground, with the temperature falling as soon as an aircraft is airborne, except in Chetak, where the cabin temperature showed continuous rise throughout the duration of sortie.

I.S.

## 06 AIRCRAFT INSTRUMENTATION

**A88-27731**

**COOLING OF AIRBORNE EQUIPMENT [OKHLAZHDENIE BORTOVOI APPARATURY AVIATIONNOI TEKHNIKI]**  
IGOR' VALENTINOVICH GLUSHITSKII Moscow, Izdatel'stvo Mashinostroenie, 1987, 184 p. In Russian. refs

Methods for the efficient cooling of airborne navigation, control, and communication equipment are presented which make it possible to maintain the electronic equipment at its normal working temperature under various service conditions. Engineering methods are proposed for solving thermophysical problems arising during the design of airborne electronic equipment, and experimental results are presented to demonstrate the validity of these methods. The cooling systems discussed include air, liquid, and evaporative systems. V.L.

**N88-16654\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

### **AVIONICS SYSTEMS INTEGRATION TECHNOLOGY**

GEORGE STECH and JAMES R. WILLIAMS *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1189-1210 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01D

A very dramatic and continuing explosion in digital electronics technology has been taking place in the last decade. The prudent and timely application of this technology will provide Army aviation the capability to prevail against a numerically superior enemy threat. The Army and NASA have exploited this technology explosion in the development and application of avionics systems integration technology for new and future aviation systems. A few selected Army avionics integration technology base efforts are discussed. Also discussed is the Avionics Integration Research Laboratory (AIRLAB) that NASA has established at Langley for research into the integration and validation of avionics systems, and evaluation of advanced technology in a total systems context. Author

**N88-16655\*#** Army Research and Technology Labs., Fort Eustis, Va. Aviation Applied Technology Directorate.

### **INTEGRATED DIAGNOSTICS**

ROGER J. HUNTHAUSEN *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1211-1230 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 01D

Recently completed projects in which advanced diagnostic concepts were explored and/or demonstrated are summarized. The projects begin with the design of integrated diagnostics for the Army's new gas turbine engines, and advance to the application of integrated diagnostics to other aircraft subsystems. Finally, a recent project is discussed which ties together subsystem fault monitoring and diagnostics with a more complete picture of flight domain knowledge. 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.*

**A88-25618**

**CALCULATION OF THE PATH OF A DROPLET IN THE COMBUSTION CHAMBER OF A HELICOPTER RAMJET ENGINE [O RASCHETE TRAEKTORII DVIZHENIIA KAPLI V KAMERE SGORANIIA VERTOLETNOGO PVRD]**

IU. N. ZOTOV and A. P. MERKULOV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1987, p. 32-35. In Russian. refs

A method for calculating the path of a droplet is proposed which is based on the analysis of the absolute motion of the droplet. Results of an analytical investigation of the parameters of

an evaporating droplet in the vortex combustion chamber of a helicopter ramjet engine are then presented. It is shown that the approach proposed here makes it possible to identify the principal physical effects and to estimate quantitatively the effect of flow swirling on the motion and heat and mass transfer parameters of droplets and gas. V.L.

**A88-25628**

**A STUDY OF THE AUTOROTATION REGIMES OF GAS TURBINE ENGINES [K VOPROSU ISSLEDOVANIIA REZHIMOV AVTOROTATSII GTD]**

V. I. DAINKO *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1987, p. 72, 73. In Russian.

The autorotation of a gas turbine is investigated experimentally using a full-scale 750-kW aircraft gas turbine engine with a seven-stage axial-centrifugal compressor (six axial stages and one centrifugal stage). It is found that, under conditions of steady-state autorotation, at air flow rates up to 0.2 of the nominal value and flow velocities less than M 0.5, the compressor uses mechanical energy and offers resistance to the incoming air flow, which results in a partial loss of pressure. The torque at the turbocompressor shaft is created by the turbine. V.L.

**A88-25638**

**REPRESENTATION OF FAN CHARACTERISTICS IN A MATHEMATICAL MODEL OF THE BYPASS ENGINE [PREDSTAVLENIE KHARAKTERISTIKI VENTILIATORA S MATEMATICHESKOI MODELI TRDD]**

B. D. FISHBEIN and V. I. TIKHONOV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1987, p. 95, 96. In Russian.

The problems associated with the representation of fan characteristics in the mathematical modeling of bypass engines are briefly examined, and a form of representation is proposed which provides an adequate description of the modeled system in a wide variety of design problems, particularly with the introduction of computer-aided design. The representation of fan characteristics proposed here applies, in particular, to a fan design with common exit guide vanes and a separator shifted downstream. V.L.

**A88-26168#**

**THEORETICAL ANALYSIS OF ROTATIONAL-SPEED FLUCTUATIONS OF TWO-SPOOL TURBOJET ENGINES [TEORETYCZNA ANALIZA WAHAN PREDKOSCI OBROTOWEJ DWUWALOWYCH SILNIKOW ODRZUTOWYCH]**

PAWEL LINDSTEDT *Technika Lotnicza i Astronautyczna* (ISSN 0040-1145), vol. 42, Oct. 1987, p. 19-22. In Polish. refs

Results of a theoretical analysis of the impeller speed fluctuation effect in a two-spool turbojet engine are presented. It is shown how these results can be used to identify the cause of the fluctuations and to correct the problem in the course of engine service. A mathematical model is used to describe the mechanism of speed fluctuations resulting from typical pump failures. B.J.

**A88-26414**

**IMPLICATION OF MODEL REDUCTION IN THE ACTIVE CONTROL OF TURBOMACHINERY VIBRATIONS**

R. FIROOZIAN (Sheffield, University, England) (EUROMECH Colloquium on Active Noise and Vibration Control, 213th, Marseille, France, Sept. 8-11, 1986) *Journal de Mecanique Theorique et Appliquee, Supplement* (ISSN 0750-7240), vol. 6, 1987, p. 183-202. refs

The problem of designing an actively controlled suspension system for a multimode rotor running on fluid-film bearings is considered. In principle, it is shown that by employing a control law any mode of vibration can be controlled by a single control force along the rotor. The problem of measuring all the state variables for active control can be overcome using a reduced-order model and a state observer. The use of the reduced-order model may cause oscillation or instability in the response due to the residual modes. It is shown that this problem indeed occurs for an undamped system but is insignificant when there is structural damping (as by fluid-film bearings). Author

A88-26588#

**THE AFFECTION OF INTERBLADE PHASE ANGLE IN OSCILLATING CASCADE ON UNSTEADY AERODYNAMIC FORCE**

ZUOYI CHEN and SHAN ZHONG (Tsinghua University, Beijing, People's Republic of China) *Journal of Engineering Thermophysics* (ISSN 0253-231X), vol. 8, Nov. 1987, p. 346-348. In Chinese, with abstract in English.

A lot of numerical experiments on the affection of interblade phase angle in oscillating cascade on unsteady aerodynamic force is presented in this article. The comparison of the unsteady aerodynamic force and corresponding aerodynamic safety analysis under different conditions, such as different flow, different oscillating mode etc., are also given. Author

A88-26589#

**A RIG TESTING METHOD OF ANNULAR COMBUSTOR IN AEROENGINE**

BAOCHENG ZHANG (Shenyang Aeronautic Institute, People's Republic of China) *Journal of Engineering Thermophysics* (ISSN 0253-231X), vol. 8, Nov. 1987, p. 382-385. In Chinese, with abstract in English.

A rig testing method appropriate to the development of the combustion chamber in lot production aeroengines is described in this paper. An example is used to demonstrate rig testing, which includes start-up performance, combustion efficiency, temperature distribution and stability of annular combustor. Comprehensive analyses are made of thrust, fuel rate, rotation rate in the operation condition, and temperature at the outlet in turbine and areas of exhaust outlet at jet nozzle in the run. The effectiveness of the rig testing method was proved in life runnings and test flights. Author

A88-26628#

**EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF DIFFUSER SHELL SHAPES ON PERFORMANCE OF DUMP DIFFUSERS IN COMBUSTOR**

GUANGSHI HUA, WEIBIN WANG, MING TANG, and BINGLU CHEN (Northwestern Polytechnical University, Xian, People's Republic of China) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 13-17, 88. In Chinese, with abstract in English. refs

The performance of a two-dimensional symmetric straight-wall diffuser at inlet Mach number 0.277 and flow split ratio 1 is investigated experimentally, varying the shape of the diffuser shell and the dump gap. The results are presented in graphs, and the shell shape is shown to have a greater effect on the overall pressure loss than on the optimal dump gap, which is found to be 40-50 mm in all cases. Zones with external static pressure lower than the pressure in the flame tube are observed under some conditions. T.K.

A88-26638#

**A DYNAMICAL MATHEMATICAL MODEL AND DIGITAL SIMULATION FOR ANTI-SURGE CONTROL SYSTEM OF A TURBOFAN ENGINE**

HUIZHU HE (Northwestern Polytechnical University, Xian, People's Republic of China) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 55-58, 93. In Chinese, with abstract in English. refs

An antisurge control system for a turbofan engine is investigated. A dynamical mathematical model of this system has been developed, and a simulation has been done on a digital computer. In the first step of the simulation, the linear system is studied and the dynamical performance is calculated under four conditions to determine the main parameters influencing dynamical performance. In the second step, the effects of nonlinearities of the dead region and backlash are studied. The results indicate that the nonlinearities enhance the relative stability of the system, but the backlash reduces it. Both effects appear not to be in agreement with the superposition principle. Finally, ways of improving the quality of the system are presented based on the results of the calculation. Author

A88-26649

**DOUBLING THRUST-TO-WEIGHT RATIO**

JAMES H. BRAHNEY *Aerospace Engineering* (ISSN 0736-2536), vol. 8, Feb. 1988, p. 22-26.

The USAF High Performance Turbine Engine Technologies (HPTET) Program has as its primary goal the doubling of turbomechanical aircraft propulsion systems' thrust/weight ratio by the year 2000, through the integration of advanced materials, novel structural concepts, and breakthroughs in aerothermodynamic cycle design. Advanced materials are judged to hold the key to the achievement of program goals; the most promising and intensively researched materials are carbon/carbon, ceramic-matrix and metal-matrix composites, high temperature Al alloys, and high-temperature nonstructural substances for lubrication and bearings. Attention is given to the potential advantages of integrally-bladed or 'blisk' disk rotors. O.C.

A88-27166

**TURBULENT HYDROGEN COMBUSTION IN A WALL JET ISSUING INTO A COMOVING SUPERSONIC STREAM OF AIR [TURBULENTNOE GORENIE VODORODA V PRISTENNOI STRUE, ISTEKAIUSHCHEI V SPUTNYI SVERKHZVUKOVOI POTOK VOZDUKHA]**

V. G. GROMOV, O. B. LARIN, and V. A. LEVIN *Fizika Goreniia i Vzryva* (ISSN 0430-6228), vol. 23, Nov.-Dec. 1987, p. 3-9. In Russian. refs

The ignition and combustion of low-temperature hydrogen in a turbulent wall jet issuing from a plane slot into a comoving supersonic stream of heated air are investigated numerically. The numerical analysis uses a multilayer algebraic model based on a mixing length hypothesis and a differential parametric k-epsilon model. It is shown that the modification of the 'nonmixing' model proposed here improves agreement with experimental data. V.L.

A88-27291#

**FLOWFIELD IN A DUAL-INLET SIDE-DUMP COMBUSTOR**

T.-M. LIOU (National Tsing Hua University, Hsinchu, Republic of China) and S.-M. WU *Journal of Propulsion and Power* (ISSN 0748-4658), vol. 4, Jan.-Feb. 1988, p. 53-60. refs

The cold flowfield of a side-dump combustor, which consisted of a plexiglass, circular duct with two 60-deg curved inlets located radially at an angle of 180 deg, is measured quantitatively using laser-Doppler velocimetry. Air was used as a flow medium. The Reynolds number, based on the combustor diameter and bulk velocity, was 26,000. Detailed profiles of mean velocities and turbulence intensities are reported. The impinging stagnation point of the inlet jets, the lengths needed to reach both one-way flow and fully developed mean-velocity profile, and the primary combustor flow regions are determined. In addition, the homogeneity and isotropy of the turbulence are documented. Furthermore, the results also identify the part of fluid dynamic characteristics unable to be predicted by two-dimensional models. This information will be useful to test and develop combustor modeling in this area. Author

A88-27295\*# Purdue Univ., West Lafayette, Ind.

**TRANSIENT ENGINE PERFORMANCE WITH WATER INGESTION**

T. HAYKIN and S. N. B. MURTHY (Purdue University, West Lafayette, IN) *Journal of Propulsion and Power* (ISSN 0748-4658), vol. 4, Jan.-Feb. 1988, p. 81-88. Previously cited in issue 20, p. 2921, Accession no. A86-42755. refs  
(Contract NAG3-481)

A88-27296\*# Clarkson Univ., Potsdam, N.Y.

**SOOT LOADING IN A GENERIC GAS TURBINE COMBUSTOR**

W. A. ECKERLE (Clarkson University, Potsdam, NY) and T. J. ROSFJORD (United Technologies Research Center, East Hartford, CT) *Journal of Propulsion and Power* (ISSN 0748-4658), vol. 4, Jan.-Feb. 1988, p. 89-96. Previously cited in issue 08, p. 1051, Accession no. A87-22544. refs  
(Contract NAS3-24223)

## 07 AIRCRAFT PROPULSION AND POWER

**A88-27730**

**DATA PROCESSING AND ANALYSIS DURING THE AUTOMATED TESTING OF GAS TURBINE ENGINES [OBRABOTKA I ANALIZ INFORMATSII PRI AVTOMATIZIROVANNYKH ISPYTANIYAKH GTD]**

RAVIL' ISKANDEROVICH ADGAMOV, VLADLEN ONISIMOVICH BOROVIK, SERGEI VASIL'EVICH DMITRIEV, I. V. KOZHEVNIKOV, and G. P. SHIBANOV Moscow, Izdatel'stvo Mashinostroenie, 1987, 216 p. In Russian. refs

The book is concerned with various aspects of data processing and analysis during the automatic computerized bench testing of gas turbine engines. In particular, attention is given to the structure and software and hardware implementation of the automatic testing process; types and sources of data in gas turbine engine testing; determination of the characteristics of gas turbine engines using a mathematical model; and the validity of the test-bench performance characteristics of gas turbine engines. The discussion also covers the organizational aspects of the computerization of experimental studies. V.L.

**A88-27742**

**MULTIFREQUENCY NONLINEAR VIBRATIONS IN A GAS-TURBINE ENGINE [MNOGOCHASTOTNYE Nelineinye KOLEBANIYA V GAZOTURBINNOM DVIGATELE]**

IOSIF L'VOVICH PIS'MENNYI Moscow, Izdatel'stvo Mashinostroenie, 1987, 128 p. In Russian. refs

The book focuses on theoretical and experimental studies of oscillatory processes in gas-turbine engines, including subharmonic and superharmonic surge phenomena. Particular attention is given to methods of protection against dangerous oscillatory regimes. Formulas and characteristics of two- and three-frequency harmonic linearization are presented for the most typical nonlinear elements. The discussion also covers protection against vibrational combustion in the afterburner and some manifestations of the nonlinear effects of vibrations. V.L.

**N88-16637\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**TECHNOLOGY DEVELOPMENTS FOR A COMPOUND CYCLE ENGINE**

GEORGE A. BOBULA, WILLIAM T. WINTUCKY, and J. G. CASTOR (Garrett Turbine Engine Co., Phoenix, Ariz.) /in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 683-697 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 21E

The Compound Cycle Engine (CCE) is a highly turbocharged, power compounded power plant which combines the light weight pressure rise capability of a gas turbine with the high efficiency of a diesel. When optimized for a rotorcraft, the CCE will reduce fuel burned for a typical 2 hour (plus 30 min reserve) mission by 30 to 40 percent when compared to a conventional advanced technology gas turbine. The CCE can provide a 50 percent increase in range-payload product on this mission. Results of recent activities in a program to establish the technology base for a CCE are presented. The objective of this program is to research and develop those critical technologies which are necessary for the demonstration of a multicylinder diesel core in the early 1990s. A major accomplishment was the initial screening and identification of a lubricant which has potential for meeting the material wear rate limits of the application. An in-situ wear measurement system also was developed to provide accurate, readily obtainable, real time measurements of ring and liner wear. Wear data, from early single cylinder engine tests, are presented to show correlation of the in-situ measurements and the system's utility in determining parametric wear trends. A plan to demonstrate a compound cycle engine by the mid 1990s is included. Author

**N88-16638\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**SMALL GAS TURBINE ENGINE TECHNOLOGY**

RICHARD W. NIEDZWIECKI and PETER L. MEITNER (Army Research and Technology Labs., Cleveland, Ohio.) /in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 698-736 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 21E

Performance of small gas turbine engines in the 250 to 1,000 horsepower size range is significantly lower than that of large engines. Engines of this size are typically used in rotorcraft, commutercraft, general aviation, and cruise missile applications. Principal reasons for the lower efficiencies of a smaller engine are well known: component efficiencies are lower by as much as 8 to 10 percentage points because of size effects. Small engines are designed for lower cycle pressures and temperatures because of smaller blading and cooling limitations. The highly developed analytical and manufacturing techniques evolved for large engines are not directly transferrable to small engines. Thus, it was recognized that a focused effort addressing technologies for small engines was needed and could significantly impact their performance. Recently, in-house and contract studies were undertaken at the NASA Lewis Research Center to identify advanced engine cycle and component requirements for substantial performance improvement of small gas turbines for projected year 2000 applications. The results of both in-house research and contract studies are presented. In summary, projected fuel savings of 22 to 42 percent could be obtained. Accompanying direct operating cost reductions of 11 to 17 percent, depending on fuel cost, were also estimated. High payoff technologies are identified for all engine applications, and recent results of experimental research to evolve the high payoff technologies are described. Author

**N88-16639\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**THE CONVERTIBLE ENGINE: A DUAL-MODE PROPULSION SYSTEM**

JACK G. MCARDLE /in NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 737-768 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 21E

A variable inlet guide vane (VIGV) convertible engine that could be used to power future high-speed rotorcraft was tested on an outdoor stand. The engine ran stably and smoothly in the turbofan, turboshaft, and dual (combined fan and shaft) power modes. In the turbofan mode with the VIGV open, fuel consumption was comparable to that of a conventional turbofan engine. In the turboshaft mode with the VIGV closed, fuel consumption was higher than that of present turboshaft engines because power was wasted in churning fan-tip air flow. In dynamic performance tests with a specially built digital engine control and using a waterbrake dynamometer for shaft load, the engine responded effectively to large steps in thrust command and shaft torque. Previous mission analyses of a conceptual X-wing rotorcraft capable of 400-knot cruise speed were revised to account for more fan-tip churning power loss that was originally estimated. The calculations confirm that using convertible engines rather than separate life and cruise engines would result in a smaller, lighter craft with lower fuel use and direct operating cost. Author

**N88-16640\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**RESULTS OF NASA/ARMY TRANSMISSION RESEARCH**

JOHN J. COY (Army Research and Technology Labs., Cleveland, Ohio.), DENNIS P. TOWNSEND, and HAROLD H. COE *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 769-801 Feb. 1988  
Avail: NTIS HC A25/MF A01 CSCL 21E

Since 1970 the NASA Lewis Research Center and the U.S. Army Aviation Systems Command have shared an interest in advancing the technology for helicopter propulsion systems. In particular, that portion of the program that applies to the drive train and its various mechanical components are outlined. The major goals of the program were (and continue to be) to increase the life, reliability, and maintainability, reduce the weight, noise, and vibration, and maintain the relatively high mechanical efficiency of the gear train. Major historical milestones are reviewed, significant advances in technology for bearings, gears, and transmissions are discussed, and the outlook for the future is presented. The reference list is comprehensive. Author

**N88-16698\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**IMPACT AND PROMISE OF NASA AEROPROPULSION TECHNOLOGY**

NEAL T. SAUNDERS and DAVID N. BOWDITCH *In its* Aeropropulsion '87. Session 1: Aeropropulsion Materials Research 30 p Nov. 1987

Avail: NTIS HC A06/MF A01 CSCL 21E

The aeropropulsion industry in the United States has established an enviable record of leading the world in aeropropulsion for commercial and military aircraft. The NASA aeropropulsion propulsion program (primarily conducted through the Lewis Research Center) has significantly contributed to that success through research and technology advances and technology demonstrations such as the Refan, Engine Component Improvement, and the Energy Efficient Engine Programs. Some past NASA contributions to engines in current aircraft are reviewed, and technologies emerging from current research programs for the aircraft of the 1990's are described. Finally, current program thrusts toward improving propulsion systems in the 2000's for subsonic commercial aircraft and higher speed aircraft such as the High-Speed Civil Transport and the National Aerospace Plane (NASP) are discussed. Author

**N88-16706#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Systems and Logistics.

**TURBINE ENGINE MONITORING SYSTEMS: CAN THEY BENEFIT COMPONENT IMPROVEMENT PROGRAM MANAGEMENT? M.S. Thesis**

LEN J. NEIST Sep. 1987 72 p  
(AD-A186992; AFIT/GLM/LSM/87S-51) Avail: NTIS HC A04/MF A01 CSCL 21E

The purpose is to verify if the data collected by Turbine Engine Monitoring Systems (TEMS) could benefit an engine's Component Improvement Program (CIP) management. The initial plan was to identify and assess any benefits by comparing an engine with a CIP (PWA TF30) but not TEMS against an engine with a CIP and a TEMS (GE TF34). This was not possible, however, because the TEMS data were not being used to assist with TF34 CIP management due to the lack of a Central Data Base to collate and transform the data. The engine duty cycle was identified as the key to many important areas of a CIP, including engine component life usage and failure replication and diagnosis. As mentioned above, the current methods used to identify an engine's duty cycle lack the accuracy and reliability required to manage modern gas turbine engines. The main thrust of the recommendations is that a central data base be established so that the TF34 CIP manager can utilize TEMS data. In addition, a comparison use cost analysis is recommended to firmly establish the benefits to both long and short term engine management. GRA

**N88-17210\*#** Systems Control Technology, Inc., Palo Alto, Calif.

**KNOWLEDGE BASED JET ENGINE DIAGNOSTICS**

TIMOTHY G. JELLISON and RONALD L. DEHOFF *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 25-30 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 21E

A fielded expert system automates equipment fault isolation and recommends corrective maintenance action for Air Force jet engines. The knowledge based diagnostics tool was developed as an expert system interface to the Comprehensive Engine Management System, Increment IV (CEMS IV), the standard Air Force base level maintenance decision support system. XMAM (trademark), the Expert Maintenance Tool, automates procedures for troubleshooting equipment faults, provides a facility for interactive user training, and fits within a diagnostics information feedback loop to improve the troubleshooting and equipment maintenance processes. The application of expert diagnostics to the Air Force A-10A aircraft TF-34 engine equipped with the Turbine Engine Monitoring System (TEMS) is presented. Author

**N88-17647#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

**ADVANCED TECHNOLOGY FOR AERO GAS TURBINE COMPONENTS**

Sep. 1987 541 p *In* ENGLISH and FRENCH Symposium held in Paris, France, 4-8 May 1987

(AGARD-CP-421; ISBN-92-835-0433-X) Avail: NTIS HC A23/MF A01

The Symposium is aimed at highlighting the development of advanced components for new aero gas turbine propulsion systems in order to provide engineers and scientists with a forum to discuss recent progress in these technologies and to identify requirements for future research. Axial flow compressors, the operation of gas turbine engines in dust laden atmospheres, turbine engine design, blade cooling, unsteady gas flow through the stator and rotor of a turbomachine, gear systems for advanced turboprops, transonic blade design and the development of a plenum chamber burner system for an advanced VTOL engine are among the topics discussed.

**N88-17648#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Turbine Engine Div.

**THE COMING REVOLUTION IN TURBINE ENGINE TECHNOLOGY**

JAMES S. PETTY and ROBERT E. HENDERSON *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p Sep. 1987

Avail: NTIS HC A23/MF A01

A major change in turbopropulsion technology development philosophy is now being pursued by the U.S. Air Force Wright Aeronautical Laboratories (AFWAL) which will provide revolutionary advancements in overall operational performance capability for future military aircraft and aerospace weapon systems. An historical perspective illustrates the significance of the advancements being pursued, with engine thrust-to-weight used as the principal performance figure-of-merit. The High Performance Turbine Engine Technologies (HPTET) effort, begun in 1982, is discussed. The overall goal of the effort is to provide the advanced materials, innovative structural concepts and advanced aerothermodynamics to double turbopropulsion capability by the year 2000. Author

## 07 AIRCRAFT PROPULSION AND POWER

**N88-17649#** Rolls-Royce Ltd., Bristol (England). Lift Engines and Future Technology Demonstrators.

### **OPTIMISATION OF MILITARY COMPRESSORS FOR WEIGHT AND VOLUME**

K. R. GARWOOD *In* AGARD Advanced Technology for Aero Gas Turbine Components 7 p Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom  
Avail: NTIS HC A23/MF A01

The high pressure compression system for future fighter engines has been projected at two different proven technology standards. For a given cycle of approximately 175 lbs. and 25:1 overall pressure ratio, three compressors have been evaluated, ranging from a seven stage unit with medium loading, to a five and a four stage unit with high loading. Test data of the original research parent compressors and two project specific units was commonised to the engine size and conditions. It is shown that apparent benefits between machines are negated and no significant advantage for lower work per stage could be identified at a given blading technology standard. Relative to the seven stage unit, a weight advantage of 20 percent is gained by the adoption of a four stage unit, and it is associated with an airfoil count reduction of 15 percent. Author

**N88-17650#** Royal Aircraft Establishment, Farnborough (England).

### **AN EXAMINATION OF THE IMPACT OF POTENTIAL ADVANCES IN COMPONENT TECHNOLOGY FOR FUTURE MILITARY ENGINES**

M. R. LITCHFIELD and M. G. PHILPOT *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p Sep. 1987  
Avail: NTIS HC A23/MF A01

The prospects for major advances in gas turbine engine component technology over the next 20 years are examined. For future military engines and aircraft, these advances could lead to considerably higher thrust/weight ratios than are currently available. The gains in engine performance resulting from various specific technology advances are outlined and their impact on sizing and performance of a typical combat aircraft are considered. In conjunction with these future projections, an examination is also made of the influences of the main engine cycle parameters such as overall pressure ratio, bypass ratio, and rating philosophy on the mass and performance of the aircraft/engine combination. Author

**N88-17652#** Technische Hochschule, Aachen (West Germany). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.

### **APPLICATION OF HIGHLY LOADED SINGLE-STAGE MIXED-FLOW COMPRESSORS IN SMALL JET-ENGINES**

R. MOENIG, K. D. BROICHHAUSEN (Motoren- und Turbinen-Union Muenchen G.m.b.H., West Germany ), and H. E. GALLUS *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p Sep. 1987 Sponsored by Bundesamt fuer Wehrtechnik und Beschaffung, Fed. Republic of Germany  
Avail: NTIS HC A23/MF A01

The predominant requirements on small jet engines are high power-to-weight ratio and low specific fuel consumption in combination with structural simplicity. The consequent demands on the compressor can be fulfilled either by a conventional two-stage unit or by an extremely loaded single stage. This single stage compressor has to be able to perform at a sufficiently large massflow and total pressure ratio. Consequently, the application of a mixed flow compressor with supersonic flow at rotor- or stator-inlet (supersonic mixed-flow compressor) turns out to be advantageous. The conception of a jet engine with a supersonic combustor demonstrates the significantly reduced size compared with other engines of the same thrust class. Author

**N88-17653#** Societe Turbomeca, Bordes (France).

### **THE ADVANTAGE OF VARIABLE GEOMETRY FOR TURBINE ENGINES AT LOW POWER [INTERET DE LA GEOMETRIE VARIABLE POUR LES TURBOMOTEURS DE FAIBLE PUISSANCE]**

H. VIGNAU, R. RODELLAR, and J. SILET *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p Sep. 1987  
In FRENCH

Avail: NTIS HC A23/MF A01

To reduce the specific fuel consumption of gas turbines at low power, various cycles of free and bound turbine engines were studied. A variable output engine permits a significant reduction of specific consumption at partial capacity. The variation in power is obtained through the change in the variable geometry component output; engine operating pressure, turbine intake temperature, and rotation velocity constants. The models which take variable geometry systems into account should be improved to specify the potential gains of such techniques. The results of a study on a centrifugal compressor with a compression rate of 8.5 and with a variable-setting radial diffuser show that an output variation of 50 percent can be obtained with a slight variation in efficiency and low sensitivity. Author

**N88-17654#** Calspan Advanced Technology Center, Buffalo, N.Y.

### **OPERATION OF GAS TURBINE ENGINES IN DUST-LADEN ENVIRONMENTS**

M. G. DUNN, C. PADOVA, and R. M. ADAMS (Defense Nuclear Agency, Washington, D.C.) *In* AGARD Advanced Technology for Aero Gas Turbine Components 16 p Sep. 1987 (Contract DNA001-83-C-0182)  
Avail: NTIS HC A23/MF A01

Results are reported for a measurement program designed to investigate the performance deterioration of gas turbine engines and the associated auxiliary equipment difficulties when operating in dust laden environments. Three TF33 turbofan engines and one J57 turbojet engine have been tested with two different dust blends. The predominant damage mechanism in all the engines was compressor blade erosion. The length of dust exposure time required to cause engine damage was dependent upon power setting and dust concentration. The turbine inlet temperature for these engines was too low to realize deposition of glassy material on the hot section components. The Environmental Control System (ECS) was monitored to ascertain the amount of injected material and the size distribution of material that makes its way to the ECS. A significant fraction of the dust is not centrifuged out of the flow and does end up in the control system air. These particles have a mean size on the order of 6 microns. The engine parameters most indicative of degradation were identified and are discussed. Author

**N88-17651#** Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

### **SPECIFICATION OF AN ENGINE AND ITS COMPONENTS STARTING FROM A CONSIDERATION OF AIRCRAFT MISSIONS [SPECIFICATION DU MOTEUR ET DE SES COMPOSANTS A PARTIR DES MISSIONS DE L'AVION]**

A. LARDELLIER and J. DUFAU *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p Sep. 1987 In FRENCH

Avail: NTIS HC A23/MF A01

A computer implemented methodology for the optimization of engine cycles is described. The integrated technique considers engine size and mechanical design features, basic aircraft aerodynamic and weight/size characteristics, and aircraft mission operational requirements. Three applications of the method are discussed: the influence of engine weight on the aircraft and mission characteristics; the influence of afterburn on supersonic cruise missions; and the influence of mission parameters on engine cycle and aircraft size. Author

**N88-17655#** National Research Council of Canada, Ottawa (Ontario). Gas Dynamics Lab.

**A RESEARCH PROGRAM ON THE AERODYNAMICS OF A HIGHLY LOADED TURBINE STAGE**

R. G. WILLIAMSON, S. H. MOUSTAPHA, J. P. HUOT, and U. OKAPUU (Pratt and Whitney Aircraft of Canada Ltd., Longueuil, Quebec) *In* AGARD Advanced Technology for Aero Gas Turbine Components 17 p Sep. 1987  
Avail: NTIS HC A23/MF A01

The main conclusions drawn from recent work in an on-going experimental program of research on the aerodynamics of a highly loaded turbine stage are discussed. Detailed data have been secured relating to the aerodynamic performance of transonic nozzles of high turning angle (tested with two outer wall contours) and the influence of the stage environment on such measurements. Further work addresses rotor performance (as affected by blade loading), and also overall stage performance. The ultimate objective of the work is the extension of turbine design methods to regimes combining high stage loadings with high pressure ratios, with special emphasis on small blade sizes. Author

**N88-17656\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EXPERIMENTAL EVALUATION OF A TRANSLATING NOZZLE SIDEWALL RADIAL TURBINE**

RICHARD J. ROELKE and CASIMIR ROGO (Teledyne CAE, Toledo, Ohio.) *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p Sep. 1987  
Avail: NTIS HC A23/MF A01 CSCL 21E

An experimental performance evaluation was made of two movable sidewall variable area radial turbines. The turbine designs were representative of the gas generator turbine of a variable flow capacity rotorcraft engine. The first turbine was an uncooled design while the second turbine had a cooled nozzle but an uncooled rotor. The cooled nozzle turbine was evaluated both with and without coolant flow. The test results showed that the movable nozzle wall is a viable and efficient means to effectively control the flow capacity of a radial turbine. Peak efficiencies of the second turbine with and without nozzle coolant were 86.5 and 88 percent respectively. These values are comparable to pivoting vane variable geometry turbines; however, the decrease in efficiency as the flow was varied from the design value was much less for the movable wall turbine. Several design improvements which should increase the turbine efficiency one or two more points are identified. These design improvements include reduced leakage losses and relocation of the vane coolant ejection holes to reduce mainstream disturbance. Author

**N88-17657#** Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).

**AN INTEGRATED AERO/MECHANICAL PERFORMANCE APPROACH TO HIGH TECHNOLOGY TURBINE DESIGN**

J. HOURMOUZIADIS and G. ALBRECHT *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p Sep. 1987  
Sponsored by German Ministry for Research and Technology, Fed. Republic of Germany  
Avail: NTIS HC A23/MF A01

Analytical and experimental experience from an advanced technology gas generator program is used to define the requirements on the engineering sciences involved in the design of gas turbine engines. Some aerodynamic, performance and cooling problems to be solved in a common approach with mechanical design for radial clearance control, hot gas path sealing and life are discussed. Author

**N88-17658#** Royal Aircraft Establishment, Farnborough (England).

**DESIGN AND TEST OF A HIGH BLADE SPEED, HIGH WORK CAPACITY TRANSONIC TURBINE**

R. C. KINGCOMBE, J. D. BRYCE, and N. P. LEVERSUCH *In* AGARD Advanced Technology for Aero Gas Turbine Components 17 p Sep. 1987  
Avail: NTIS HC A23/MF A01

A high rim-speed turbine was designed and tested. A major objective in the design was to achieve high aerodynamic efficiency at high work capacity by way of reduced stage loading facilitated by high blade speed. The design includes three dimensional features such as a parabolic distribution of exit angle and compound trailing edge lean on the nozzle guide vane and a thick rotor, highly tapered rotor blade - necessary in an engine turbine to reduce blade stress. Author

**N88-17659#** Rolls-Royce Ltd., Bristol (England). Advanced Turbine Technology Dept.

**ADVANCED TECHNIQUES EMPLOYED IN BLADE COOLING RESEARCH**

H. E. ROGERS, C. GRAHAM, and K. MCNICHOLAS *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p Sep. 1987  
Sponsored by Procurement Executive Ministry of Defence, United Kingdom  
Avail: NTIS HC A23/MF A01

The design of an advance cooling system for moderately cooled second stage gas turbine engine blades was undertaken as part of a demonstration project. The design process involving complex computer modeling and hot rig testing of the blades is described. The test results confirmed that substantial increases in cooling efficiency can be gained by introducing small scale turbulators into radial hole cooling systems. A development temperature measurement technique based on a video camera operating in the near infrared region is described. The results of video pyrometry were validated from results obtained from a series of demonstrator hot rig tests. Also discussed are a number of problems relating to surface temperature measurement. Author

**N88-17660#** Stuttgart Univ. (West Germany). Inst. fuer Aerodynamik und Gasdynamik.

**THE UNSTEADY GAS FLOW THROUGH STATOR AND ROTOR OF A TURBOMACHINE**

K. M. FOERSTER *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p Sep. 1987  
Avail: NTIS HC A23/MF A01

The difficulties of computing unsteady transonic flow in multiple connected domains with a minimum of neglections and approximations have been overcome by using individual computational grids fixed to each cascade, a novel gridless finite difference scheme, and physically real inflow and outflow boundaries. The resulting computer program is capable of computing the inviscid, plane gas flow through the stator and rotor of a turbomachine stage made from arbitrarily shaped (thick, round nosed) blades of arbitrary spacing, up to local Mach numbers of 1.8. Author

**N88-17662#** Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec). Turbine Aerodynamics.

**DESIGN AND AERODYNAMIC PERFORMANCE OF A SMALL MIXED-FLOW GAS GENERATOR TURBINE**

U. OKAPUU *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p Sep. 1987  
Avail: NTIS HC A23/MF A01

Design details and results from aerodynamic rig tests are presented for four variants of a mixed flow turbine having a design target pressure ratio of 3:1. This experimental turbine, designed to satisfy the aerodynamic requirements of a gas generator turbine in a hypothetical small turboprop engine, demonstrated a design point efficiency substantially in excess of that predicted for a single stage axial turbine of equivalent duty. Design and material implications are discussed and potential constraints identified. Author

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**N88-17663#** Ecole Centrale de Lyon (France).  
**NUMERICAL SIMULATION OF DIFFUSER/COMBUSTOR DOME INTERACTION [SIMULATION NUMERIQUE DE L'INTERACTION DIFFUSEUR TETE DE CHAMBRE]**

D. JEANDEL, G. BRUN, S. MEUNIER, and M. DESAULTY (Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel, France) *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p Sep. 1987 *In* FRENCH  
Avail: NTIS HC A23/MF A01

The design of a turbojet diffuser and combustion chamber dome can be realized, not only by researching low pressure loss, but also by assuring flow stability around a flame tube. A finite element method developed by Ecole Centrale de Lyon is described. The method employs an elliptic logic and a triangular type mesh which is well adapted for simulating complex geometric configurations. The application of the algorithm to various elementary and industrial configurations demonstrates the method's robustness and its ability to describe the principal flow characteristics in combustion dome regions. Author

**N88-17664#** Rolls-Royce Ltd., Bristol (England).  
**DEVELOPMENT OF A PLENUM CHAMBER BURNER SYSTEM FOR AN ADVANCED VTOL ENGINE**

J. S. LEWIS, T. W. MURRAY, and D. STEELE *In* AGARD Advanced Technology for Aero Gas Turbine Component 10 p Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom  
Avail: NTIS HC A23/MF A01

The research and development programs that were carried out on model and full size rigs to design and evaluate advanced concepts to meet the anticipated thrust requirements for a plenum chamber burner system for an advanced vertical takeoff and landing (VTOL) aircraft are described. The system characteristics of pressure loss, ignition, efficiency, thermal integrity and velocity profiles at nozzle exit under non-combusting (dry) and combusting conditions are discussed. Author

**N88-17665#** Lucas Aerospace Ltd., Birmingham (England).  
Engine Systems Div.  
**PUMPING SYSTEMS AND FLOW INTERFACES FOR RAPID RESPONSE ELECTRONIC REHEAT CONTROLS**

THOMAS C. YATES and TREVOR S. SMITH *In* AGARD Advanced Technology for Aero Gas Turbine Components 20 p Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom  
Avail: NTIS HC A23/MF A01

The problems of fuel pumping and metering which are associated with digital electronic reheat controls are discussed. A survey is carried out of various pumping options including reheat and main engine fuel pumping. A technical description of single, twin, and three pump systems, including rotodynamic and positive displacement pumps is given together with comments on the relative advantages and disadvantages of the various options. A fuel flow interface designed for rapid response reheat control systems is described. The application is a digital electronic control for a future bypass engine. Comparison is made between computer simulation of the control characteristics and test results of the hardware. Author

**N88-17666\*#** General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.  
**AERODYNAMIC PERFORMANCE OF A SCALE-MODEL, COUNTER-ROTATING UNDUCTED FAN**

THOMAS J. SULLIVAN *In* AGARD Advanced Technology for Aero Gas Turbine Components 16 p Sep. 1987 Sponsored by NASA, Washington, D.C.  
Avail: NTIS HC A23/MF A01 CSCL 21E

The aerodynamic performance of a scale model, counter-rotating unducted fan has been determined and the results are discussed. Experimental investigations were conducted using the scale model propulsor simulator and uniquely shaped fan blades. The blades, designed for a high disk loading at Mach 0.72 at 35,000 feet altitude maximum climb condition are

aft-mounted on the simulator in a pusher configuration. Data are compared with analytical predictions at the design point and show good agreement. Author

**N88-17667\*#** General Motors Corp., Indianapolis, Ind. Gas Turbine Div.

**GEAR SYSTEMS FOR ADVANCED TURBOPROPS**  
DOUGLAS A. WAGNER *In* AGARD Advanced Technology for Aero Gas Turbine Components 9 p Sep. 1987 Sponsored by NASA, Washington, D.C.  
Avail: NTIS HC A23/MF A01 CSCL 21E

A new generation of transport aircraft will be powered by efficient, advanced turboprop propulsion systems. Systems that develop 5,000 to 15,000 horsepower have been studied. Reduction gearing for these advanced propulsion systems is discussed. Allison Gas Turbine Division's experience with the 5,000 horsepower reduction gearing for the T56 engine is reviewed and the impact of that experience on advanced gear systems is considered. The reliability needs for component design and development are also considered. Allison's experience and their research serve as a basis on which to characterize future gear systems that emphasize low cost and high reliability. Author

**N88-17668#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Entwurfsaerodynamik.

**NUMERICAL METHODS FOR PROPELLER AERODYNAMICS AND ACOUSTICS AT DFVLR**

N. KROLL, D. LOHMANN, and J. SCHOENE *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p Sep. 1987  
Avail: NTIS HC A23/MF A01

Linear and nonlinear analysis methods for flow fields around propellers were developed. Here, two singularity methods are presented. In the first, a doublet point scheme was formulated for the calculation of steady and unsteady loads on surfaces having helical motion in an incompressible medium, e.g., propellers in uniform and nonuniform inflows and counter rotating propellers. The second is a surface panel method for computations of steady subsonic flows around propeller blades moving in a compressible medium. The method has been extended for the prediction of acoustic quantities. In order to predict the characteristics of transonic propeller flow fields, a Euler code for solving the three dimensional Euler equations was extended. The equations are formulated in a rotating cartesian reference frame. The solution procedure is based on a finite volume method using an explicit Runge-Kutta time stepping scheme. Numerical results for various propeller geometries are presented and compared with experimental data. Author

**N88-17669#** Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

**ANALYSIS OF HIGHSPEED PROPELLERS AERODYNAMICS**  
J. M. BOUSQUET *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p Sep. 1987 *In* FRENCH; ENGLISH summary  
Avail: NTIS HC A23/MF A01

Highspeed propellers are studied. A synthesis of aerodynamic developments leading to the HT3 propeller definition and test in the S1 Modane wind tunnel is presented. The validity of the main calculation methods used in this research is analyzed. Counterrotating highspeed propellers are also studied. Their performance benefits against single rotation propellers are presented. Author

**N88-17670#** Fiat Aviazione S.p.A., Turin (Italy). Direzione Progettazione.

**ANALYSIS OF POSSIBLE TRANSMISSION ARRANGEMENTS APPLICABLE FOR DRIVING SINGLE OR TWIN COUNTERROTATING FANS ON PROPFAN ENGINES**

L. BATTEZZATO and S. TURRA *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p Sep. 1987

Avail: NTIS HC A23/MF A01

A number of different designs of propfan engines are now being defined by the main engine manufacturers in the world. Some of these designs require a reduction gearbox between the LP turbine and the propfan; the propfan itself is conceived as single stage, variable pitch blade or double counterrotating stage variable pitch solution. In order to satisfy these requirements, the authors propose different mechanical arrangements of the reduction gearbox and, for given engine interfaces, compare their relative merits in order to eventually show the optimum solution. The comparison is made on the basis of various aspects: lightness, quietness, life, reliability, safety and maintainability. Author

**N88-17672#** Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

**INVESTIGATION OF DIHEDRAL EFFECTS IN COMPRESSOR CASCADES**

F. A. E. BREUGELMANS *In* AGARD Advanced Technology for Aero Gas Turbine Components 14 p Sep. 1987

Avail: NTIS HC A23/MF A01

An experimental investigation of the influence of blade dihedral on the secondary flow in the two dimensional NACA 65-series compressor cascade is performed. Different inlet boundary layer thicknesses are used on the endwalls. Three different stacking lines have been chosen, namely a straight line inclined at 15, 25 and 35 degrees, a circular arc and an elliptic arc. The incidence range up to stall has been investigated and the local and overall losses are compared. The obtuse angle between the blade suction surface and the endwall has a beneficial effect on overall and secondary flow loss. Some limitations have to be accepted, depending on boundary layer thickness and incidence. Author

**N88-17674#** Technische Univ., Hanover (West Germany). Inst. fuer Stroemungsmaschinen.

**POSSIBILITIES FOR ON-LINE SURGE SUPPRESSION BY FAST GUIDE VANE ADJUSTMENT IN AXIAL COMPRESSORS**

W. RIESS and U. BLOECKER *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p Sep. 1987

Avail: NTIS HC A23/MF A01

The usual surge suppression regulation is realized by integration of a fixed limit line into the regulation system at a safe distance from the stability limit of the compressor. With appropriate means for detection of stall and surge in addition to fast response of the guide vane adjustment, an adaptive system for surge suppression which takes into account the actual state of the compressor could be realized. Experimental results for stall detection and for different modes of guide vane adjustment are presented. A six stage axial compressor is equipped with fast acting guide vane adjustment in all stages. Author

**N88-17675#** Norges Tekniske Hoegskole, Trondheim. Div. of Hydro- and Gas Dynamics.

**RADIAL COMPRESSOR DESIGN USING AN EULER SOLVER**

JAN TORE BILLDAL and ANDREW WILSON *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p Sep. 1987

Avail: NTIS HC A23/MF A01

The steady inviscid flow through a radial compressor is computed by solving the three dimensional Euler equations on both an H-type and O-type grid. The centered finite volume method with an explicit integration scheme is used to solve the equations. The numerical programs were developed as a tool in the design process of new, high pressure radial compressors with complex geometries and spitterblades. Author

**N88-17676#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Antriebstechnik.

**SECONDARY FLOW MEASUREMENTS WITH L2F-TECHNIQUE IN CENTRIFUGAL COMPRESSORS**

H. KRAIN *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p Sep. 1987

Avail: NTIS HC A23/MF A01

The flow characteristics of a 30 degree backswept impeller are analyzed by means of the L2F measurement technique. Significant cross flows, noticeable distortions of the through flow patterns and considerable velocity fluctuations were found inside the blade passages of the impeller. The distortions of the velocity patterns are smoothing towards the impeller exit. A detailed analysis of the measured data reveals the existence of two counter rotating channel vortices that are significantly influencing the overall flow character. Author

**N88-17677#** Centre National de la Recherche Scientifique, Marseilles (France).

**METHOD FOR PREDICTING PERFORMANCE LIMITS OF CENTRIFUGAL COMPRESSORS [METHODE DE PREVISION DES LIMITES DE FONCTIONNEMENT EN DEBIT DES COMPRESSEURS CENTRIFUGES]**

H. MILTON, G. SENATORE, and J. CHAUVIN (LEMFI, Orsay, France) *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p Sep. 1987 *In* FRENCH

Avail: NTIS HC A23/MF A01

Currently, the phenomena which impose performance limits in centrifugal compressors are not clearly identifiable. If pumping and rotating stall are frequently observed at partial output, it is not certain whether the pumping limit is imposed by purely nonstationary phenomena. The approach described here consists of determining that limit by specifically applying the load criteria in the axial region of the moving impeller and the diffuser semi-blade section. The performance limit is assumed to be reached when impeller and diffuser are simultaneously stalled. The results of a simple analysis method, applied to two compressors having very different geometric characteristics, show a fairly good agreement between the performance limit defined with this criterion and the experimental pumping limit. M.G.

**N88-17678#** Pratt and Whitney Aircraft, West Palm Beach, Fla. Engineering Div.

**DESIGN AND DEVELOPMENT OF AN ADVANCED F100 COMPRESSOR**

CHARLES M. LOVE *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p Sep. 1987

Avail: NTIS HC A23/MF A01

The aerodynamic and mechanical design features of an advanced F100 compressor are described. The design objectives were to increase the efficiency and stability, along with simplifying the mechanical configuration in order to reduce the number of parts. Test results from a compressor rig and core engine are shown. Comparisons of the performance to the current F100 compressor are made. Results of testing with inlet pressure distortion are shown. Configuration features to improve reliability, durability, maintainability and producibility are shown. Author

**N88-17679#** Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

**DESIGN AND TESTING OF A FRONT STAGE FOR AN ADVANCED HIGH PRESSURE COMPRESSOR [CONCEPTION ET ESSAIS D'UN ETAGE DE TETE D'UN COMPRESSEUR HP AVANCE]**

MARIUS GOUTINES and HENRI NAVIERE *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p Sep. 1987 *In* FRENCH Sponsored by Direction des Recherches, Etudes et Techniques du Ministere de la Defense, France

Avail: NTIS HC A23/MF A01

Studies of an advanced high pressure compressor show that the front stage rotor is supersonic all along the span of the blades. SNECMA designed and constructed a monostage compressor to

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evaluate performances, especially secondary flows. The approach used in the compressor project, the design configuration, and velocity triangles selected for nominal operation level are described. The supersonic profiles were optimized by the direct solution of the three dimensional Euler equations. The subsonic profiles were optimized by a direct potential method coupled with a boundary layer calculation. The global performances are addressed. The measured aerodynamic fields and azimuthal means are compared to the theoretical predictions for the front wall secondary flow region. Author

**N88-17680#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Antriebstechnik.

### EXPERIMENTAL INVESTIGATION OF A SUPERCRITICAL COMPRESSOR ROTOR BLADE SECTION

R. FUCHS, R. KAYMAZ, H. STARKEN, and W. STEINERT *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p Sep. 1987

Avail: NTIS HC A23/MF A01

A controlled diffusion rotor blade section was designed for a supercritical inlet Mach number of  $M_{sub} = 1$  equals 0.85 and a flow turning of 29 degrees. The blade section has been tested in a cascade wind tunnel under various inlet flow conditions and axial velocity density ratios. A detailed investigation about transition and separation points was carried out at the design and at two off-design inlet flow conditions. The results are presented and discussed. Author

**N88-17681#** Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

### COMPUTATION OF SECONDARY FLOWS IN AN AXIAL MULTISTAGE COMPRESSOR [CALCUL DES ECOULEMENTS SECONDAIRES DANS UN COMPRESSEUR AXIAL MULTIETAGE]

F. FALCHETTI and J. BROCHET *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p Sep. 1987 *In* FRENCH; ENGLISH summary Sponsored by Direction des Recherches, Etudes et Techniques, France and Societe National d'Etude et de Construction de Moteurs d'Aviation, France

Avail: NTIS HC A23/MF A01

SNECMA has developed and extended the use of a secondary flow computation method for axial flow compressors. This method takes into account the secondary phenomena through a viscous correction applied to a through flow calculation. This correction is calculated to the complete meridian plane, including the bladerows. A set of equations deduced from three dimensional parabolized and pitchwise averaged Navier-Stokes equations are solved. A classical coupling process between the secondary flow and the through flow computations is insured through mass flow injection. After reviewing the main features of the method, an application to a multistage compressor is presented. The application of this method to the design of end-bend blades is shown. Author

## 08

### AIRCRAFT STABILITY AND CONTROL

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

**A88-25622**

### ESTIMATION OF AIRCRAFT MOTION PARAMETERS WITH ALLOWANCE FOR ATMOSPHERIC TURBULENCE [OTSENKA PARAMETROV DVIZHENIIA SAMOLETA S UCHETOM TURBULENTNOSTI ATMOSFERY]

T. K. SIRAZETDINOV and P. V. SMIRNOV *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1987, p. 53-57. *In* Russian. refs

A method and an algorithm are presented for solving the problem of estimating the aircraft state vector from measurement

data during a flight in a turbulent atmosphere, with constraints in the form of inequalities imposed on the estimation error variance. The algorithm described here has been implemented in a set of computer programs written in FORTRAN IV. V.L.

**A88-27320**

### AIRCRAFT GUIDANCE FOR FORMATION FLYING BASED ON OPTIMAL CONTROL THEORY

S. J. FU (Boeing Military Airplane Co., Wichita, KS) *IN*: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1 . New York, Institute of Electrical and Electronics Engineers, 1987, p. 393, 394.

Application of Linear Quadratic Regulator (LQR) theory to aircraft guidance and control for formation flying is discussed in this paper. Based on a second order mathematical model, the guidance law provides the reference acceleration command to the flight and propulsion control system of the wingman aircraft. Author

**A88-27321**

### AN OPTIMIZED YAW DAMPER FOR ENHANCED PASSENGER RIDE COMFORT

T. J. GOSLIN, F. H. ANSARI, and A. CHAKRAVARTY (Boeing Commercial Airplane Co., Seattle, WA) *IN*: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1 . New York, Institute of Electrical and Electronics Engineers, 1987, p. 395, 396.

An optimized yaw damper for the enhancement of passenger ride comfort is discussed which aims at improving dutch roll damping for low dynamic pressure flight conditions without increasing the rms rudder deflection. A robust low-order controller design algorithm, SANDY, is combined with a root locus method in order to achieve a good design. For conditions under which the dutch roll damping coefficient is lowest, a 6-15 percent improvement in dutch roll damping is obtained. R.R.

**A88-27322**

### ON THE DESIGN OF ROBUST COMPENSATORS FOR AIRPLANE MODAL CONTROL

JOHN K. HO, STEVE R. COOPER, CHUONG B. TRAN, and ABHIJIT CHAKRAVARTY (Boeing Commercial Airplane Co., Seattle, WA) *IN*: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1 . New York, Institute of Electrical and Electronics Engineers, 1987, p. 397, 398.

A design procedure for a modal suppression system is proposed which enhances the capability of a classical yaw damper by suppressing some of the vibration due to structural modes in addition to controlling the dutch roll response. The plant model for the compensator design consists of an airplane structural model, a control law with a fast frame time, a wide bandwidth servo, and a power control actuator. Comparison of results obtained with both the basic airplane and the closed-loop airplane illustrates the improved airplane performance. R.R.

**A88-27352**

### ACCURATE MODELING OF NONLINEAR SYSTEMS USING VOLTERRA SERIES SUBMODELS

HAROLD STALFORD, WILLIAM T. BAUMANN, FREDERICK E. GARRETT, and TERRY L. HERDMAN (*Virginia Polytechnic Institute and State University, Blacksburg*) *IN*: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2 . New York, Institute of Electrical and Electronics Engineers, 1987, p. 886-891. refs (Contract F33615-86-K-3617)

The problem of accurately modeling nonlinear systems (such as aircraft flight in high angle-of-attack/sideslip flight) using simple low-order Volterra submodels is investigated. First, this technique is applied to a simplified nonlinear stall/post-stall aircraft model for the case of a longitudinal limit cycle. The simulation study demonstrates that the responses of the Volterra submodels accurately match the responses of the original nonlinear model, whereas the responses of a piecewise-linear model do not. Next,

the technique is applied to a simplified high alpha nonlinear model of wing rock. The simulation study demonstrates that the second-order Volterra approximation predicts the wing rock limit cycle, while a linear approximation does not. Third-, fourth- and fifth-order Volterra approximations are observed to give wing rock amplitudes that converge quadratically to the nonlinear value.

Author

#### A88-27365

##### FLIGHT CONTROL FOR THE F-8 OBLIQUE WING RESEARCH AIRCRAFT

DALE F. ENNS, DANIEL J. BUGAJSKI (Honeywell Systems and Research Center, Minneapolis, MN), and MARTIN J. KLEPL (Rockwell International Corp., El Segundo, CA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1112-1117. refs

This paper will discuss multivariable flight control laws for the F-8 Oblique Wing Research Aircraft. The control laws were developed using a loopshaping methodology to support the NASA/Navy program to ultimately flight test a supersonic aircraft with an oblique wing with as much as 65 degree wing skew. The objective of the control laws is to obtain decoupling of the longitudinal and lateral-directional motions of the unsymmetrical aircraft, as well as to satisfy conventional flight control objectives including gust attenuation, good command tracking, good handling qualities, and stability robustness with respect to model uncertainty. A multivariable proportional plus integral element is the basic ingredient of the control laws, along with sensor blending into regulated variables, and pilot command precompensation. Various analyses including frequency and time responses will be presented. Stability robustness properties of the control laws will be presented using singular value and structured singular value techniques. Handling qualities will be analyzed using the equivalent systems technique. Responses of the controlled aircraft to pilot inputs will be presented using time histories.

Author

#### A88-27370

##### AN MRAC SYSTEM FOR AIRCRAFT LONGITUDINAL CONTROL

D. G. RAO, M. M. KULKARNI, and J. CHANDRASEKHAR (Indian Institute of Technology, Bombay, India) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1133, 1134. Research supported by the Aeronautical Research and Development Board of India.

A model reference adaptive pitch rate controller is reported which is suitable for aircraft applications. The controller has fast model matching characteristics and is differentiator-free. Hybrid simulation results show excellent error convergence both in terms of speed and output voltage.

C.D.

#### A88-27727

##### ADAPTIVE PREDICTION FLIGHT CONTROL SYSTEMS [ADAPTIVNYE PROGNOZIRUIUSHCHIE SISTEMY UPRAVLENIIA POLETOM]

VALENTIN NIKOLAEVICH BYKOV Moscow, Izdatel'stvo Nauka, 1987, 232 p. In Russian. refs

Algorithms for the adaptive control of dynamic processes are considered which combine optimal control synthesis with the use of prediction models and real-time estimation of the controlled process parameters. The algorithms make it possible to allow, in a complete and natural manner, for both a priori and in-service information on the dynamic characteristics of the system. Control of an essentially nonlinear process does not require model simplification. The adaptive prediction algorithms proposed here are not limited to problems of flight control and are applicable to most manufacturing processes, control of moving systems, and other problems.

V.L.

#### A88-27754

##### APPLICATIONS OF SINGULAR PERTURBATION TECHNIQUES TO AIRCRAFT TRAJECTORY OPTIMIZATION [APPLICATIONS DES TECHNIQUES DE PERTURBATIONS SINGULIERES A L'OPTIMIZATION DES TRAJECTOIRES D'AVION]

A. J. FOSSARD (Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, Toulouse; ONERA, Centre d'Etudes et de Recherches de Toulouse, France) and A. FREITAS (IPD, Rio de Janeiro, Brazil) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 105-127. In French. DRET-supported research. refs

The method of forced singular perturbation is applied to various aeronautical problems for which a closed loop solution can be obtained as a function of the instantaneous state. The method involves the separation of problem variables into distinct dynamic classes. With the system equations written in this form, a real-time or closed-loop optimal global control law can be obtained providing that the solution in the external boundary can be obtained. It is shown that in certain critical cases it is possible to improve the degree of optimization by a different classification. Given two dynamic classifications, the switching of one to the other is made automatically on a surface of the state-space.

R.R.

#### A88-27759

##### ACTIVE CONTROL OF HELICOPTER VIBRATIONS BY SELF-ADAPTIVE MULTICYCLIC CONTROL [CONTROLE ACTIF DES VIBRATIONS SUR HELICOPTERE PAR COMMANDES MULTICYCLIQUES AUTO-ADAPTIVES]

MARC ACHACHE (Aerospatiale, Division Helicopteres, Marignane, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 227-268. In French. Research supported by the Service Technique des Programmes Aeronautiques, Direction Generale de l'Aviation Civile, and DRET.

A self-adaptive multicyclic control system for the active control of helicopter rotor blade vibrations has been developed and tested aboard the Gazelle SA 349. The system architecture consists of vibration sensors, an analog computer, a digital computer to determine the optimal control vectors, and a system of multicyclic actuators. Tests performed with a rotor test rig have demonstrated satisfactory functioning of the system and have led to improvements in the self-adaptive deterministic and stochastic control algorithms. Flight tests have validated the present concept and provided data which can be used to refine helicopter structure and rotor models.

R.R.

#### A88-27761

##### STABILITY OF HELICOPTER BLADE MOTION IN THE CASE OF TURBULENT AIR FLOW [STABILITE DU MOUVEMENT DES PALES D'HELICOPTERE DANS LE CAS D'UN ECOULEMENT TURBULENT DE L'AIR]

E. PARDOUX (Aix-Marseille I, Universite, Marseille; Institut National de Recherche en Informatique et en Automatique, Rocquencourt, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 295-303. In French. refs

Recent mathematical results are used to investigate the stability of linear differential systems subjected to random perturbation. For the case of forward motion, helicopter blade movement is studied as a function of flutter and torsion. The system is subjected to random aerodynamic forces when the angle between the blade plane and that of the wind velocity becomes sufficiently great. The results illustrate both the effect of random fluctuations on the critical velocity, and the sensitivity of the critical velocity to bandwidth. Liapunov exponents are used to describe the stability of helicopter blade movement.

R.R.

## 08 AIRCRAFT STABILITY AND CONTROL

**A88-27762**

**DESIGN OF A HELICOPTER AUTOMATIC FLIGHT CONTROL SYSTEM [CONCEPTION D'UN SYSTEME DE PILOTAGE AUTOMATIQUE POUR HELICOPTERE]**

THUY LAN VU and ALAIN VAISSIERE (Societe de Fabrication d'Instruments de Mesure, Massy, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 305-337. In French. refs  
(Contract DRET-84-428)

Multivariable synthesis methods are applied to the design of a helicopter automatic flight control system. The characteristic Nyquist/Bode loci design methods are extended to the multivariable case, and the synthesis method is implemented in a tangent linearized model based on a mathematical formulation for an equilibrium point. Simulation results are presented for a nonlinear helicopter model and for models of sensors and actuators. The present approach is aimed at obtaining satisfactory stabilization of the system, excellent dynamic characteristics, and a reduction in coupling between the axes. R.R.

**A88-27763**

**NONLINEAR CONTROL FOR LEVEL FLIGHT OF A HELICOPTER [COMMANDE NON-LINEAIRE POUR LE VOL EN PALIER D'UN HELICOPTERE]**

DANIEL CLAUDE (CNRS, Laboratoire des Signaux et Systemes, Gif-sur-Yvette, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 339-355. In French. refs  
(Contract DRET-81-492)

Nonlinear decoupling techniques have been applied to the multivariable control of helicopters for the case of level flight, and a physical interpretation of the singularities encountered is presented. The decoupling and immersion of nonlinear systems are first considered. The level flight of a helicopter is modeled by obtaining a fourth degree polynomial approximation with tangent linear-model coefficients as a function of translation velocity. Control laws are determined for a range of applicable translation velocities, and a singularity is noted in the neighborhood of 347 km/hr. R.R.

**A88-27764**

**NONLINEAR IDENTIFICATION TECHNIQUE FOR HELICOPTER FLIGHT MECHANICS [TECHNIQUE D'IDENTIFICATION NON-LINEAIRE DE LA MECANIQUE DE VOL D'UN HELICOPTERE]**

H. DANG VAN MIEN (Electricite de France, Clamart), F. DEBLON, and MR. NORMAND-CYROT (CNRS, Laboratoire des Signaux et Systemes, Gif-sur-Yvette, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 357-368. In French. refs  
(Contract DRET-83-34-231-00-470-750-1)

Helicopter flight mechanics are modeled using a black-box method that employs an input-output approximation. The present identification technique leads to equations which have linear differences in state but which are nonlinear in control and output. The method is applied to the case of stabilized level flight for velocities of between 140 and 300 km/h with respect to the ground. A linear identification in canonical form is presented, following which a nonlinear identification is performed. The results demonstrate the ability of the refined-state model to faithfully reproduce oscillating and exponential-type dynamics. R.R.

**A88-27765**

**IDENTIFICATION TECHNIQUES IN FLIGHT MECHANICS [TECHNIQUES D'IDENTIFICATION EN MECANIQUE DU VOL]**

PIERRE MEREAU (ADERSA/GERBIOS, Verrieres-le-Buisson, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 369-415. In French. refs

Identification techniques for determining the flight mechanics of rigid aircraft are discussed which have application to flight simulation, aircraft flight quality, control systems, and breakdown detection. The mathematical basis of flight mechanics modeling is first reviewed. The identification process consists of five steps: (1) data acquisition using both measured aerodynamic values and optimized test data from open-loop (pilot controlled) and closed-loop (autopiloted) aircraft; (2) data processing, including data correction and the reconstitution of nonmeasured variables; (3) the characterization of linear and nonlinear aerodynamic coefficients; (4) the identification of structural parameters using estimation and optimization techniques; and (5) model validation. R.R.

**A88-27769**

**PROBLEMS RELATED TO THE APPLICATION OF FLIGHT CONTROL TO THE FIELD OF COMBAT AIRCRAFT GUIDANCE [PROBLEMES LIES AUX APPLICATIONS DE L'AUTOMATIQUE DANS LE DOMAINE DU PILOTAGE DES AVIONS DE COMBAT]**

JEAN CHOPLIN and JEAN-PIERRE BELMONT (Avions Marcel Dassault Breguet Aviation, Division des Etudes Avancees, Saint-Cloud, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 495-510. In French.

The evolution of flight control systems for combat aircraft is reviewed and is illustrated with the examples of the Mirage 1, Mirage 2000, and Rafale aircraft. Requirements for the development of flight control systems in the areas of modelization of complex aerodynamic phenomena, signal processing, and control are identified. Adaptation control techniques for closed-loop and open-loop systems are considered. Various flight control systems are evaluated and compared with respect to such criteria as global cost, robustness of the compensator obtained, and ability to conform to production specifications and implementation constraints. R.R.

**A88-27770**

**TREATMENT METHODS FOR THE ALLEVIATION OF GUSTS ON AIRCRAFT [METHODES DE TRAITEMENT CONCERNANT L'ABSORPTION DE RAFALES SUR AVION]**

G. COULON (ADERSA/GERBIOS, Verrieres-le-Buisson, France) and R. HIRSCH IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 531-540. In French. refs

The detection, alleviation, and simulation of gusts on aircraft are discussed. Three different simulation programs are considered: (1) a program simulating longitudinal aircraft motion and taking into account the effects of lift on the wings and tail; (2) a variant of (1) developed for rigid aircraft which includes tail motion for gust alleviation; and (3) a variant of (1) for canard aircraft, taking into account canard-wing, wing-tail, and canard-tail deflections. Simulation results are found to compare well with results obtained with a GH80 aircraft. R.R.

**A88-27889#**

**FLAT SPIN OF AXISYMMETRIC BODIES IN THE CRITICAL REYNOLDS NUMBER REGION**

L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Nov.-Dec. 1987, p. 532-538. Previously cited in issue 23, p. 3385, Accession no. A86-47671. refs

**A88-28261\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**ROBUST ADAPTIVE FLIGHT-PATH RECONSTRUCTION TECHNIQUE FOR NONSTEADY LONGITUDINAL FLIGHT TEST MANEUVERS**

M. H. VERHAEGEN (NASA, Ames Research Center, Moffett Field, CA) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 11, Jan.-Feb. 1988, p. 73-79. Previously cited in issue 23, p. 3412, Accession no. A86-47653. refs

**A88-28265\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**APPROACH TRAJECTORY GUIDANCE FOR MAXIMUM CONCEALMENT**

DAVID N. WARNER, JR. (NASA, Ames Research Center, Moffett Field, CA) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), vol. 11, Jan.-Feb. 1988, p. 94, 95.

An energy-management concept is examined with a view to provision of a near-optimum maneuver guidance system for military aircraft tactical operations. The data thus obtained indicate that the Quiet Short-Haul Research Aircraft, as modeled in the aircraft-specific energy-rate tables, could fly the flight paths in question. The fuel-conservative guidance system's ability to minimize pop-up flight time and carefully coordinate the aircraft's controls for this performance-oriented requirement is demonstrated. O.C.

**N88-16628\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**A SUMMARY OF RECENT NASA/ARMY CONTRIBUTIONS TO ROTORCRAFT VIBRATIONS AND STRUCTURAL DYNAMICS TECHNOLOGY**

RAYMOND G. KVATERNIK, FELTON D. BARTLETT, JR., and JOHN H. CLINE (Army Aerostructures Directorate, Hampton, Va.) *In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity* p 71-179 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01C

The requirement for low vibrations has achieved the status of a critical design consideration in modern helicopters. There is now a recognized need to account for vibrations during both the analytical and experimental phases of design. Research activities in this area were both broad and varied and notable advances were made in recent years in the critical elements of the technology base needed to achieve the goal of a jet smooth ride. The purpose is to present an overview of accomplishments and current activities of govern and government-sponsored research in the area of rotorcraft vibrations and structural dynamics, focusing on NASA and Army contributions over the last decade or so. Specific topics addressed include: airframe finite-element modeling for static and dynamic analyses, analysis of coupled rotor-airframe vibrations, optimization of airframes subject to vibration constraints, active and passive control of vibrations in both the rotating and fixed systems, and integration of testing and analysis in such guises as modal analysis, system identification, structural modification, and vibratory loads measurement. Author

**N88-16631\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**ROTORCRAFT AEROELASTIC STABILITY**

ROBERT A. ORMISTON, WILLIAM G. WARMBRODT, DEWEY H. HODGES, and DAVID A. PETERS (Georgia Inst. of Tech., Atlanta.) *In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 1: Aerodynamics, and Dynamics and Aeroelasticity* p 353-529 Feb. 1988

Avail: NTIS HC A23/MF A01 CSCL 01C

Theoretical and experimental developments in the aeroelastic and aeromechanical stability of helicopters and tilt-rotor aircraft are addressed. Included are the underlying nonlinear structural mechanics of slender rotating beams, necessary for accurate modeling of elastic cantilever rotor blades, and the development of dynamic inflow, an unsteady aerodynamic theory for low-frequency aeroelastic stability applications. Analytical treatment

of isolated rotor stability in hover and forward flight, coupled rotor-fuselage stability in hover and forward flight, and analysis of tilt-rotor dynamic stability are considered. Results of parametric investigations of system behavior are presented, and correlation between theoretical results and experimental data from small and large scale wind tunnel and flight testing are discussed. Author

**N88-16642\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**HELICOPTER MATHEMATICAL MODELS AND CONTROL LAW DEVELOPMENT FOR HANDLING QUALITIES RESEARCH**

ROBERT T. N. CHEN, J. VICTOR LEBACQZ, EDWIN W. AIKEN, and MARK B. TISCHLER (Army Aviation Systems Command, Moffett Field, Calif.) *In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Material and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics* p 837-899 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 01C

Progress made in joint NASA/Army research concerning rotorcraft flight-dynamics modeling, design methodologies for rotorcraft flight-control laws, and rotorcraft parameter identification is reviewed. Research into these interactive disciplines is needed to develop the analytical tools necessary to conduct flying qualities investigations using both the ground-based and in-flight simulators, and to permit an efficient means of performing flight test evaluation of rotorcraft flying qualities for specification compliance. The need for the research is particularly acute for rotorcraft because of their mathematical complexity, high order dynamic characteristics, and demanding mission requirements. The research in rotorcraft flight-dynamics modeling is pursued along two general directions: generic nonlinear models and nonlinear models for specific rotorcraft. In addition, linear models are generated that extend their utilization from 1-g flight to high-g maneuvers and expand their frequency range of validity for the design analysis of high-gain flight control systems. A variety of methods ranging from classical frequency-domain approaches to modern time-domain control methodology that are used in the design of rotorcraft flight control laws is reviewed. Also reviewed is a study conducted to investigate the design details associated with high-gain, digital flight control systems for combat rotorcraft. Parameter identification techniques developed for rotorcraft applications are reviewed. Author

**N88-16643\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**ROTORCRAFT FLIGHT-PROPULSION CONTROL INTEGRATION**

JAMES R. MIHALOEWSKI, MARK G. BALLIN, and D. G. C. RUTTLEDGE (Sikorsky Aircraft, Stratford, Conn.) *In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics* p 900-928 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 01C

The NASA Ames and Lewis Research Centers, in conjunction with the Army Research and Technology Laboratories have initiated and completed, in part, a joint research program focused on improving the performance, maneuverability, and operating characteristics of rotorcraft by integrating the flight and propulsion controls. The background of the program, its supporting programs, its goals and objectives, and an approach to accomplish them are discussed. Results of the modern control governor design of the T700 and the Rotorcraft Integrated Flight-Propulsion Control Study, which were key elements of the program, are also presented. Author

## 08 AIRCRAFT STABILITY AND CONTROL

**N88-16645\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **ROTORCRAFT HANDLING-QUALITIES DESIGN CRITERIA DEVELOPMENT**

EDWIN W. AIKEN, J. VICTOR LEBACQZ, ROBERT T. N. CHEN, and DAVID L. KEY (Army Aviation Systems Command, Moffett Field, Calif.) *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 948-998 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 01C

Joint NASA/Army efforts at the Ames Research Center to develop rotorcraft handling-qualities design criteria began in earnest in 1975. Notable results were the UH-1H VSTOLAND variable stability helicopter, the VFA-2 camera-and-terrain-board simulator visual system, and the generic helicopter real-time mathematical model, ARMCOPI. An initial series of handling-qualities studies was conducted to assess the effects of rotor design parameters, interaxis coupling, and various levels of stability and control augmentation. The ability to conduct in-flight handling-qualities research was enhanced by the development of the NASA/Army CH-47 variable-stability helicopter. Research programs conducted using this vehicle include vertical-response investigations, hover augmentation systems, and the effects of control-force characteristics. The handling-qualities data base was judged to be sufficient to allow an update of the military helicopter handling-qualities specification, MIL-H-8501. These efforts, including not only the in-house experimental work but also contracted research and collaborative programs performed under the auspices of various international agreements. The report concludes by reviewing the topics that are currently most in need of work, and the plans for addressing these topics. B.G.

**N88-16647\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **IDENTIFICATION AND PROPOSED CONTROL OF HELICOPTER TRANSMISSION NOISE AT THE SOURCE**

JOHN J. COY, ROBERT F. HANDSCHUH, DAVID G. LEWICKI (Army Research and Technology Labs., Cleveland, Ohio.), RONALD G. HUFF, EUGENE A. KREJSA, and ALLAN M. KARCHMER *In* NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 1045-1065 Feb. 1988

Previously announced as N87-16816

Avail: NTIS HC A25/MF A01 CSCL 01C

Helicopter cabin interiors require noise treatment which is expensive and adds weight. The gears inside the main power transmission are major sources of cabin noise. Work conducted by the NASA Lewis Research Center in measuring cabin interior noise and in relating the noise spectrum to the gear vibration of the Army OH-58 helicopter is described. Flight test data indicate that the planetary gear train is a major source of cabin noise and that other low frequency sources are present that could dominate the cabin noise. Companion vibration measurements were made in a transmission test stand, revealing that the single largest contributor to the transmission vibration was the spiral bevel gear mesh. The current understanding of the nature and causes of gear and transmission noise is discussed. It is believed that the kinematical errors of the gear mesh have a strong influence on that noise. The completed NASA/Army sponsored research that applies to transmission noise reduction is summarized. The continuing research program is also reviewed. Author

**N88-16707\*#** Integrated Systems, Inc., Palo Alto, Calif.  
**AIRCRAFT FLIGHT TEST TRAJECTORY CONTROL Final Contractor Report**

P. K. A. MENON and R. A. WALKER Jan. 1988 197 p

(Contract NAS2-11877)  
(NASA-CR-179428; H-1345; NAS 1.26:179428) Avail: NTIS HC A09/MF A01 CSCL 01C

Two design techniques for linear flight test trajectory controllers (FTTCs) are described: Eigenstructure assignment and the minimum error excitation technique. The two techniques are used

to design FTTCs for an F-15 aircraft model for eight different maneuvers at thirty different flight conditions. An evaluation of the FTTCs is presented. Author

**N88-16708#** National Aerospace Lab., Tokyo (Japan).  
**EXPERIMENTAL STUDY ON THE EFFECT OF FIBER ORIENTATION ON FLUTTER CHARACTERISTICS OF HIGH-ASPECT-RATIO TRANSPORT WING**

HIROSHI EJIRI, JIRO NAKAMICHI, TAKAO KIKUCHI, and MASAKATSU MINEGISHI 1987 13 p *In* JAPANESE; ENGLISH summary

(NAL-TR-936; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

The basic effects of aeroelastic tailoring on flutter velocity are investigated. Six different models of high aspect ratio swept back wings were designed. The models consisted of composite plate-spars and wing sections of balsa wood. The dominant lamination angle of each spar was changed in a parametric manner. A vibration test was performed for each model. The frequencies and the vibration modes were measured to check the variations of the vibration characteristics due to differences of the laminate angle of the spars. The flutter tests were conducted in a low-speed tunnel and the hard flutter points are found for all models. It was shown that the flutter velocity of a model which was the wash-in type of the first bending mode is larger by 50 percent than that of a model of which the first bending mode is the wash-out type. Author

**N88-16709#** National Aerospace Lab., Tokyo (Japan).  
**EFFECT OF AN OPTIMIZED FIBER ORIENTATION ON TRANSONIC FLUTTER CHARACTERISTICS OF A HIGH-ASPECT-RATIO COMPOSITE WING**

K. ISOGAI, H. EJIRI, T. KIKUCHI, K. YAMANE, I. KUMAKURA, T. SOTOZAKI, M. MINEGISHI, and Y. NOGUCHI 1987 12 p *In* JAPANESE; ENGLISH summary

(NAL-TR-930; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

The feasibility is examined of using a direct search method, which does not depend on the flutter velocity derivative, to find the optimum fiber orientations which maximize the flutter velocity of a composite wing. The Sequential Simplex Method, as one candidate for such a method, was applied to the design of a transonic flutter model of a high-aspect-ratio transport wing, and was proven to be very effective in finding the optimum fiber orientation to give the maximum flutter velocity. The experimental verification of this has also been conducted in the National Aerospace Laboratory (NAL) 0.6 m x 0.6 m transonic blow down tunnel, by flutter tests with two kinds of models; i.e., one with an optimum fiber orientation, and one without. The experimental results have shown that the flutter velocities of the optimized model are about 60 percent higher than those of the non-optimized model over the entire transonic Mach number range tested. Author

**N88-17601\*#** Sikorsky Aircraft, Stratford, Conn.  
**THE IMPACT OF CIRCULATION CONTROL ON ROTARY AIRCRAFT CONTROLS SYSTEMS**

R. F. KINGLOFF and D. E. COOPER *In* NASA. Ames Research Center Proceedings of the Circulation-Control Workshop, 1986 p 353-362 May 1987

Avail: NTIS HC A25/MF A01 CSCL 01C

Application of circulation to rotary wing systems is a new development. Efforts to determine the near and far field flow patterns and to analytically predict those flow patterns have been underway for some years. Rotary wing applications present a new set of challenges in circulation control technology. Rotary wing sections must accommodate substantial Mach number, free stream dynamic pressure and section angle of attack variation at each flight condition within the design envelope. They must also be capable of short term circulation blowing modulation to produce control moments and vibration alleviation in addition to a lift augmentation function. Control system design must provide this primary control moment, vibration alleviation and lift augmentation function. To accomplish this, one must simultaneously control the compressed air source and its distribution. The control law algorithm must therefore address the compressor as the air source, the

## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

plenum as the air pressure storage and the pneumatic flow gates or valves that distribute and meter the stored pressure to the rotating blades. Also, mechanical collective blade pitch, rotor shaft angle of attack and engine power control must be maintained.

Author

**N88-17682#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

**EFFECTIVENESS OF VARIOUS CONTROL SURFACES IN QUASI-STEADY AND UNSTEADY CONDITIONS [EFFICACITE DE DIFFERENTES SURFACES DE CONTROLE EN QUASI-STATIONNAIRE ET INSTATIONNAIRE]**

R. DESTUYNER, R. BARREAU, and G. ANDERS Apr. 1986 26 p In FRENCH Presented at the 6th Meeting of the AGARD Panel on Structures and Materials, Oberammergau, Fed. Republic of Germany, 8-13 Sept. 1985 (AGARD-R-735; ISBN-92-835-2113-7) Avail: NTIS HC A03/MF A01

This report describes tests conducted in the Modane S1 wind tunnel in France to measure the unsteady pressures on two half-models of wings outfitted with different control surfaces such as vented or unvented spoilers, flaperons, or ailerons. One of the wings, the ZKP model, is a standard configuration from the AGARD-SMP Compendium of Unsteady Pressure Measurements. The movements imposed on the control surfaces could be white noise, fixed frequency harmonics and ramp. A data base with a very wide range of parameters such as the Mach number, wing angle of attack, deflection of one or several control surfaces, and reduced frequencies was obtained. One of the goals was to establish semiempirical corrections to the theory of the efficiency of control surfaces. All of the excitation tests and acquisition and processing work for the unsteady condition studies were completely directed by a computer.

Author

**N88-17684\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, Va.

**AN APPLICATION OF EIGENSPACE METHODS TO SYMMETRIC FLUTTER SUPPRESSION Final Report**

ROBERT E. FENNEL (Clemson Univ., S.C.) Jan. 1988 22 p Submitted for publication (Contract NAS1-18107; N00014-86-K-0693) (NASA-CR-181618; ICASE-88-9; NAS 1.26:181618) Avail: NTIS HC A03/MF A01 CSCL 01C

An eigenspace assignment approach to the design of parameter insensitive control laws for linear multivariable systems is presented. The control design scheme utilizes flexibility in eigenvector assignments to reduce control system sensitivity to changes in system parameters. The methods involve use of the singular value decomposition to provide an exact description of allowable eigenvectors in terms of a minimum number of design parameters. In a design example, the methods are applied to the problem of symmetric flutter suppression in an aeroelastic vehicle. In this example the flutter mode is sensitive to changes in dynamic pressure and eigenspace methods are used to enhance the performance of a stabilizing minimum energy/linear quadratic regulator controller and associated observer. Results indicate that the methods provide feedback control laws that make stability of the nominal closed loop systems insensitive to changes in dynamic pressure.

Author

**N88-17836#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Unternehmensgruppe Transport- und Verkehrsflugzeuge.

**LIGHT ELECTRONIC CONTROL SYSTEM (LECOS): A PROPOSAL FOR A INTERCONNECTED ERROR-TOLERANT, OPTOELECTRONIC CONTROL SYSTEM [LECOS - EIN VORSCHLAG FUER EIN VERMASCHTES, FEHLERTOLERANTES, LICHELEKTRONISCHES STEUERUNGSSYSTEM]**

HANS-JOACHIM WENDT *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 115-118 1987 In GERMAN (MBB-UT-004/87) Avail: NTIS HC A14/MF A01

A flight control system, based on optical waveguide technology, is presented. The system aims at the replacement of cables in fly-by-wire systems, at the consequent use of microprocessor techniques with bus and sensor technology, as well as at developments in actuators.

ESA

**N88-17845#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.

**ACTIVE CONTROL TECHNOLOGY WITH ADAPTIVE CONTROL CONCEPT IN THE AIRCRAFT CONSTRUCTION [AKTIVE KONTROLL TECHNOLOGIE MIT ADAPTIVEM REGLERKONZEPT IM FLUGZEUGBAU]**

HEINZ HOENLINGER *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 167-172 1987 In GERMAN (MBB/LKE-294/S/PUB/295) Avail: NTIS HC A14/MF A01

An adaptive control concept for active control techniques in structural dynamics was developed. The applicability of active control techniques in structural dynamics, the control principle for shimmy damping and loading reduction, and conventional electronics for active control technology are discussed. Wind tunnel tests of the adaptive control concept for active shimmy damping show that even the experimental, nonoptimized version has the same performances as the conventional systems. The use of an optimized target function for phase as well as for amplification can substantially improve performance and robustness.

ESA

## 09

### RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

**A88-25010**

**FLIGHT SIMULATORS FOR UNDER \$100,000**

MICHAEL J. ZYDA, ROBERT B. MCGHEE, RON S. ROSS, DOUGLAS B. SMITH, and DALE G. STREYLE (U.S. Naval Postgraduate School, Monterey, CA) IEEE Computer Graphics and Applications (ISSN 0272-1716), vol. 8, Jan. 1988, p. 19-27. Army-Navy-supported research. refs

To demonstrate the feasibility and practicability of designing and building 'low-cost' flight simulators, a prototype system has been developed to model the performance of a new U.S. Army remotely piloted missile system. This article presents the results of the design, development, and implementation of the flight simulation system, focusing on the relevant hardware, software, and data base issues. The capabilities and limitations of the prototype system are also discussed, as are the potential uses of such devices.

C.D.

## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

**A88-25750\*** # National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

### **NASA-LANGLEY RESEARCH CENTER SHAPES TOMORROW THROUGH INNOVATIVE RESEARCH**

JEAN DRUMMOND CLOUGH (NASA, Langley Research Center, Hampton, VA) AIAA Student Journal (ISSN 0001-1460), vol. 25, Fall 1987, p. 34-36.

NASA-Langley is the home of the world's most advanced wind tunnel, the National Transonic Facility, which uses cryogenic nitrogen vapor to test models of advanced aircraft and spacecraft. Langley also employs hundreds of computers of every type and capacity in order both to gather and analyze wind tunnel data and to undertake mathematical visualizations of complex flow phenomena. Langley has been involved in every major NASA space program, and had primary responsibility for the development of the Viking Mars probes. Currently, Langley is involved in the National Aerospace Plane Program and in the development of erectable space structures. O.C.

**A88-26172**

### **DEVELOPMENT OF AN ALGORITHM FOR EVALUATING CALIBRATION DATA FOR SIX-COMPONENT STRAIN-GAGE BALANCES [ENTWICKLUNG EINES ALGORITHMUS ZUR AUSWERTUNG DER EICHVERSUCHE AN 6-KOMPONENTEN DMS-WAAGEN]**

F. SCHNABL (Darmstadt, Technische Hochschule, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, Nov.-Dec. 1987, p. 342-346. In German.

The response of a six-component wind-tunnel balance employing strip-type strain gages to typical loading conditions is investigated analytically, and a numerical algorithm for the reduction and processing of balance calibration data is developed. A nonlinear system of 206 equations is obtained by a least-squares procedure and solved by a Newton algorithm. Diagrams, drawings, and graphs are provided. T.K.

**A88-27158**

### **SOME METHODOLOGICAL ASPECTS OF THE STUDY OF GASDYNAMIC MODELS WITH HEAT AND MASS TRANSFER IN AN IMPULSE WIND TUNNEL [NEKOTORYE METODICHESKIE ASPEKTY ISSLEDOVANIYA GAZODINAMICHESKIKH MODELEI S TEPLOMASSOPODVODOM V IMPUL'SNOI AERODINAMICHESKOI TRUBE]**

V. K. BAEV, V. V. SHUMSKII, and M. I. IAROSLAVTSEV Fizika Gorenii i Vzryva (ISSN 0430-6228), vol. 23, Sept.-Oct. 1987, p. 45-54. In Russian. refs

With reference to experimental results obtained for a variety of problems involving heat and mass transfer in gasdynamic paths under conditions of hypersonic flow, it is shown that such problems can be efficiently solved by using high-enthalpy blowdown wind tunnels. The possibility of achieving a highly efficient process in complex channels of small length under conditions of impulse hypersonic flow is demonstrated experimentally. Results obtained for various models with combustion in the Mach range 5-8 are presented. V.L.

**N88-16651\*** # National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

### **STATUS OF NASA/ARMY ROTORCRAFT RESEARCH AND DEVELOPMENT PILOTED FLIGHT SIMULATION**

GREGORY W. CONDON and TERENCE D. GOSSETT (Army Aviation Systems Command, Moffett Field, Calif.) In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 3: Systems Integration, Research Aircraft, and Industry p 1119-1153 Feb. 1988

Avail: NTIS HC A17/MF A01 CSCL 14B

The status of the major NASA/Army capabilities in piloted rotorcraft flight simulation is reviewed. The requirements for research and development piloted simulation are addressed as well as the capabilities and technologies that are currently available or are being developed by NASA and the Army at Ames. The application of revolutionary advances (in visual scene, electronic

cockpits, motion, and modelling of interactive mission environments and/or vehicle systems) to the NASA/Army facilities are also addressed. Particular attention is devoted to the major advances made in integrating these individual capabilities into fully integrated simulation environment that were or are being applied to new rotorcraft mission requirements. The specific simulators discussed are the Vertical Motion Simulator and the Crew Station Research and Development Facility. Author

**N88-16710#** Aeronautical Research Labs., Melbourne (Australia).

### **CALIBRATION OF THE ARL (AERONAUTICAL RESEARCH LABORATORIES) RAIN AND ICING FACILITY**

P. N. DOOGOOD Jan. 1987 21 p

(Contract ARL-AERO-PROP-TM-442)

(AD-A186776; DODA-AR-004-527) Avail: NTIS HC A03/MF A01 CSCL 14B

A rain and icing test facility was set up at the Aeronautical Research Laboratories in the early seventies to test anti-icing systems for aircraft engine air intakes. This report describes modifications made to facility to meet a specific test requirement and analyses the effect that these have made on its performance. GRA

**N88-16711#** Karlsruhe Univ. (West Germany).

Sonderforschungsbereich 210.

### **WIND TUNNEL MODELING TECHNIQUES [MODELLIERUNGSTECHNIKEN IM WINDKANAL]**

J. MAIER-ERBACHER and TH. ELSAESSER Nov. 1986 87 p In GERMAN

(KU-SFB-210/E/33; ETN-88-91054) Avail: NTIS HC A05/MF A01

Wind tunnel measurements were performed in order to simulate an atmospheric boundary layer. The requirements for the simulation of the natural boundary, wind tunnel techniques, and the Aylesbury comparative experiment are outlined. The required boundary layer (scale 1:100) was simulated in a 10 m long wind tunnel using the roughness-vortex-threshold technique. The boundary layer parameters can be systematically modified by simulation techniques. The simulation of the degree of turbulence is difficult with standard techniques and requires active production mechanisms at the tunnel entrance. The measured average pressure coefficients agree well with results from other wind tunnels. Larger deviations are found for the coefficients of the fluctuating pressures. Proposals for a better comparison with other wind tunnel data and with natural data are given. ESA

**N88-16712#** National Aerospace Lab., Amsterdam (Netherlands). Aerodynamics Dept.

### **THE WIND TUNNEL AS A YARDSTICK FOR AIRCRAFT DESIGN**

A. ELSENAAR Apr. 1985 20 p In DUTCH; ENGLISH summary Presented at the NVvL-VSV Symposium on Recente Ontwikkelingen op Aerodynamisch Gebied, Delft, Netherlands, 26 Apr. 1985

(NLR-MP-85032-U; ETN-88-91325) Avail: NTIS HC A03/MF A01

The accuracy of the measurement of drag is used to illustrate problems in wind tunnel testing, like balance performance, determination of angle of incidence, wall and support interference, scale effects, and engine simulation. Flexible walls, cryogenic testing, and the application of turbine powered engine simulators are discussed. The increasing role of computers to determine or eliminate wind tunnel corrections is noted. It is concluded that the wind tunnel and the computer are essentially complementary in aerodynamic design and verification and in data reduction and data handling. ESA

**N88-16714#** Eidgenoessisches Flugzeugwerk, Emmen (Switzerland). Abteilung Versuchs- und Forschungsanlage. **TRANSONIC WIND TUNNEL CALIBRATION 1986: FORCE MEASUREMENTS ON THREE ONERA-C5 MODELS AND THREE HALF SPHERE CYLINDER CALIBRATION BODIES IN THE F+W TRANSONIC TEST SECTION**

HEINZ BLAETTLER 19 Jan. 1987 138 p In GERMAN; ENGLISH summary  
(F+W-FO-1854; ETN-88-91687) Avail: NTIS HC A07/MF A01

Force measurements were taken on three C5 calibration models and three half-sphere-cylinder calibration bodies of different size to establish the effect of blockage on drag. The C5 model is a body of revolution with the same distribution of cross-sectional area as a civil airplane model. The blockage-ratio of the three models is: 0.5 percent; 1 percent and 2 percent. Good coincidence with previous measurements are observed with the 0.5 percent and 1 percent models. Measurements in the region of Ma less than or equal 0.5 diverge considerably from measurements taken elsewhere. ESA

**N88-16715#** Eidgenoessisches Flugzeugwerk, Emmen (Switzerland). Abteilung Aerodynamik und Flugmechanik. **INFLUENCE OF THE WALL BOUNDARY LAYER ON FORCE MEASUREMENTS ON HALF MODELS IN THE TRANSONIC WIND TUNNEL**

PHILIPPE BLATTER and FELIX HIRT 21 Apr. 1987 89 p Partly in GERMAN and ENGLISH  
(F+W-TF-1876; ETN-88-91688) Avail: NTIS HC A05/MF A01

Characteristics of the lateral wall boundary layer in relation to the Mach number are experimentally determined and their effect on systematic measuring errors on a half model is investigated. A linear flow model together with the boundary layer characteristics is used to determine the optimal thickness of the lateral plate. ESA

**N88-16717\*#** Eloret Corp., Sunnyvale, Calif. **UPGRADING OF NASA-AMES HIGH-ENERGY HYPERSONIC FACILITIES: A STUDY Final Technical Report, 1 Oct. 1987 - 31 Jan. 1988**

CHARLES E. SHEPARD and WILLIAM C. A. CARLSON 24 Feb. 1988 80 p  
(Contract NCC2-503)  
(NASA-CR-182475; NAS 1.26:182475) Avail: NTIS HC A05/MF A01 CSCL 14B

This study reviews facility capabilities of NASA, Ames Research Center to simulate hypersonic flight with particular emphasis on arc heaters. Scaling laws are developed and compared with ARCFLO II calculations and with existing data. The calculations indicate that a 300 MW, 100 atmosphere arc heater is feasible. Recommendations for the arc heater, which will operate at voltages up to 50 kilovolts, and the associated elements needed for a test facility are included. Author

**N88-17687#** Oak Ridge Gaseous Diffusion Plant, Tenn. **ULTRA-LOW FREQUENCY VIBRATION DATA ACQUISITION CONCERNS IN OPERATING FLIGHT SIMULATORS**

B. W. VANHOY 1988 20 p Presented at the 6th International Modal Analysis Conference, Orlando, Fla., 1 Feb. 1988 Prepared in cooperation with ORNL, Tenn.  
(Contract DE-AC05-84OT-21400)  
(DE88-004795; K/D-5739; CONF-880220-13) Avail: NTIS HC A03/MF A01

The measurement of ultra-low frequency vibration (.01 to 1.0 Hz) in motion based flight simulators was undertaken to quantify the energy and frequencies of motion present during operation. Methods of measurement, the selection of transducers, recorders, and analyzers and the development of a test plan, as well as types of analysis are discussed. Analysis of the data using a high-speed minicomputer and a comparison of the computer analysis with standard FFT analysis are also discussed. Measurement of simulator motion with the pilot included as part of the control dynamics had not been done up to this time. The data are being used to evaluate the effect of low frequency energy

on the vestibular system of the air crew, and the incidence of simulator induced sickness. DOE

## 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.

**N88-17215\*#** Air Force Human Resources Lab., Wright-Patterson AFB, Ohio. Manpower and Personnel Div.

**TUTORING ELECTRONIC TROUBLESHOOTING IN A SIMULATED MAINTENANCE WORK ENVIRONMENT**

SHERRIE P. GOTT In NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 61-69 Oct. 1987  
Avail: NTIS HC A23/MF A01 CSCL 14B

A series of intelligent tutoring systems, or intelligent maintenance simulators, is being developed based on expert and novice problem solving data. A graded series of authentic troubleshooting problems provides the curriculum, and adaptive instructional treatments foster active learning in trainees who engage in extensive fault isolation practice and thus in conditionalizing what they know. A proof of concept training study involving human tutoring was conducted as a precursor to the computer tutors to assess this integrated, problem based approach to task analysis and instruction. Statistically significant improvements in apprentice technicians' troubleshooting efficiency were achieved after approximately six hours of training. Author

## 11

## CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

**A88-25106**  
**THE METALLURGICAL ASPECTS OF ALUMINUM-LITHIUM ALLOYS IN VARIOUS PRODUCT FORMS FOR HELICOPTER STRUCTURAL APPLICATIONS**

A. F. SMITH (Westland Helicopters, Ltd., Materials Laboratory, Yeovil, England) (Societe Francaise de Metallurgie, International Aluminium Lithium Conference, 4th, Paris, France, June 10-12, 1987) Journal de Physique (Colloque C3), Supplement (ISSN 0449-1947), vol. 48, Sept. 1987, p. C3-49 to C3-59. Research supported by the Ministry of Defence Procurement Executive. refs

An account is given of the results of metallurgical investigations of low density/high elastic modulus Al-Li alloys for helicopter applications. Attention is given to the 8090, 8091, and 9052XL Al-Li alloys' tensile, compressive, fatigue, and fracture-toughness characteristics; these are generally found to be comparable to those of current, conventional Al aircraft alloys. The Al-Li alloys are, however, noted to be more sensitive to the surface anodization conditions required for adhesive bonding. O.C.

## 11 CHEMISTRY AND MATERIALS

**A88-25176**

### **FATIGUE CRACK PROPAGATION BEHAVIOR OF 2091 T8 AND 2024 T3 UNDER CONSTANT AND VARIABLE AMPLITUDE LOADING**

N. OHRLOFF (Messerschmitt-Boelkow-Blohm GmbH, Hamburg, Federal Republic of Germany), A. GYSLER, and G. LUETJERING (Hamburg, Technische Universitaet, Federal Republic of Germany) (Societe Francaise de Metallurgie, International Aluminium Lithium Conference, 4th, Paris, France, June 10-12, 1987) Journal de Physique (Colloque C3), Supplement (ISSN 0449-1947), vol. 48, Sept. 1987, p. C3-801 to C3-807. BMFT-supported research. refs

The fatigue crack propagation behavior of the damage tolerant 2091 T8 was compared with that of 2024 T3. Constant amplitude tests were performed in vacuum, air, and NaCl solution at  $R = 0.175$  and in air at  $R = 0.7$ . The variable amplitude tests included periodic underloads superimposed on constant amplitude tests at  $R = 0.7$ , and periodic overloads in combination with low R-ratio tests. In general it was found that the crack propagation resistance of 2091 was slightly inferior in the lower Delta K-region as compared to 2024, but somewhat better at higher Delta K-values. For both alloys predicted propagation rates based on constant amplitude tests were lower than the experimentally measured values with periodic underloads. Periodic overloads resulted in crack growth retardation. Author

**A88-25178**

### **FATIGUE CRACK INITIATION AND PROPAGATION PROPERTIES OF AL-LI-CU ALLOYS IN AIR AND IN AQUEOUS CORROSIVE SOLUTIONS**

T. MAGNIN, P. RIEUX (Saint Etienne, Ecole Nationale Supérieure des Mines, France), C. LESPINASSE, and C. BATHIAS (Compiègne, Université de Technologie, France) (Societe Francaise de Metallurgie, International Aluminium Lithium Conference, 4th, Paris, France, June 10-12, 1987) Journal de Physique (Colloque C3), Supplement (ISSN 0449-1947), vol. 48, Sept. 1987, p. C3-817 to C3-822. refs

Fatigue tests are performed on an Al-Li-Cu CP271 alloy in air and in different corrosive solutions on smooth and notched specimens to determine the crack initiation and crack propagation properties of the CP271 alloy in the peak aged conditions. Crack propagation properties are shown to be very interesting in regards with the conventional Al-Zn-Mg alloys. Crack initiation properties are shown to be very sensitive to the texture of the specimens both in air and in a 3.5 pct NaCl solution. The anodic dissolution accelerates crack initiation in the corrosive solution but the corresponding reduction of the fatigue life is less important than for conventional Al-Zn-Mg alloys. Author

**A88-25266**

### **STRUCTURAL PROPERTIES OF BRAIDED GRAPHITE/EPOXY COMPOSITES**

LEE W. GAUSE and JAMES M. ALPER (U.S. Navy, Naval Air Development Center, Warminster, PA) Journal of Composites Technology and Research (ISSN 0885-6804), vol. 9, no. 4, Winter 1987, p. 141-150. U.S. Navy-supported research. refs

The mechanical, impact, and fatigue properties of graphite/epoxy composites manufactured using a general braiding process are being evaluated for possible flight vehicle applications. This new process achieves a fully integrated, multidimensional orientation of the fibers and allows the braiding of complex shapes, such as I-beams and cylinders. Motivating this study is the desire to improve the impact resistance, thickness-direction strength, and overcome the delamination tendencies of conventional laminated composites. Two styles of braided test coupons have been fabricated and tested. Style I is the basic (1 x 1 x 1) braid pattern. Style II is constructed by holding half of the yarns as straight columns and braiding the rest of the yarns about the fixed yarns. Some difficulties were encountered developing the processing methods to vacuum draw the hot melt Hercules 3501 resin into the Celion 12,000 graphite braided preforms and obtain a satisfactory autoclave cure. Results show the braid to have similar strength and elastic properties to corresponding, angle-ply

laminates while greatly limiting the extent of impact damage. The braid does not increase the impact damage threshold, however. Tests performed on braided specimens with 6.35 mm diameter open holes show no tensile strength reduction because of the hole. Bearing strength, transverse strength, and transverse stiffness properties are lower than laminated composites. Tensile fatigue properties are similar to conventional laminates, but compressive fatigue performance is worse. Author

**A88-27285#**

### **FLAME STABILIZATION USING LARGE FLAMEHOLDERS OF IRREGULAR SHAPE**

A. H. LEFEBVRE (Purdue University, West Lafayette, IN) and R. M. STWALLEY, III Journal of Propulsion and Power (ISSN 0748-4658), vol. 4, Jan.-Feb. 1988, p. 4-13. Previously cited in issue 08, p. 1066, Accession no. A87-22656. refs

**A88-28299**

### **EFFECT OF HIGH TEMPERATURE SPIKES ON A CARBON FIBRE-REINFORCED EPOXY LAMINATE**

T. A. COLLINGS and D. L. MEAD (Royal Aircraft Establishment, Farnborough, England) Composites (ISSN 0010-4361), vol. 19, Jan. 1988, p. 61-66. refs

Carbon fiber-reinforced epoxy composite laminates were exposed to programs of temperature and humidity intended to represent the high temperature excursions (thermal spikes) caused by ground-reflected engine efflux experienced by VTOL aircraft. Measurement of the laminate weight change during the tests indicated a change in the laminate moisture kinetics resulting in increased moisture equilibrium levels at spike temperatures up to 175 C. Spiking at temperatures of 200-300 C showed a marked loss of laminate weight which cannot be attributed to loss of water alone. Permanent damage such as cracking was evident in some cases. The contribution of moisture to laminate degradation is discussed. Author

**N88-16634\*#** Army Research and Technology Labs., Fort Eustis, Va. Aerostructures Directorate.

### **DELAMINATION DURABILITY OF COMPOSITE MATERIALS FOR ROTORCRAFT**

T. KEVIN OBRIEN /n NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 573-605 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 11D

Delamination is the most commonly observed failure mode in composite rotorcraft dynamic components. Although delamination may not cause immediate failure of the composite part, it often precipitates component repair or replacement, which inhibits fleet readiness, and results in increased life cycle costs. A fracture mechanics approach for analyzing, characterizing, and designing against delamination will be outlined. Examples of delamination problems will be illustrated where the strain energy release rate associated with delamination growth was found to be a useful generic parameter, independent of thickness, layup, and delamination source, for characterizing delamination failure. Several analysis techniques for calculating strain energy release rates for delamination from a variety of sources will be outlined. Current efforts to develop ASTM standard test methods for measuring interlaminar fracture toughness and developing delamination failure criteria will be reviewed. A technique for quantifying delamination durability due to cyclic loading will be presented. The use of this technique for predicting fatigue life of composite laminates and developing a fatigue design philosophy for composite structural components will be reviewed. Author

**N88-16700\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**HIGH TEMPERATURE POLYMER MATRIX COMPOSITES**

MICHAEL A. MEADOR *In its* Aeropropulsion '87. Session 1: Aeropropulsion Materials Research 15 p Nov. 1987

Avail: NTIS HC A06/MF A01 CSCL 11D

With the increased emphasis on high performance aircraft the need for lightweight, thermal/oxidatively stable materials is growing. Because of their ease of fabrication, high specific strength, and ability to be tailored chemically to produce a variety of mechanical and physical properties, polymers and polymer matrix composites present themselves as attractive materials for a number of aeropropulsion applications. In the early 1970s researchers at the NASA Lewis Research Center developed a highly processable, thermally stable (600 F) polyimide, PMR-15. Since that time, PMR-15 has become commercially available and has found use in military aircraft, in particular, the F-404 engine for the Navy's F/A-18 strike fighter. The NASA Lewis' contributions to high temperature polymer matrix composite research will be discussed as well as current and future directions. Author

**N88-16703\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**SELF-LUBRICATING COATINGS FOR HIGH-TEMPERATURE APPLICATIONS**

HAROLD E. SLINEY *In its* Aeropropulsion '87. Session 1: Aeropropulsion Materials Research 13 p Nov. 1987

Avail: NTIS HC A06/MF A01 CSCL 11C

Some present-day aeropropulsion systems impose severe demands on the thermal and oxidative stability of lubricant, bearing, and seal materials. These demands will be much more severe for operational systems around the turn of the century. Solid lubricants with maximum temperature capabilities of about 1100 C are known. Unfortunately, none of the solid lubricants with the highest temperature capabilities are effective below approximately 400 C. However, research shows that silver and stable fluorides, such as calcium and barium fluoride act synergistically to provide lubrication from below room temperature to approximately 900 C. Plasma-sprayed, self-lubricating composite coatings that were developed at Lewis are described. Background information is given on coatings, designed as PS100 and PS101, that contain the solid lubricants in a Nichrome matrix. These coatings have low friction coefficients over a wide temperature range, but they have inadequate wear resistance for some long-duration applications. Wear resistance was dramatically improved in a recently developed coating PS200, by replacing the Nichrome matrix material with metal-bonded chromium carbide containing dispersed silver and calcium fluoride/barium fluoride eutectic (CaF<sub>2</sub>/BaF<sub>2</sub>). The lubricants control friction and the carbide matrix provides excellent wear resistance. Successful tests of these coatings are discussed. Author

**N88-16823#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).

**MOISTURE PLOTTING OF CARBON FIBER COMPOSITE IN FLIGHT OPERATIONS [FEUCHTEAUFNAHME VON CFK IM FLUGBETRIEB]**

I. KROEBER 1987 26 p In GERMAN Presented at the DGLR Symposium on Entwicklung und Anwendung von Faserverbund-Strukturen', Berlin, Federal Republic of Germany, 14-15 May 1987

(MBS-UT-119/87; ETN-88-90793) Avail: NTIS HC A03/MF A01

The data of the proposed flight simulation model agree with those of the samples fixed on the aircraft. The maximal moisture content of the composite material depends mostly on the relative humidity of the air. The annual variations in the climates cause a difference in the moisture content of carbon fiber composite of 1.4 mm in depth. The upper limit of the relative humidity is 86 percent. ESA

**N88-16827#** National Aerospace Lab., Tokyo (Japan).

**MECHANICAL PROPERTIES OF CARBON FIBER REINFORCED THERMOPLASTIC MATRIX COMPOSITES**

YOSHIO NOGUCHI 1987 15 p In JAPANESE; ENGLISH summary

(NAL-TR-934; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Carbon fiber reinforced thermoplastic (CFRTP) composites have a great potential for use in aircraft structures especially where toughness is concerned. In this study, experiments are conducted on a fabric-CFRTP and fabric CFRP composites subjected to the effect of elevated temperature on short beam shear strength and flexural fatigue strength. Composites were fabricated from carbon fiber 8-harness satin fabric reinforced with two thermoplastic matrices, polyethersulphon (PES) and polyetheretherketon (PEEK) and compared with those of an epoxy matrix system. The CFRTP laminates were prepared by the film stacking method, namely thermoplastic resin films and carbon fiber fabric were stacked alternately then consolidated into a laminate by heat and pressure. Short beam shear tests were performed under environmental conditions at temperatures of 25 to 180 C. Flexural fatigue tests were performed at a room temperature of 25 C and elevated temperatures of 80 to 90 and 130 to 140 C. Short beam shear strength under elevated temperature conditions for fabric-CFRTP is comparable to that obtained with most fabric-CFRP. The fatigue failure specimens indicated that the tough thermoplastic matrix system shows an improved fatigue behavior compared to the brittle epoxy matrix system, mainly due to resistance to the initiation and growth of fatigue damage related to the matrix. Author

**N88-16859#** Construcciones Aeronauticas S.A., Madrid (Spain). **LOW FREQUENCY EDDY CURRENT DETECTION AND EVALUATION OF CORROSION IN AIRCRAFT SKINS**

J. M. BERNARDO, B. SAINZ, C. VALDECANTOS, and V. CORTES 1987 7 p Presented at the 4th European Conference on Nondestructive Testing, London, United Kingdom, 13-18 Sep. 1987

(ETN-88-91664) Avail: NTIS HC A02/MF A01

Applicability of low frequency eddy current test for the detection and evaluation of corrosion on aircraft fuselage skins was evaluated with two different commercially available eddy current instruments, one with needle indicator and the other with flying dot CRT display. Experiments carried out on laboratory samples 1.8 mm thick chemically milled to simulated corrosion, show that results are quite good when only 1 sheet is involved and frequencies between 4 and 10 KHz are applied. But when corrosion is under doubler areas the separation between skin and doubler is a major variable in quantitative measurements. ESA

**N88-16878\*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Center for Adhesion Science.

**FACTORS AFFECTING THE STICKING OF INSECTS ON MODIFIED AIRCRAFT WINGS Annual Report, 1 Jan. - 31 Jul. 1987**

O. YI, M. R. CHITSAZ-Z, N. S. EISS, and J. P. WIGHTMAN 8 Feb. 1988 31 p

(Contract NAG1-300)

(NASA-CR-182451; NAS 1.26:182451; REPT-102;

CAS/CHEM/ME-18-87) Avail: NTIS HC A03/MF A01 CSCL 11B

Previous work showed that the total number of insects sticking to an aluminum surface was reduced by coating the aluminum surface with elastomers. Due to a large number of possible experimental errors, no correlation between the modulus of elasticity, the elastomer, and the total number of insects sticking to a given elastomer was obtained. One of the errors assumed to be introduced during the road test is a variable insect flux so the number of insects striking one surface might be different from that striking another sample. To eliminate this source of error, the road test used to collect insects was simulated in a laboratory by development of an insect impacting technique using a pipe and high pressure compressed air. The insects are accelerated by a compressed air gun to high velocities and are then impacted with a stationary target on which the sample is mounted. The velocity

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of an object exiting from the pipe was determined and further improvement of the technique was achieved to obtain a uniform air velocity distribution. Author

**N88-16884\*#** Boeing Aerospace Co., Seattle, Wash.  
**EVALUATION OF HIGH TEMPERATURE STRUCTURAL ADHESIVES FOR EXTENDED SERVICE, PHASE 5 Final Report**  
C. L. HENDRICKS, S. G. HILL, J. N. HALE, and W. G. DUMARS  
Feb. 1987 68 p  
(Contract NAS1-15605)  
(NASA-CR-178176; NAS 1.26:178176) Avail: NTIS HC A04/MF A01 CSCL 11B

The evaluation of 3 experimental polymers from NASA-Langley and a commercially produced polymer from Mitsui Toatsu Chemicals as high temperature structural adhesives is presented. A polyphenylquinoxaline (PPQ), polyimide (STPI/LARC-2), and a polyarylene ether (PAE-SO<sub>2</sub>) were evaluated as metal-to-metal adhesives. Lap shear, crack extension, and climbing drum peel specimens were fabricated from all three polymers and tested after thermal, combined thermal/humidity, and stressed hydraulic fluid (Skydrol) exposure. The fourth polymer, LARC-TPI was evaluated as an adhesive for titanium honeycomb sandwich structure. All three experimental polymers performed well as metal-to-metal adhesives from 219 K (-65 F) to 505 K (450 F), including humidity exposure. Structural adhesive strength was also maintained at 505 K for a minimum of 3000 hours. LARC-TPI was evaluated as a high temperature (505 K) adhesive for titanium honeycomb sandwich structure. The LARC-TPI bonding process development concentrated on improving the honeycomb core-to-skin bond. The most promising approach of those evaluated combined a LARC-TPI polymer solution with a semi-crystalline LARC-TPI powder for adhesive film fabrication and fillet formation.

Author

**N88-16890#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.  
**MILITARY JET FUELS, 1944-1987 Summary Report, Oct. 1985 - Oct. 1987**  
CHARLES R. MARTEL Nov. 1987 67 p  
(AD-A186752; AFWAL-TR-87-2062) Avail: NTIS HC A04/MF A01 CSCL 21D

This report consists of a brief history of US military fuels for aircraft turbine jet engines and ramjet engines. The report discusses the requirements of past and current US military jet fuel specifications, when and why the specification requirements originated, and the importance of these requirements today. The purpose and origin of the various specification test methods are presented, and an extensive discussion of jet fuel additives is provided. This report should be of value to anyone involved in research and development, logistics, and use of jet fuels. We hope that it will serve as a handy reference for the jet fuel specialist. GRA

**N88-17813#** Chevron Research Co., Richmond, Calif.  
**HIGH-DENSITY JET FUELS FROM COAL SYNCRUCDES, APPENDIX 4**  
R. F. SULLIVAN 1987 12 p Presented at the 193rd National Meeting of the American Chemical Society, Denver, Colo., 5 Apr. 1987  
(Contract DE-AC22-76ET-10532)  
(DE88-003132; CONF-870410-40-APP-4) Avail: NTIS HC A03/MF A01

Very dense jet-boiling-range hydrocarbons can be obtained by hydrotreating and hydrocracking syncrudes made from coal in direct liquefaction processes. Heteroatom impurities must be removed, and most of the aromatics must be hydrogenated at high severity in order to produce kerosene jet fuels from coal syncrudes that meet smoke point and stability specifications. The resulting hydrotreated products consist mainly of naphthenes containing from one to three rings. If hydrocracking is added as a conversion step, some four-ring naphthenes are found in the 250 to 550 F jet fuel products. Polycyclic naphthenes are desirable components for jet fuel because of their high volumetric energy contents and

low freezing points. Products from the ITSL liquefaction process from bituminous coal had the lowest paraffin contents and the highest densities (for a given boiling range and aromatic content) of any of the coal liquids studied. Actual engine tests, however, would be needed to demonstrate that these fuels qualify for service in jet aircraft. DOE

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### ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

**A88-24847#**  
**PRESSURE LOSSES AND FLOW FIELD DISTORTION INDUCED BY TIP CLEARANCE OF CENTRIFUGAL AND AXIAL COMPRESSORS**

YASUTOSHI SENOO (Kyushu University, Fukuoka, Japan) Kyushu University, Research Institute of Industrial Science, Reports (ISSN 0368-6841), no. 82, 1987, p. 1-13. In Japanese, with abstract in English. refs

The flow field near the tip of compressor rotor blades is distorted by leakage through the tip clearance, and the performance of the compressor deteriorates. Empirical equations expressing the pressure loss and the efficiency drop are varied. They are related to the lift coefficient in different ways such as proportional to  $C(L)$ ,  $C(L) \exp 1.5$ ,  $C(L) \text{ sq}$ , or the sum of two terms, depending upon the ways of understanding the mechanics of pressure losses. These methods are examined and compared. Also included is a brief discussion on the optimum value of the tip clearance.

Author

**A88-25566**  
**ANALYSIS OF THE TWO-RING SUSPENSION OF A DYNAMICALLY TUNABLE GYROSCOPE [ANALIZ DVUKHKO-LECHNOGO PODVESA DINAMICHESKI NASTRAIVAEMOGO GIROSKOPA]**

IU. I. KUZNETSOV (Permskii Politekhnikheskii Institut, Perm, USSR) Priboroostroenie (ISSN 0021-3454), vol. 30, Dec. 1987, p. 42-45. In Russian.

Structural and static analyses are carried out for the two-ring suspension of a dynamically tunable gyroscope. Formulas are obtained for estimating the drift due to the specific properties of the two-ring suspension. Possible ways of improving the accuracy of dynamically tunable gyroscopes with a two-ring suspension are discussed. V.L.

**A88-25614**  
**EFFECT OF THE BLADE NUMBER RATIO OF THE ROTOR AND THE NOZZLE RING ON THE VIBRATION ACTIVITY OF AXIAL-FLOW AND RADIAL-FLOW TURBINES [VLIANIE SOOTNOSHENIIA CHISEL LOPATOK RABOCHEGO KOLESA I SOPLOVOGO APPARATA NA VIBROAKTIVNOST' OSEVYKH I RADIAL'NYKH TURBIN]**

B. I. BOROVSKII, A. I. CHUCHEROV, and V. L. KHITRIK Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 14-18. In Russian.

The paper is concerned with the problem of determining the ratio between the number of rotor blades and nozzle ring blades that would minimize the vibration activity of axial-flow and radial-flow turbines. Blade number ratios are determined for which no aerodynamic forces are transferred to either the rotor or the nozzle ring. The relationships obtained here are also valid for pumps and compressors. V.L.

A88-25621

**AXISYMMETRIC DEFORMATIONS OF AIRCRAFT TRANSPARENCIES WITH ALLOWANCE FOR THE COMPLIANCE OF THE SUPPORT FASTENINGS [OSESIMMETRICHNYE DEFORMATSII ELEMENTOV OSTEKLENNII LETATEL'NYKH APPARATOV S UCHETOM PODATLIVOSTI OPORNYKH ZAKREPLENIII]**

V. N. PAIMUSHIN, V. A. FIRSOV, and KH. B. MAMEDOV  
Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 43-48. In Russian.

Mathematical models and algorithms are developed for investigating the axisymmetric deformations of aircraft transparencies under static loading. The models and algorithms presented here are based on the statement of problems of contact interaction between thin shells and discrete-continuous supports. Results of a parametric analysis of the effect of the characteristics of elastic supports on the stress-strain state of shell structures are presented. V.L.

A88-25623

**STABILITY OF A WING BOX WITH ELASTIC RIBS [OB USTOICHIVOSTI KESSONA S UPRUGIMI NERVIURAMI]**

V. I. SHALASHILIN, V. N. MARTYNOV, S. M. NAUMOV, and V. K. SIBIRIAKOV  
Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 57-61. In Russian. refs

The effect of the elastic properties of stiffening ribs on the critical load of the general loss of stability of wing box panels is investigated analytically. The results obtained are compared with experimental data and with critical loads for the case of absolutely stiff ribs. It is shown that the insufficient stiffness of the ribs results in a significantly lower critical load of the general loss of stability of wing box panels. V.L.

A88-25630

**A STUDY OF THE EFFECT OF LEAKAGE FLOW ON THE MAIN FLOW AHEAD OF THE ROTOR OF A CENTRIFUGAL PUMP OR A COMPRESSOR [ISSLEDOVANIE VLIANIIA POTOKA UTECHKI NA OSNOVNOI POTOK PERED RABOCHIM KOLESOM TSENTROBEZHNOGO NASOSA ILI KOMPRESSORA]**

S. S. EVGEN'EV  
Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 76, 77. In Russian.

The relationship between the principal geometrical parameters of multistage centrifugal pump or compressor stages is investigated experimentally using the static blow test method in the Mach and Reynolds number ranges 0.2-0.3 and  $(0.5-1) \times 10$  to the 6th, respectively. The experimental results obtained are approximated by two simple formulas. The validity of the formulas is verified experimentally for an actual final stage of a centrifugal pump. V.L.

A88-25637

**AN EXPERIMENTAL STUDY OF THE EFFECT OF THE LOWER AND UPPER OVERLAP ON THE EFFICIENCY OF RADIAL INWARD-FLOW MICROTURBINES WITH AN ENCLOSED ROTOR [EKSPERIMENTAL'NOE ISSLEDOVANIE VLIANIIA VELICHIN VERKHNEI I NIZHNEI PEREKRYSH NA EKONOMICHNOST' RADIAL'NYKH TSENTROSTREMTEL'NYKH MIKROTURBIN S ZAKRYTYM RABOCHIM KOLESOM]**

N. T. TIKHONOV and V. N. MATVEEV  
Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 92-94. In Russian.

As shown in earlier studies, the efficiency of axial-flow and inward-flow microturbines can be increased by 12-20 percent by optimizing the upper and lower overlaps. The objective of the experimental study reported here was to determine optimal overlap values for radial inward-flow microturbines with an enclosed rotor. Based on the results obtained, upper and lower overlaps of 0.2-0.4 and 0.1-0.3, respectively, are recommended for this type of turbines. V.L.

A88-25640

**CHARACTERISTICS OF FLOW AROUND A HEMISPHERE MOUNTED ON A PLANE [OB OSOBNOSTIAXH OBTEKANIIA POLUSFERY, USTANOVLENNOI NA PLOSKOSTI]**

N. A. SHUSHIN  
Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 99-101. In Russian.

Wind tunnel experiments were carried out at Mach 2.02 and Reynolds numbers up to  $3 \times 10$  to the 6th to investigate flow around a hemisphere mounted on a plane. The model hemisphere, made of Plexiglas, had a diameter of 38 mm, with the ratio of the boundary layer thickness ahead of the model to its radius equal to 0.2-0.3. It is shown that flow around a hemisphere on a plane represents a synthesis of flows behind a cylinder and a sphere and flows ahead of and behind steps. Pressure pulsations, which are particularly strong behind a hemisphere, can be significantly reduced by tangential injection. V.L.

A88-26158

**INFLUENCE OF TRANSFORMATION SEQUENCE ON NONLINEAR BENDING AND TORSION OF ROTOR BLADES**

V. T. NAGARAJ and NIRANJAN SAHU (Helicopter Design Bureau, Bangalore, India)  
Vertica (ISSN 0360-5450), vol. 11, no. 4, 1987, p. 649-664. refs

An essential ingredient in the modeling of helicopter rotor blades undergoing moderately large deformations is the transformation matrix relating the orientations of the deformed and undeformed blade cross-sections. The use of modified Euler angles for this purpose is shown to lead to sequence-dependent equations of equilibrium. A sequence-free transformation matrix is proposed and the influence of the different matrices is demonstrated with respect to two problems. The first is the static response of an end-loaded cantilever beam for which an approximate closed-form solution is derived for the tip deflections and tip rotation. In the second problem, the various transformation matrices are used to obtain the stability boundaries of a rigid, centrally hinged rotor blade. Both these problems demonstrate the importance of the transformation matrix in the adequate modelling of the nonlinear behavior of slender rotor blades. Author

A88-26159

**ELASTIC HINGELESS SCISSOR DESIGN**

MELVIN NIEDERER and DANIEL B. GOETSCHER (Rensselaer Polytechnic Institute, Troy, NY)  
Vertica (ISSN 0360-5450), vol. 11, no. 4, 1987, p. 761-764. Army-supported research.

This paper discusses the development of a graphite epoxy hingeless scissor mechanism. Structural concepts are discussed and the design solution is described. The selected solution provides a structural member which is stiff in torsion and soft bending. This type of structural concept has apparently not been addressed before. Analysis is presented along with stiffness and strength test data to verify the concept. The results are very positive, showing the structure to be extremely promising. Continuing areas of development are also discussed. Author

A88-26171

**SIMPLIFIED CALCULATION OF THE CRUSHING PROCESS IN STRUCTURAL ELEMENTS [VEREINFACHTE BERECHNUNG DES KNAUTSCHVORGANGS VON BAUELEMENTEN]**

E. GIENCKE (Berlin, Technische Universitaet, Federal Republic of Germany)  
Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, Nov.-Dec. 1987, p. 329-341. In German. DFG-supported research. refs

The crash-absorbing elements in aircraft structures, especially helicopter structures, consist of thin-walled beams and sheets which buckle locally due to the crash forces and then fold. The deformation pattern starts with the usual linear-elastic behavior, which is followed by the folding range with very large deformations. The solution of such problems with FEM programs for large deformations and inelastic material behavior is normally very expensive. The analysis becomes simpler if different structural models are used in the elastic and folding range. In the initial linear phase, elastic behavior is assumed. During folding, the panels are assumed to be subdivided into rigid elements connected by

plastic links, with deformation occurring only at the fold lines and only slight distortion of the central surface. The different folding processes for corrugated sheets, hollow profiles, and stringer-stiffened panels are discussed. Analytical force deformation functions are also derived. The results are compared with other calculations and with experiments. Author

A88-26173

**A CLOSE COUPLING PROCEDURE FOR ZONAL SOLUTIONS OF THE NAVIER-STOKES, EULER AND BOUNDARY-LAYER EQUATIONS**

K. M. WANIE (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany), M. A. SCHMATZ, and F. MONNOYER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) *Zeitschrift fuer Flugwissenschaften und Weltraumforschung* (ISSN 0342-068X), vol. 11, Nov.-Dec. 1987, p. 347-359. refs  
(Contract DFG-HI-342/1-3; DFG-HI-342/1-4)

The steady high-Re flow of a viscous fluid around an arbitrary three-dimensional body is investigated analytically, applying a close coupling procedure to link solutions of the Euler, potential, and boundary-layer equations for zones with weak interactions with solutions of the Navier-Stokes equations for strong-interaction zones. The zonal solution concept and the derivation of the governing equations are explained; the fundamental principles of close coupling are reviewed; the numerical implementation is described; and results for the subsonic and transonic two-dimensional flow past elliptical bodies and airfoils at various angles of attack are presented in extensive graphs and characterized in detail. Good agreement with global Navier-Stokes solutions is obtained when the coupling analysis is based on second-order boundary-layer theory. T.K.

A88-26253

**A SUBMILLIMETER HETERODYNE RECEIVER FOR THE KUIPER AIRBORNE OBSERVATORY AND THE DETECTION OF THE 372 MICRON CARBON MONOXIDE LINE  $J = 7-6$  IN OMC-1 AND W3**

H. P. ROESER, F. SCHAEFER, J. SCHMID-BURGK, G. V. SCHULTZ, P. VAN DER WAL (Max-Planck-Institut fuer Radioastronomie, Bonn, Federal Republic of Germany) et al. *International Journal of Infrared and Millimeter Waves* (ISSN 0195-9271), vol. 8, Dec. 1987, p. 1541-1556. refs

A compact heterodyne receiver system used in the Kuiper Airborne Observatory is described, and calibration techniques for the elimination of standing wave effects are discussed. Results for the detection of the  $J = 7-6$  rotational transition of CO in OMC-1 and W3 are presented. The peak antenna temperature of OMC-1 is 55 K, and the relatively high total line flux of  $7.8 \times 10$  to the  $-13$ th W/sq m suggests that OMC-1 might be extended over several arcmin in CO ( $J = 7-6$ ). In W3, the peak antenna temperature is found to be  $6 +$  or  $- 2$  K, with the line center at  $-42 +$  or  $- 2$  km/sec and a FWHM of about 9 km/sec. R.R.

A88-26256

**GRAPHICAL DESIGN OF MILLIMETER-WAVE FINLINE BANDPASS FILTERS**

CAM NGUYEN (Martin Marietta Corp., Orlando, FL) *International Journal of Infrared and Millimeter Waves* (ISSN 0195-9271), vol. 8, Dec. 1987, p. 1581-1603. refs

A very simple yet accurate design procedure for the finline bandpass filters at millimeter wavelengths is presented. The technique enables the geometry of finline bandpass filters to be obtained accurately from simple closed-form equations and curves. Using this graphical approach, various millimeter-wave finline bandpass filters have been designed. Results in V-band (50 to 75 GHz) and W-band (75 to 110 GHz) are presented and indicate a good agreement between the calculated and measured performances. Author

A88-26344

**NONLINEAR EQUATIONS OF LAMINATED PANELS WITH LAMINATED STIFFENERS**

IZHAK SHEINMAN (Technion - Israel Institute of Technology, Haifa) *Composite Structures* (ISSN 0263-8223), vol. 8, no. 4, 1987, p. 287-292. refs

The nonlinear equations for a stiffened laminated panel, which modeled by plate and beam elements, are derived by applying the variational principle on the potential energy. The equations include the equation for the panel sections between the stiffeners, the continuity requirements and the boundary conditions. These nonlinear equations by which the post-buckling behavior is characterized are exact in terms of Von Karman's kinematic relations. Author

A88-26419

**KNOWLEDGE-BASED MULTI-SENSOR IMAGE FUSION**

THOMAS C. REARICK (Lockheed Aeronautical Systems Co., Marietta, GA) *Lockheed Horizons* (ISSN 0459-6773), Dec. 1987, p. 22-30.

A technique for generating a composite, synergistic image from multispectral sensors is described, with an emphasis on several aerospace applications (besides multisensor fusion) including target detection using scene context, navigation by terrain landmarks, and piloting by spatial reasoning. It is concluded that while a typical image contains thousands of generalized cylinder pixels (gyxels) and hundreds of homogeneous regions, data parallelism may be sufficient to account for an execution time improvement of at least 100:1. However another 100:1 improvement may be gained by exploiting pipeline and control parallelism, reduction of overhead, and use of faster microelectronic technologies. A.S.

A88-26571

**AN EXACT SOLUTION FOR COUPLED BENDING AND TORSION VIBRATIONS OF UNIFORM BEAMS HAVING SINGLE CROSS-SECTIONAL SYMMETRY**

E. DOKUMACI (Dokuz Eylul University, Bornova, Turkey) *Journal of Sound and Vibration* (ISSN 0022-460X), vol. 119, Dec. 22, 1987, p. 443-449. refs

This paper presents an exact determination of coupled bending and torsion vibration characteristics of uniform beams having single cross-sectional symmetry. A novel feature of the analysis is the expression of the exact solutions in terms of real functions, as is usual in more elementary vibration problems of beams. Numerical results are given to explain the effect of the shear center offset on the natural frequencies. Author

A88-26632#

**INVESTIGATION ON STEADY-STATE RESPONSE OF A ROTOR-SUPPORT SYSTEM WITH TWO SQUEEZE-FILM DAMPERS**

XIFAN LI and CAIGAO FU (Gas Turbine Establishment, People's Republic of China) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 31-34, 90. In Chinese, with abstract in English.

The rotor investigated is supported on two major ball bearings with squeeze-film dampers in the absence of centralizing retaining springs. The coefficients of the film forces are linearized using the dynamical performance of the damper in the fixed coordinate system (four oil-film stiffness and four oil-film damping coefficients). The steady-state unbalance response of an asymmetrical flexible rotor system has been easily determined by means of transfer-matrix and linear iterative methods. Generally speaking, for the rotor system with nonlinear squeeze-film dampers, the optimum damper design with a suitable rotor unbalance level (i.e., mass eccentricity  $e = 0.01$  cm) will achieve vibration suppression. The calculations show that the vibration suppression with two-squeeze-film dampers is better than that with one. This conclusion has also been proved using measured vibration data for a jet engine. Author

A88-26641#

**DYNAMIC FLEXIBILITY COEFFICIENT MATRIX AND ITS MEASUREMENT FOR AEROENGINE SUPPORTING SYSTEM**

ZHIWEI LI and SHENJI YANG (Northwestern Polytechnical University, Xian, People's Republic of China) *Journal of Aerospace Power*, vol. 3, Jan. 1988, p. 73-75, 95. In Chinese, with abstract in English. refs

A88-26793#

**CALCULATION OF METAL FLOW STRESS IN PRECISION CLOSED-DIE FORGING OF BLADE**

JIN ZHU and ZHIWEN ZHANG (Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 6, Jan. 1988, p. 11-19. In Chinese, with abstract in English. refs

It is pointed out here that, in order to obtain fine-quality aeromotor blade forging quality, the distribution of flow stress over the blade airfoil and the influence of the temperature field on the forging finish must be determined. It is found that, when deformation, strain, and temperature field reach a certain degree, flow stress is mainly affected by the rate of strain. A computer program based on this finding is presented which gives a method for calculating strain rate, flow stress, and temperature field in both forging and flash. The experimental measurement of temperature field on blade airfoil during the precision closed-die forging process is reported, and temperature distribution graphs based on the resulting data are presented. C.D.

A88-26890

**BUCKLING OF DELAMINATED, LONG, CYLINDRICAL PANELS UNDER PRESSURE**

GEORGE J. SIMITSES and ZIQI CHEN (Georgia Institute of Technology, Atlanta) *Computers and Structures* (ISSN 0045-7949), vol. 28, no. 2, 1988, p. 173-184. refs  
(Contract AF-AFOSR-86-0038)

Delamination is one of the basic defects inherent to laminar materials. The investigation of the buckling characteristics of delaminated cylindrical shells or panels, when subjected to external pressure, is presented herein. The geometry is such that it covers a wide range of length to radius ratios as well as panels of different widths. Results are presented only for very long cylinders and panels. The boundaries are either simply supported or clamped. Furthermore, the material is such that it leads to (quasi)isotropic laminates for all sections involved, the overall as well as the ones separated by the delamination. Finally, the geometry is free of initial geometric imperfections. Because of the last two assumptions, a primary membrane state exists and bifurcational buckling is possible. Buckling loads are calculated for a wide range of parameters. The width and the through-the-thickness position of delamination greatly affect the bifurcation load. Author

A88-26972

**A CONICAL ELEMENT FOR FINITE ELEMENT ROTOR DYNAMICS**

G. GENTA and A. GUGLIOTTA (Torino, Politecnico, Turin, Italy) *Journal of Sound and Vibration* (ISSN 0022-460X), vol. 120, Jan. 8, 1988, p. 175-182. refs

A conical beam element for rotor dynamic analysis is proposed. The element, with circular or annular cross-section, is based on the Timoshenko beam theory. It has two complex degrees of freedom at each node. The procedure for the computation of the stiffness, mass, gyroscopic damping matrices and of the unbalance vector is fully described. Author

A88-27248

**STRESS-STRAIN STATE OF AN OPENING PARACHUTE [NAPRIAZHENNO-DEFORMIROVANNOE SOSTOIANIE RASKRYVAIUSHCHEGOSIA PARASHIUTA]**

N. L. GORSKIĬ, I. V. DNEPROV, I. V. MOSEEV, A. T. PONOMAREV, and O. V. RYSEV IN: Statics and dynamics of flexible systems. Moscow, Izdatel'stvo Nauka, 1987, p. 194-201. In Russian. refs

A method for the stress-strain analysis of an opening parachute is proposed which is based on the use of aeroelasticity models of

different levels. A version of the finite element method developed for the problem in question is examined. The approach proposed here is illustrated by a specific example. V.L.

A88-27482

**FINE-SCALE MEASUREMENTS OF MICROWAVE REFRACTIVITY PROFILES WITH HELICOPTER AND LOW-COST ROCKET PROBES**

JOHN R. ROWLAND and STEVEN M. BABIN (Johns Hopkins University, Laurel, MD) *Johns Hopkins APL Technical Digest* (ISSN 0270-5214), vol. 8, Oct.-Dec. 1987, p. 413-417.

The recent development of computer models that can accurately predict radar performance under ducting or other anomalous propagation conditions has produced a need for high-resolution profiles of microwave refractivity in the lower troposphere. This article contains a brief description of two systems that can make the required meteorological measurements for use in those models. The first system is helicopter-based and has been used for research purposes to verify model performance. The second uses a low-cost rocket to carry a lightweight telemetry package to the desired altitudes. The rocket system shows promise for shipboard use where accurate, high-resolution refractivity profiles near the ocean surface are required. Author

A88-27775#

**A STUDY OF THE DYNAMIC BEHAVIOR OF ROTOR-BEARING SYSTEMS BY THE FINITE ELEMENT METHOD**

SHIH-SHYN J. WU (National Chungshing University, Taichung, Republic of China) *Chinese Society of Mechanical Engineers, Journal* (ISSN 0257-9731), vol. 8, Aug. 1987, p. 239-250. refs

Natural characteristics of the rotor-bearing systems were investigated. On the basis of Jeffcott's flexible rotor theory and the finite element method, equations of motion for the rotor-bearing systems with respect to either the fixed frame or the rotary frame were presented. Illustrations included a single, uniform rotor with bearing supports, a stepped rotor with bearings and rigid disks, and a dual rotor system. Numerical results include the whirl modes and whirl speeds. Physical meanings concerning the dynamic behavior of the rotor-bearing systems were discussed in detail, and the critical speeds related to the excitations were introduced. The computational procedures and results shown in this paper are significant for the understanding of the dynamic behavior of the rotor-bearing systems and helpful for the design of a turbine engine. Author

A88-28042#

**OPTIMUM DESIGN OF STRUCTURES WITH MULTIPLE CONSTRAINTS**

R. A. CANFIELD, V. B. VENKAYYA (USAF, Wright-Patterson AFB, OH), and R. V. GRANDHI (Wright State University, Dayton, OH) (Structures, Structural Dynamics, and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 398-408) *AIAA Journal* (ISSN 0001-1452), vol. 26, Jan. 1988, p. 78-85. USAF-supported research. Previously cited in issue 18, p. 2617, Accession no. A86-38845. refs

A88-28046#

**VAN LEER FLUX VECTOR SPLITTING IN MOVING COORDINATES**

IJAZ H. PARPIA (Texas, University, Arlington) *AIAA Journal* (ISSN 0001-1452), vol. 26, Jan. 1988, p. 113-115.

The present derivation of split-flux vectors referred to moving curvilinear coordinates makes possible the application of the split-flux method of van Leer (1982) to problems in which it might be convenient or necessary to use moving grids, such as helicopter-blade calculations in which the grid is attached to a blade undergoing translation, rotation, and deformation. The time-accurate calculation of flows on solution-adaptive grids is a further instance of the necessity of allowing for grid-point motion. O.C.

A88-28047#

**TURBULENT NEAR WAKE OF A SYMMETRICAL BODY**

R. H. PAGE and C. OSTOWARI (Texas A & M University, College Station) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988, p. 115, 116. refs  
(Contract NSF CBT-84-18493)

Attention is given to the near-wake profile of a symmetrical body immersed in uniform flow at zero angle-of-attack, for cases in which vortex-shedding is negligible. It is demonstrated by the centerline velocity values which provide the most probable equilibrium solution, that there exists a unique value of the time-averaged centerline velocity, in the near wake of this body, that represents the limiting case for turbulent high Re number flow. O.C.

N88-16633\*# National Aeronautics and Space Administration, Langley Research Center, Hampton, Va.

**REVIEW OF FATIGUE AND FRACTURE RESEARCH AT NASA LANGLEY RESEARCH CENTER**

RICHARD A. EVERETT, JR. In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 535-572 Feb. 1988

Avail: NTIS HC A25/MF A01 CSCL 20K

Most dynamic components in helicopters are designed with a safe-life constant-amplitude testing approach that has not changed in many years. In contrast, the fatigue methodology in other industries has advanced significantly in the last two decades. Recent research at the NASA Langley Research Center and the U.S. Army Aerostructures Directorate at Langley are reviewed relative to fatigue and fracture design methodology for metallic components. Most of the Langley research was directed towards the damage tolerance design approach, but some work was done that is applicable to the safe-life approach. In the areas of testing, damage tolerance concepts are concentrating on the small-crack effect in crack growth and measurement of crack opening stresses. Tests were conducted to determine the effects of a machining scratch on the fatigue life of a high strength steel. In the area of analysis, work was concentrated on developing a crack closure model that will predict fatigue life under spectrum loading for several different metal alloys including a high strength steel that is often used in the dynamic components of helicopters. Work is also continuing in developing a three-dimensional, finite-element stress analysis for cracked and uncracked isotropic and anisotropic structures. A numerical technique for solving simultaneous equations called the multigrid method is being pursued to enhance the solution schemes in both the finite-element analysis and the boundary element analysis. Finally, a fracture mechanics project involving an elastic-plastic finite element analysis of J-resistance curve is also being pursued. Author

N88-16701\*# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**CREEP AND FATIGUE RESEARCH EFFORTS ON ADVANCED MATERIALS**

JOHN GAYDA In its Aeropropulsion '87. Session 1: Aeropropulsion Materials Research 18 p Nov. 1987

Avail: NTIS HC A06/MF A01 CSCL 20K

Two of the more important materials problems encountered in turbine blades of aircraft engines are creep and fatigue. To withstand these high-temperature phenomena modern engines utilize single-crystal, nickel-based superalloys as the material of choice in critical applications. Recent research activities at Lewis on single-crystal blading material as well as future research initiatives on metal matrix composites related to creep and fatigue are discussed. The goal of these research efforts is improving the understanding of microstructure-property relationships and thereby guide material development. Author

N88-16893# Rolls-Royce Ltd., Derby (England). Precision Casting Facility.

**DEVELOPMENT OF A SHELL SYSTEM FOR DS MOULDS AT RR PRECISION CASTING FACILITY**

K. L. HARRISON 24 Apr. 1987 8 p Submitted for publication (PNR-90400; ETN-88-91529) Avail: NTIS HC A02/MF A01

Shells used in directional solidification casting of aircraft engine parts are described. Zircon flour slurry is used. Refractory stucco grains are still not ideal, and require two coats of shell to achieve the required thickness. Binder is hydrolyzed ethyl silicate, containing 24 percent silica. ESA

N88-16901# Naval Postgraduate School, Monterey, Calif.

**OPTIMIZING HF ANTENNA SYSTEMS ON THE DOLPHIN AND SEA HAWK HELICOPTERS M.S. Thesis**

JAMES B. CRAWFORD Sep. 1987 394 p  
(AD-A186552) Avail: NTIS HC A17/MF A01 CSCL 01C

Making an aircraft available and modifying it to test various antenna systems and configurations is extremely costly. The computer model is an excellent alternative means of analyzing antenna systems for optimum communication system performance. In this study electromagnetic wire grid computer models of two helicopters and eight HF antenna configurations are developed using Interactive Graphics Utility for Automated NEC Analysis (IGUANA). Numerical Electromagnetics Code (NEC) is used to obtain radiation patterns, and the Advanced Prophet program is used to develop the criteria for judging system effectiveness. These computer results compare favorably with test range data, showing great savings of cost. They provide the additional advantage of showing radiation patterns at an elevated angle for sky wave propagation analysis (patterns which cannot be obtained on an antenna test range). GRA

N88-16951# Naval Postgraduate School, Monterey, Calif.

**FLOW FIELD MEASUREMENTS USING HOTWIRE ANEMOMETRY M.S. Thesis**

GREGORY J. DOREMUS Sep. 1987 105 p  
(AD-A187029) Avail: NTIS HC A06/MF A01 CSCL 01A

A computer controlled data acquisition system utilizing hotwire anemometry has been designed, built, and installed at the Low Speed Wind Tunnel Facility. All relevant wind tunnel data is obtained by the use of a computer guided data acquisition system. Two computer programs were written to coordinate hotwire system calibration with hotwire experimentation. An experiment, Wake Velocity Profile Analysis and Drag Coefficient Measurement of an Airfoil, was used as a vehicle to test the system. The final output of the data acquisition system, including graphical information, compared favorably with previous results from an older data acquisition system already in use. Drag coefficient output compared very favorably to data supplied by the National Advisory Committee on Aeronautics. GRA

N88-16956\*# Nebraska Univ., Lincoln. Lab. for Electro-Optical Measurements.

**COMPARISON OF UNL LASER IMAGING AND SIZING SYSTEM AND A PHASE/DOPPLER SYSTEM FOR ANALYZING SPRAYS FROM A NASA NOZZLE Final Report, 1 Apr. 1985 - 19 Aug. 1987**

DENNIS R. ALEXANDER 14 Feb. 1988 139 p  
(Contract NAG3-634)

(NASA-CR-182437; NAS 1.26:182437) Avail: NTIS HC A07/MF A01 CSCL 20D

Aerosol spray characterization was done using a P/DPA and a laser imaging/video processing system on a NASA MOD-1 air-assist nozzle being evaluated for use in aircraft icing research. Benchmark tests were performed on monodispersed particles and on the NASA MOD-1 nozzle under identical laboratory operating conditions. The laser imaging/video processing system and the P/DPA showed agreement on calibration tests in monodispersed aerosol sprays of + or - 2.6 microns with a standard deviation of + or - 2.6 microns. Tests were performed on the NASA MOD-1 nozzle on the centerline and radially at one-half inch increments to the outer edge of the spray plume at a distance two feet (0.61

m) downstream from the exit of the nozzle. Comparative results at two operating conditions of the nozzle are presented for the two instruments. For the first case, the deviation in arithmetic mean diameters determined by the two instruments was in a range of 0.1 to 2.8 microns, and the deviation in Sauter mean diameters varied from 0 to 2.2 microns. Operating conditions in the second case were more severe which resulted in the arithmetic mean diameter deviating from 1.4 to 7.1 microns and the deviation in the Sauter mean diameters ranging from 0.4 to 6.7 microns.

Author

**N88-16966#** Aeronautical Research Inst. of Sweden, Stockholm. Dept. of Aerodynamics.

**NAVIER-STOKES SOLUTIONS FOR LAMINAR INCOMPRESSIBLE FLOW OVER A NACA 0012 AIRFOIL AND A BACKWARD FACING STEP**

PETER ELIASSON 19 Aug. 1987 49 p Sponsored by the Swedish Board for Technical Development (FFA-TN-1987-50; ETN-88-91668) Avail: NTIS HC A03/MF A01

For the solution of the incompressible Navier-Stokes equation, an explicit Runge-Kutta finite-volume solver was created. The gradients due to the viscous terms were approximated in the cells by surface integrals along the cell boundaries. A stability analysis for the condition of the local time step for the Runge-Kutta scheme was performed. Results for external and internal flow in two dimensions are presented. The code was verified for the external flow over a NACA 0012 airfoil at different Reynolds numbers and angles of attack, and the results were compared to corresponding compressible cases and to experiments. The code was also applied for the internal flow over a backward facing step for different Reynolds numbers, for which experimental data and numerical results are available. The results agree with other numerical results and with experimental data.

ESA

**N88-16988\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**NUMERICAL MODELING OF MULTIDIMENSIONAL FLOW IN SEALS AND BEARINGS USED IN ROTATING MACHINERY**

R. C. HENDRICKS, L. T. TAM, A. PRZEKOWAS, A. MUSZYNSKA, M. J. BRAUN, and R. L. MULLEN (Case Western Reserve Univ., Cleveland, Ohio.) 1988 30 p Prepared for presentation at the 2nd International Symposium on Transport Phenomena, Dynamics, and Design of Rotating Machinery, Honolulu, Hawaii, 4-6 Apr. 1988; sponsored in part by ASME and JSME (NASA-TM-100779; E-3909; NAS 1.15:100779) Avail: NTIS HC A03/MF A01 CSCL 20D

The rotordynamic behavior of turbomachinery is critically dependent on fluid dynamic rotor forces developed by various types of seals and bearings. The occurrence of self-excited vibrations often depends on the rotor speed and load. Misalignment and rotor wobbling motion associated with differential clearance were often attributed to stability problems. In general, the rotative character of the flowfield is a complex three dimensional system with secondary flow patterns that significantly alter the average fluid circumferential velocity. A multidimensional, nonorthogonal, body-fitted-grid fluid flow model is presented that describes the fluid dynamic forces and the secondary flow pattern development in seals and bearings. Several numerical experiments were carried out to demonstrate the characteristics of this complex flowfield. Analyses were performed by solving a conservation form of the three dimensional Navier-Stokes equations transformed to those for a rotating observer and using the general-purpose computer code PHOENICS with the assumptions that the rotor orbit is circular and that static eccentricity is zero. These assumptions have enabled a precise steady-state analysis to be used. Fluid injection from ports near the seal or bearing center increased fluid-film direct dynamic stiffness and, in some cases, significantly increased quadrature dynamic stiffness. Injection angle and velocity could be used for active rotordynamic control; for example, injection, when compared with no injection, increased direct dynamic stiffness, which is an important factor for hydrostatic bearings.

Author

**N88-17001#** Eidgenoessisches Flugzeugwerk, Emmen (Switzerland). Abteilung Versuchs- und Forschungsanlage.

**STRAIN GAGE BALANCE FOR HALF MODELS 302-6. CALIBRATION REPORT**

HEINZ BLAETTLER 28 Feb. 1986 106 p In GERMAN; ENGLISH summary

(F+W-FO-1803; ETN-88-91685) Avail: NTIS HC A06/MF A01

A six-component strain gage balance for half models 302-6 for the transonic wind tunnel was developed and calibrated. The calibration was executed with a special lever, so that forces and moments could be loaded at the point of attack of the model. Point 8 (for recording buffering) was also measured. The balance is conceived for:  $X = +/- 100$  (N);  $M_x = +/- 200$  (Nm);  $Y = +/- 200$  (N);  $M_y = +/- 35$  (Nm);  $Z = +/- 1000$  (N); and  $M_z = +/- 30$  (Nm).

ESA

**N88-17009#** National Aerospace Lab., Tokyo (Japan).

**TURBINE FLOW METER WITH OPTICAL FIBER PICK-UP**

YUKIO MATSUDA and MASANORI ENDOH 1987 15 p In JAPANESE; ENGLISH summary

(NAL-TR-923; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

For measurement of the flow rate of liquid and gas, a turbine flow meter is widely used for its easy handling characteristics and high reliability. However, there are still problems of narrow covering range and electric noise. These problems are mainly caused by the electromagnetic pick-up. An optical fiber pick-up turbine flow meter (OTF) has been developed to resolve these problems by using an optical fiber pick-up instead of the conventional electromagnetic pick-up to detect the passage of turbine blades. The OTF output signal is a pulse train with a constant amplitude (1V peak) in all ranges covered. An eminent improvement of linearity is realized in the lower flow rate range. Various kinds of aeroengine start and performance tests have proved the OTF to be very useful.

Author

**N88-17010#** National Aerospace Lab., Tokyo (Japan).

**STUDY ON A UNIDIRECTIONAL RING LASER GYRO. PART 1: PROPOSITION OF THE PRINCIPLE AND STUDIES ON THE COMPONENTS**

MINORU TAKIZAWA May 1987 39 p In JAPANESE; ENGLISH summary

(NAL-TR-933; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Study of a Unidirectional Ring Laser Gyro (URLG) is being carried out at NAL (National Aerospace Laboratory) in studies on an advanced automatic flight control system (Fly-By-Light System) for STOL aircraft. The purpose of the study is to develop a laser gyroscope which has such properties as high accuracy, high reliability, a very long service life and low cost. The laser gyro has no lock-in region and no moving parts. The principle of the laser gyro is proposed, and the behavior and the potential performance of the laser gyro are discussed theoretically. Furthermore, the results of the experimental studies of the main components, i.e., a ring laser, a V shaped linear laser, an optical diode and an optical read-out device are described.

Author

**N88-17045\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**DYNAMIC ANALYSIS OF MULTIMESH-GEAR HELICOPTER TRANSMISSIONS**

FRED K. CHOY, DENNIS P. TOWNSEND, and FRED B. OSWALD Feb. 1988 22 p

(NASA-TP-2789; E-3191; NAS 1.60:2789) Avail: NTIS HC A03/MF A01 CSCL 13I

A dynamic analysis of multimesh-gear helicopter transmission systems was performed by correlating analytical simulations with experimental investigations. The two computer programs used in this study, GRDYNMLT and PGT, were developed under NASA/Army sponsorship. Parametric studies of the numerical model with variations on mesh damping ratios, operating speeds, tip-relief tooth modifications, and tooth-spacing errors were performed to investigate the accuracy, application, and limitations of the two computer programs. Although similar levels of dynamic loading were predicted by both programs, the computer code

GRDYNMLT was found to be superior and broader in scope. Results from analytical work were also compared with experimental data obtained from the U.S. Army's UH-60A Black Hawk 2240-kW (3000-hp) class, twin-engine helicopter transmission tested at the NASA Lewis Research Center. Good correlation in gear stresses was obtained between the analytical model simulated by GRDYNMLT and the experimental measurements. More realistic mesh damping can be predicted through experimental data correlation. Author

**N88-17049#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Systems and Logistics.

**ANALYSIS OF THE RELIABILITY OF ROYAL AUSTRALIAN AIR FORCE NON-DESTRUCTIVE INSPECTION M.S. Thesis**

MARK CASSIDY Sep. 1987 96 p  
(AD-A186979; AFIT/GLM/LSMA/87S-11) Avail: NTIS HC A05/MF A01 CSCL 14B

The purpose of this research was to establish, via examination of the available literature, and appropriate means of quantifying the reliability of Non-Destructive Inspection (NDI) as practiced by the Royal Australian Air Force (RAAF) NDI technicians. Further, actual measurement of this NDI reliability was to be attempted and the correlation, if any, between the NDI technician's reported and measured results and the actual flaw lengths was to be established. GRA

**N88-17062#** Shock and Vibration Information Center (Defense), Washington, D. C.

**THE SHOCK AND VIBRATION BULLETIN. PART 4: STRUCTURAL DYNAMICS AND MODAL TEST AND ANALYSIS Monthly Report**

Jan. 1987 146 p Presented at the 57th Symposium on Shock and Vibration, New Orleans, La., 14-16 Oct. 1986  
(AD-A186751; SVIC-BULL-57-PT-4) Avail: NTIS HC A07/MF A01 CSCL 20K

Various topics related to shock and vibration are discussed. Qualification by analysis of Inertial Upper Stage plume deflectors, the analysis of reinforced concrete structures under the effects of localized detonations, reinforced concrete arches under blast and shock environments, reliability of structures with stiffness and strength degradation, frequency response functions of a nonlinear system, and system optimization in nonlinear random vibration are among the topics covered.

**N88-17073#** Concordia Univ., Montreal (Quebec). Dept. of Mechanical Engineering.

**DYNAMIC RESPONSE OF A GEARED TRAIN OF ROTORS SUBJECTED TO RANDOM SUPPORT EXCITATIONS**

S. V. NERIYA, R. B. BHAT, and T. S. SANKAR *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 4: Structural Dynamics and Modal Test and Analysis p 107-119 Jan. 1987

Avail: NTIS HC A07/MF A01 CSCL 13I

The response of a geared train of rotors subjected to random support excitations is investigated. Support excitations occur, for instance, on board moving vehicles. These excitations are, in general, random in nature, and the response can be obtained using a statistical analysis. Here, the geared train of rotors is modeled using finite elements and the coupling between torsion and flexure is considered. The geared rotor system is excited by a displacement type of support excitation which is the output of a filter, the input to which is a Gaussian stationary process with a white noise type of power spectral density. The excitation is assumed to be in the vertical direction only, and the excitations through the supports are assumed to be uncorrelated. Results for the response power spectral densities are presented for two kinds of filters. Author

**N88-17084#** Aeronautical Research Inst. of Sweden, Stockholm. Aerodynamics Dept.

**SELF-ADAPTIVE ANALYSIS OF THREE-DIMENSIONAL STRUCTURES USING A P-VERSION OF FINITE ELEMENT METHOD**

BOERJE ANDERSSON and URBAN FALK Aug. 1987 47 p  
Presented at the First World Congress on Computational Mechanics, Austin, Tex., 22-26 Sep. 1986 Sponsored by the Swedish Material (Material Dept.) Air Administration of Armed Forces

(FFA-TN-1987-31; ETN-88-91666) Avail: NTIS HC A03/MF A01

The self-adaptive finite element program STRIPE for solution of problems in three-dimensional elastomechanics is described. It uses a p-version of the finite element method where each finite element automatically is assigned an order of approximation  $p_i$  for the  $x_i$ -displacements to obtain the lowest error in the energy norm given the number of degrees of freedom. A simple energy error estimator used to terminate the adaptive process is outlined. A method for calculating the mode 1, 2, and 3 stress intensity factors in solids of isotropic materials was developed. The high accuracy obtained using this method is demonstrated. The rates of convergence to expect from the p-version of the finite element method when solving three-dimensional problems are illustrated. The computational efficiency of the p-version of the finite element method for solving real-life problems is demonstrated by analyzing a complex main frame fuselage of fighter aircraft. ESA

**N88-17090\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**ACCURACIES OF SOUTHWELL AND FORCE/STIFFNESS METHODS IN THE PREDICTION OF BUCKLING STRENGTH OF HYPERSONIC AIRCRAFT WING TUBULAR PANELS**

WILLIAM L. KO Nov. 1987 28 p  
(NASA-TM-88295; H-1415; NAS 1.15:88295) Avail: NTIS HC A03/MF A01 CSCL 20K

Accuracies of the Southwell method and the force/stiffness (F/S) method are examined when the methods were used in the prediction of buckling loads of hypersonic aircraft wing tubular panels, based on nondestructive buckling test data. Various factors affecting the accuracies of the two methods were discussed. Effects of load cutoff point in the nondestructive buckling tests on the accuracies of the two methods were discussed in great detail. For the tubular panels under pure compression, the F/S method was found to give more accurate buckling load predictions than the Southwell method, which excessively overpredicts the buckling load. It was found that the Southwell method required a higher load cutoff point, as compared with the F/S method. In using the F/S method for predicting the buckling load of tubular panels under pure compression, the load cutoff point of approximately 50 percent of the critical load could give reasonably accurate predictions. Author

**N88-17434#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Theoretische Stroemungsmechanik.

**NUMERICAL FLUID MECHANICS [NUMERISCHE STROEMUNGSMECHANIK]**

HERBERT OERTEL *In its* Scientific Colloquium in Honor of Prof. Dr. Rer. Nat. Hermann L. Jordan p 37-55 Jun. 1987 In GERMAN

Avail: NTIS HC A07/MF A01; DFVLR, Cologne, Fed. Republic of Germany DM 29

Solutions of fluid-mechanical model equations are treated. The dynamics of nonlinear systems is discussed. The flow transition process and the production of turbulence are explained. It is discussed to what extent the nonlinear interaction between a few modes can describe the transition to turbulent flow, and hence show the way towards transition and turbulence modeling. The use of numerical methods for the practical calculation of transonic passenger aircraft wings, and for the aerothermodynamic design of reentry vehicles, is presented. ESA

**N88-17623\*#** Environmental Research Inst. of Michigan, Ann Arbor. Radar Science Lab.

**RADAR BACKSCATTER FROM AIRPORTS AND SURROUNDING AREAS**

ROBERT G. ONSTOTT *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 183-191 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 17B

Vugraphs used in a presentation to describe the ground clutter environment at or near airports are given. R.J.F.

**N88-17624\*#** Northeastern Univ., Boston, Mass.

**RADAR RETURNS FROM GROUND CLUTTER IN VICINITY OF AIRPORTS**

H. R. RAEMER, R. RAHGAVAN, and A. BHATTACHARYA *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 193-205 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 17B

The objective of this project is to develop a dynamic simulation of the received signals from natural and man-made ground features in the vicinity of airports. The simulation is run during landing and takeoff stages of a flight. Vugraphs of noteworthy features of the simulation, ground clutter data bases, the development of algorithms for terrain features, typical wave theory results, and a gravity wave height profile are given. R.J.F.

**N88-17632\*#** Massachusetts Inst. of Tech., Lexington.

**STATUS OF FAA TERMINAL DOPPLER WEATHER RADAR PROGRAMS**

MARK W. MERRITT *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 411-444 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 17I

The status of the Federal Aviation Administration (FAA) Doppler weather radar programs are presented in vugraph form. Abstracts of relevant reports are given. R.J.F.

**N88-17819#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Zentralbereich Technik.

**RESEARCH AND DEVELOPMENT. TECHNICAL-SCIENTIFIC PUBLICATIONS (1956-1987): RETROSPECTIVE VIEW AND PROSPECTS. JUBILEE EDITION ON THE OCCASION OF THE 75TH BIRTHDAY OF DIPL.-ENGR. DR.-ENGR. E. H. LUDWIG BOELKOW [FORSCHUNG UND ENTWICKLUNG. TECHNISCH-WISSENSCHAFTLICHE VEROEFFENTLICHUNGEN 1956-1987 EIN RUECK- UND AUSBLICK. JUBILAEUMSAUSGABE ANLAESSLICH DES 75 GEBURTSTAGES VON DIPL.-ING. DR.-ING. E. H. LUDWIG BOELKOW]**

1987 319 p Partly in GERMAN and ENGLISH (ISSN-0931-9751; ETN-88-91025) Avail: NTIS HC A14/MF A01

Fighter aircraft, transport aircraft, helicopters, astronautics, and military techniques are discussed.

ESA

**N88-17855#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensgruppe Wehrtechnik.

**ROTOR SAR (ROSAR): A NEW HIGH-RESOLUTION ALL-WEATHER VISION METHOD FOR HELICOPTERS [ROSAR - EIN NEUES HOCHAUFLOESENDES ALLWETTERSICHTVERFAHREN FUER HUBSCHRAUBER]**

HORST KALTSCHMIDT and HELMUT KLAUSING (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen, West Germany) *In its* Research and Development. Technical-Scientific Publications (1956-1987): Retrospective View and Prospects. Jubilee Edition on the Occasion of the 75th Anniversary of Dipl.-Engr. Dr.-Engr. E.H. Ludwig Boelkow p 235-240 1987 In GERMAN

(MBB-UA-1046/87) Avail: NTIS HC A14/MF A01

The concept of an all-weather, high-resolution SAR system, based on rotating antennas integrated in helicopter blade tips (ROSAR) is presented. The opposition between resolution and transparency at several wavelengths, and antenna aperture increase as a solution are discussed. The principle of synthetic aperture radar, and determination of the resolution by theoretical signal recognition methods are explained. The fundamentals of the ROSAR concept are presented. As a systems design example, the SAR parameters for the frequencies 35 and 94 GHz are given. ESA

**N88-17871#** New Mexico Univ., Albuquerque. Engineering Research Inst.

**EVALUATION OF BITUMINOUS MATERIALS USED IN PAVEMENT RECYCLING PROJECTS AT TYNDALL, MACDILL, AND HURLBURT AIR FORCE BASES Final Report, Feb. 1985 - Dec. 1986**

B. KIGGUNDU, R. MARTINEZ, B. HUMPHREY, and T. SHULER Jul. 1987 212 p

(Contract F2901-84-C-0080)

(AD-A188068; NMERI-WA5-11(5.07); AFESC/ESL-TR-86-50)

Avail: NTIS HC A10/MF A01 CSCL 13C

This report presents results of a study involving bituminous materials from Tyndall and MacDill Air Force Bases and Hurlburt Field. These materials included Reclaimed Asphalt Pavement (RAP), modifiers, virgin asphalts, and new aggregates. A tentative modifier selection criterion was used to judge the quality of materials used in the recycling efforts at the respective sites. The results showed that independent adequacy of physical properties from chemical properties in selection of modifiers could not be established. However, some of the results showed that physical properties were more sensitive indicators of changes in binders due to aging. In addition, this report includes the tentative modifier selection criteria and results of an interlaboratory study from which variability limits to parameters determined using modified Clay-Gel and Heithaus procedures are established. The modified Clay-Gel and Heithaus procedures are included. GRA

**N88-17929** Stanford Univ., Calif.

**A COMPUTATIONAL STUDY OF THRUST AUGMENTING EJECTORS BASED ON A VISCOUS-INVISCID APPROACH Ph.D. Thesis**

THOMAS SCOTT LUND 1987 165 p

Avail: Univ. Microfilms Order No. DA8723044

Today's VSTOL designer is in need of an accurate theoretical model that can swiftly evaluate various ejector configurations. A viscous-inviscid interaction technique is advocated as both an efficient and accurate means of predicting the performance of two-dimensional thrust augmenting ejectors. The flowfield is divided into a viscous region that contains the turbulent jet, and an inviscid region that contains the ambient fluid drawn into the device. The inviscid region is computed with a higher order panel method, while an integral method is used for the description of the viscous part. The strong viscous-inviscid interaction present within the injector is simulated in an iterative process where two regions influence each other en route to a converged solution. This formulation retains much of the essential physics of the problem, but at the same time requires only a small amount of computing effort. The model is applied to a variety of parametric and

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optimization studies involving ejectors having either one or two primary jets. In all cases, it was found that the dual-jet ejector outperforms its single jet counterpart. This fact is attributed to enhanced mixing due to an increase in effective ejector length.

Dissert. Abstr.

**N88-17957#** Pennsylvania State Univ., University Park. Dept. of Mechanical Engineering.

**EXPERIMENTAL RESEARCH ON SWEEP SHOCK WAVE/BOUNDARY LAYER INTERACTIONS Interim Technical Report, 1 Apr. 1986 - 31 Mar. 1987**

GARY S. SETTLES Jun. 1987 29 p

(Contract AF AFOSR-0082-86)

(AD-A187250; PSU/ME-R-86/87-0034; AFOSR-87-1453TR)

Avail: NTIS HC A03/MF A01 CSCL 20D

Experiments were carried out to assess Mach number effects on boundary layer due to generic fin and swept compression corner geometries. An extensive set of fin interaction experiments was carried out at constant Reynolds number over the Mach number range of 2.5 to 4.0. Data thus far consist of surface flow visualization photographs and laser light-screen visualizations of flowfield structure. Additional experiments were conducted to assess the possibility that experimental data of this type might depend on the wind tunnel facility in which the experiments were performed. That was not found to be the case. Results of the parametric Mach number study revealed that Mach number effects over the range considered are essentially inviscid. These were accounted for simply by referencing measured quantities to the freestream Mach angle. The interaction growth with increasing shock strength was found to be nonlinear, contrary to previous results. Initial results from swept compression corner experiments are also reported.

GRA

**N88-17962#** Oxford Univ. (England). Dept. of Engineering Science.

**WAKE INTERACTION EFFECTS ON THE TRANSITION PROCESS ON TURBINE BLADES Report, 1 Sep. 1986 - 31 Aug. 1987**

R. W. AINSWORTH and J. E. LAGRAFF 30 Oct. 1987 33 p

Prepared in cooperation with Syracuse Univ., N.Y.

(Contract AF AFOSR-0295-85)

(AD-A188020; AFOSR-87-1919TR; SR-2) Avail: NTIS HC

A03/MF A01 CSCL 20D

The characterization of the nozzle guide vane inlet and exit conditions in the Oxford University Isentropic Light Piston Tunnel fully 3-D annular rotating stage has been undertaken. Measurements included hot wire anemometry and pressure/Mach number distributions. Preparations for the rotor heat transfer instrumentation/data acquisition hardware and software are also in progress. Further development of a numerical model to predict the effects of wake passing and transition is reported. The convection of the wake through the passage is predicted, allowing for estimations of the expected times for which the boundary layer is disturbed by the wake fluid. The new model for the random generation and subsequent growth and convection of the turbulent spots produces a time-resolved prediction of the intermittent heat transfer signals by use of a time-marching procedure. By superimposing the two numerical models it is possible to simulate the measured instantaneous heat transfer characteristics and to estimate the effective average intermittency along the blade surface and compare the results to the measured intermittency values.

GRA

**N88-18007\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**CERAMIC BEARINGS FOR USE IN GAS TURBINE ENGINES**

ERWIN V. ZARETSKY 1988 15 p Proposed for presentation at the 33rd International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, 5-9 Jun. 1988; sponsored by ASME

(NASA-TM-100288; E-3934; NAS 1.15:100288) Avail: NTIS HC A03/MF A01 CSCL 13I

Three decades of research by U.S. industry and government laboratories have produced a vast body of data related to the use of ceramic rolling element bearings and bearing components for aircraft gas turbine engines. Materials such as alumina, silicon carbide, titanium carbide, silicon nitride, and a crystallized glass ceramic have been investigated. Rolling-element endurance tests and analysis of full-complement bearings have been performed. Materials and bearing design methods have continuously improved over the years. This paper reviews a wide range of data and analyses with emphasis on how early NASA contributions as well as more recent data can enable the engineer or metallurgist to determine just where ceramic bearings are most applicable for gas turbines.

Author

**N88-18013#** Northrop Corp., Hawthorne, Calif. Aircraft Div.

**DURABILITY AND DAMAGE TOLERANCE OF ALUMINUM CASTINGS Interim Report No 1, Sep. 1985 - 31 May 1987**

M. W. OZELTON and G. R. TURK Sep. 1987 108 p Prepared in cooperation with Ohio State Univ., Columbus, Aluminum Co. of America, Corona, Calif., Hitchcock Industries, Inc., Minneapolis, Minn. and Fansteel Wellman Dynamics, Creston, Iowa

(Contract F33615-85-C-5015)

(AD-A186444; NOR-87-85) Avail: NTIS HC A06/MF A01 CSCL 11F

The results from the initial 21 months of the program are presented. They include: (1) an assessment of nondestructive methods for castings, and (2) the effect of process variables on the mechanical properties and microstructure of A357-Tb and A201-T7. A new ultrasonic nondestructive inspection (NDI) method called *Frequency Attenuation Inflection (FAI)* was evaluated for determining the type and amount defects in A357 and A201 aluminum castings. A low frequency eddy current method for detecting the presence of cracks through face sheet and fasteners was assessed. Relationship among chemical composition, heat treatment, solidification rate, microstructure, and mechanical properties of the premium quality casting alloys A357-T6 and A201-T7 were investigated.

GRA

**N88-18036\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**VIBRATION AND FLUTTER CHARACTERISTICS OF THE SR7L LARGE-SCALE PROPFAN**

RICHARD AUGUST (Sverdrup Technology, Inc., Cleveland, Ohio.) and KRISHNA RAO V. KAZA Jan. 1988 22 p

(NASA-TM-100272; E-3908; NAS 1.15:100272) Avail: NTIS HC A03/MF A01 CSCL 20K

An investigation of the vibration characteristics and aeroelastic stability of the SR7L Large-Scale Advanced Propfan was performed using a finite element blade model and an improved aeroelasticity code. Analyses were conducted for different blade pitch angles, blade support conditions, number of blades, rotational speeds, and freestream Mach numbers. A finite element model of the blade was used to determine the blade's vibration behavior and sensitivity to support stiffness. The calculated frequencies and mode shape obtained with this model agreed well with the published experimental data. A computer code recently developed at NASA Lewis Research Center and based on three-dimensional, unsteady, lifting surface aerodynamic theory was used for the aeroelastic analysis to examine the blade's stability at a cruise condition of Mach 0.8 at 1700 rpm. The results showed that the blade is stable for that operating point. However, a flutter condition was predicted if the cruise Mach number was increased to 0.9.

Author

## GEOSCIENCES

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

**A88-27456\*** Harvard Univ., Cambridge, Mass.

**MIDLATITUDE CLO BELOW 22 KM ALTITUDE - MEASUREMENTS WITH A NEW AIRCRAFT-BORNE INSTRUMENT**

WM. H. BRUNE, E. M. WEINSTOCK, and J. G. ANDERSON (Harvard University, Cambridge, MA) Geophysical Research Letters (ISSN 0094-8276), vol. 15, Feb. 1988, p. 144-147. refs (Contract NASW-3960; NAG2-443)

Midlatitude stratospheric CIO at altitudes below 22 km has been measured for the first time. Measurements were made at latitudes between 27 and 48 deg N during three flights from Moffett Field, CA, in June and July of 1987, with a new instrument flown on the NASA ER-2 aircraft. The result from these flights is that the CIO mixing ratio increases from less than 0.5 pptv at 16.8 km to 2.0 pptv at 18.3 km and 10.1 pptv at 21 km. These altitude profiles agree with an extrapolated profile from a May 1986 balloon-borne experiment (Brune and Anderson, 1986). Author

**N88-17617\*#** Mesoscale Environmental Simulations, Inc., Hampton, Va.

**NASA WIND SHEAR MODEL: SUMMARY OF MODEL ANALYSES**

FRED PROCTOR /in NASA Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 29-66 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 04B

A summary of an analysis of a wind shear model is presented in the form of vugraphs. Information is given on the Terminal Area Simulation System, two dimensional axisymmetric simulations, precipitation, ambient temperature and humidity profiles over Denver, and the structure of microbursts. It was concluded that the intensity of microbursts depends upon the environment temperature and humidity profile, the diameter of the microburst downdraft, the type of precipitation and the precipitation rate. The depth of the outflow layer depends primarily upon the diameter of the downdraft. Dry microbursts are more likely to be produced by precipitation initially falling as snow. R.J.F.

## 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.

**A88-25627**

**THE PROBLEM OF THE DEVELOPMENT OF FORMAL-LOGIC MODELS OF AIRCRAFT ASSEMBLY [K VOPROSU O POSTROENII FORMAL'NO-LOGICHESKIKH MODELEI SBORKI LETATEL'NYKH APPARATOV]**

R. I. GUSEVA and E. N. RYZHOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1987, p. 70-72. In Russian.

An approach to the development of aircraft assembly models is proposed which emphasizes the set-theory concept, with the identification and formal description of the common assembly elements followed by an analysis of the resulting formal structure and logical relations between the elements of the structure. A

set-theory model is synthesized using the analogy principle whereby mathematical analogies and relations are established between the elements of the actual assembly process. A proof is presented for the theorem of forbidden combinations of assembly bases, and its use in assembly process modeling is discussed. V.L.

**A88-25878**

**ON THE IMPROVEMENT OF AN ADAPTIVE OBSERVER FOR MULTI-OUTPUT SYSTEMS**

NORIYUKI HORI, PETER N. NIKIFORUK (Saskatchewan University, Saskatoon, Canada), KIMIO KANAI, and SHIGERU UCHIKADO (Defence Academy, Yokosuka, Japan) IEE Proceedings, Part D - Control Theory and Applications (ISSN 0143-7054), vol. 135, pt. D, no. 1, Jan. 1988, p. 67-71. refs

The paper proposes a design for an adaptive observer for multivariable systems and considers possible improvements for the identification of the unknown parameters. An orthogonalized projection algorithm which provides good convergence is described for identifying the unknown parameters of an aircraft. An adaptive observer which does not identify the plant's initial state vector, and which differs in design from one presented in an earlier paper, is also presented. Simulation studies are carried out using the data for the Japanese T-2 CCV aircraft to show that the orthogonalized projection method has better parameter convergence, and gives a better insight of how well the system is excited for parameter identification, than the least-squares method in ideal cases. Author

**A88-26264**

**A GEOMETRIC APPROACH TO NONLINEAR SINGULARLY PERTURBED CONTROL SYSTEMS**

R. MARINO (Roma II, Universita, Rome, Italy) and P. V. KOKOTOVIC (Illinois, University, Urbana) Automatica (ISSN 0005-1098), vol. 24, Jan. 1988, p. 31-41. refs (Contract NSF ECS-87-15811; N00014-84-C-0149)

Applications of two-time-scale singular perturbation methods have been limited to the class of models appearing in a 'standard form'. Many nonlinear control systems, such as models of aircraft and robotic manipulators with flexible joints, are two-time-scale systems, but do not appear in the standard form. The main result of this paper is a coordinate-free characterization of time-scales in terms of invariant manifolds which express conservation and equilibrium properties of the control system. A procedure for finding slow and fast states is given. Previously developed slow-fast composite control designs are thus made applicable to a wider class of nonlinear systems. Author

**A88-26627#**

**A SYSTEM OF DATA ACQUISITION AND PROCESSING IN AEROENGINE TESTING**

WENQING HAN, LONGQIANG LI, and ZHIQING HUANG (Nanjing Aeronautical Institute, People's Republic of China) Journal of Aerospace Power, vol. 3, Jan. 1988, p. 9-12, 87, 88. In Chinese, with abstract in English. refs

The design and performance of a comprehensive computer-controlled system for acquiring and processing aircraft-engine test data are described. The specialized hardware and PL/M-based software permit measurement rates of up to 5 kHz, real-time calibration and analog/digital signal conversion, and reliable and easy operation. Compared with manual processing, the system reduces test-run time (by about 20 percent), processing time (from several hours to a few minutes), and measurement error (from 0.8 to 0.3 percent). T.K.

## 15 MATHEMATICAL AND COMPUTER SCIENCES

**A88-26726**

**NUMERICAL GRID GENERATION IN COMPUTATIONAL FLUID DYNAMICS; PROCEEDINGS OF THE INTERNATIONAL CONFERENCE, LANDSHUT, FEDERAL REPUBLIC OF GERMANY, JULY 14-17, 1986**

J. HAEUSER, ED. (Landshut, College, Federal Republic of Germany) and C. TAYLOR, ED. (Swansea, University College, Wales) Swansea, Wales, Pineridge Press, 1986, 805 p. For individual items see A88-26727 to A88-26765.

The present conference on numerical flow visualization grid-generation techniques and their application to fluid flow problems discusses adaptive and orthogonal techniques, composite methods, grid generation for aircraft design and for internal flow problems, triangular grid generation. The use of multigrids, the solution of the Navier-Stokes equations, computational hydraulics, thermal and fluid-flow problems, and the application of grid generation to technical problems. Attention is given to one-parameter mesh-generation for spheroidal domains, the evaluation of algebraic adaptive grid strategies, interface procedures for overlapping grids, the elliptic generation of three-dimensional grids, adaptive triangular meshes for compressible flow solutions, numerical grid generation in coastal hydrodynamics, and grid generation for gas lubrication. O.C.

**A88-26732**

**SURFACE MESH GENERATION USING ELLIPTIC EQUATIONS**

Z. U. A. WARSI and W. N. TIARN (Mississippi State University, Mississippi State) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 95-110. refs (Contract AF-AFOSR-85-0143)

This paper is devoted to a computational method of mesh generation in arbitrary surfaces by utilizing a set of elliptic partial differential equations. These equations depend explicitly on the mean curvature and the unit normal vector of the surface in which the coordinates are to be generated. To determine the mean curvature for a given surface in global coordinates, first a piecewise least-squares method is used to fit a surface through the given data points. Next, mesh generation results for various geometrically complicated shapes have been obtained to demonstrate the versatility of the proposed equations. An example of a monoclinic coordinate system with contraction in the coordinate leaving the surface has also been presented. Author

**A88-26746**

**AN APPROACH TO THE INTERACTIVE GENERATION OF BLOCKSTRUCTURED VOLUME GRIDS USING COMPUTER GRAPHICS DEVICES**

WERNER SEIBERT (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 319-328.

An account is given of a novel approach to easy, fast grid generation with great geometric complexity, enlisting advanced, menu-driven interactive computer graphics to create a 'block-structured' grid. Implementation involves a combination of existing CAD software and application-oriented programs. The illustrative examples presented are taken from external aerodynamic and internal, pipe-flow problems; attention is given to the geometry-preparation and grid-generation subtasks, as well as to the method of topological description. O.C.

**A88-26748**

**ELLIPTIC GRID GENERATION SYSTEM FOR THREE-DIMENSIONAL CONFIGURATIONS USING POISSON'S EQUATION**

W. SCHWARZ (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Numerical grid generation in computational fluid dynamics; Proceedings of the International Conference, Landshut, Federal Republic of Germany, July 14-17, 1986. Swansea, Wales, Pineridge Press, 1986, p. 341-352. refs

Two higher-order elliptic grid generation systems for three-dimensional applications have been developed. The fourth-order (biharmonic) system is implemented as a set of two second-order equations (Poisson's and Laplace's equation) while the sixth-order system is solved as a system of three second-order equations. These higher-order grid generation systems allow two (or three) boundary conditions at each boundary. Therefore it is possible to fully specify the geometry of the first, or even the first two grid cells off the boundary. A grid quality check which includes graphic display of cell volume and cells skewness quantities, even for three-dimensional configurations, is also included. This grid generation method has been applied successfully to a number of two- and three-dimensional problems, including airfoils, ducts, cars, wings, wing-body configurations and even a complete fighter aircraft. Author

**A88-27148**

**SYNTHESIS OF THE FLEXIBLE STRUCTURES OF COMPLEX SYSTEMS [SINTEZ GIBKIKH STRUKTUR SLOZHNYKH SISTEM]**

M. A. MUZIUKIN and V. K. AKINFIEV IN: Methods for the optimization of complex systems. Moscow, Izdatel'stvo Nauka, 1987, p. 54-63. In Russian.

The problem of improving the structure and increasing the efficiency of globally distributed information/control systems is examined with particular reference to the automatic control systems of flight vehicles. The problem of the synthesis of the flexible structure of complex systems is formulated as a nonlinear mathematical programming problem. An optimization-simulation approach to the solution of such problems is proposed which involves the development of procedures using optimization and simulation or computational models for the synthesis of the optimal version of the structure. V.L.

**A88-27312**

**LOOP SHAPING WITH OUTPUT FEEDBACK**

B. L. STEVENS, P. VESTY (Lockheed-Georgia Co., Marietta), B. S. HECK, and F. L. LEWIS (Georgia Institute of Technology, Atlanta) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 146-149. refs

It is shown how to use output feedback design in the frequency domain to achieve desired robustness and performance criteria. A low-frequency bound is derived which shows the robustness of the design to plant parameter variations, and can therefore be used to help minimize the number of gain-scheduling points. Author

**A88-27318**

**ROBUSTNESS/PERFORMANCE TRADEOFFS IN EIGENSTRUCTURE ASSIGNMENT WITH FLIGHT CONTROL APPLICATION**

K. M. SOBEL (City College, New York) and E. Y. SHAPIRO (HR Textron, Inc., Valencia, CA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 380-385. refs

A constrained optimization is employed to tradeoff the desired eigenvector assignments and the eigenvalue sensitivity, with application to the development of flight control systems. The sum of the 2-norms of the differences between each desired eigenvector and its corresponding closed loop eigenvector is used as a measure of eigenvector assignment. The sum of the squares of the 2-norms of the left eigenvectors is proposed for eigenvalue sensitivity. The

example of a yaw pointing/lateral translation controller is discussed, revealing some possible undesirable consequences of attempting to obtain the minimum sensitivity solution. R.R.

**A88-27326**  
**DESIGNING STABILIZING CONTROLLERS FOR UNCERTAIN SYSTEMS USING THE RICCATI EQUATION APPROACH**

W. E. SCHMITENDORF (Northwestern University, Evanston, IL) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 502-505. refs (Contract NSF ECS-84-15591; AF-AFOSR-ISSA-85-00051)

The Riccati approach of Petersen and Hollot (1986) for computing the gains in a linear controller are generalized to include problems with time-varying uncertainty in the input connection matrix. The method is illustrated for examples including the dynamics of a helicopter in a vertical plane and the problem of stabilizing the longitudinal short period of a F4E fighter aircraft at two operating points. It is noted that the Riccati method has previously been extended to problems where the complete state is not available for feedback. R.R.

**A88-27327**  
**CONTROL OF LINEAR SYSTEMS BY OUTPUT PROPORTIONAL PLUS DERIVATIVE FEEDBACK**

A. HARALDSDOTTIR, P. T. KABAMBA, and A. G. ULSOY (Michigan, University, Ann Arbor) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 526-531. refs

This paper presents a control design procedure for linear time invariant systems using output proportional plus derivative feedback. The traditional linear quadratic performance index is used with additional terms to penalize disturbance and noise response and eigenvalue and response sensitivities. The sensitivity terms represent measures of stability robustness. It is shown that the derivative feedback improves the measure of performance. This design procedure has been applied to obtain an improved autopilot for the lateral dynamics of an L1011 aircraft. Author

**A88-27381**  
**NON-LINEAR INVERSE DYNAMICS CONTROL LAWS - A SAMPLED DATA APPROACH**

ROBERT F. STENGEL (Princeton University, NJ) and STEPHEN H. LANE IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1224-1226. Research sponsored by the Schultz Foundation. refs

A sampled-data approach for the implementation of Nonlinear Inverse Dynamics (NID) control laws in real time is presented. The control laws developed place the same number of poles as their continuous-time counterparts, take into account the system dynamics in between the sample points, and embed the computational delays associated with the inverse calculations directly into their design. Author

**A88-27405**  
**AN ARCHITECTURE FOR REAL-TIME RULE-BASED CONTROL**

ROBERT F. STENGEL (Princeton University, NJ) and DAVID A. HANDELMAN IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1636-1642. refs (Contract DAAG29-84-K-0048)

A method for control employing rule-based search is reviewed, and a Rule-Based Controller achieving economical real-time performance is described. Code optimization, in the form of LISP-to-Pascal knowledge base translation, provides real-time search execution speed and a processing environment enabling highly integrated symbolic and numeric computation. With a multiprocessor software architecture specifying rule-based protocol for control task communication, and a hardware architecture

providing concurrent implementation within a multimicroprocessor system, the controller realizes a set of cooperating real-time expert systems. Based on experience gained through the design and implementation of a Rule-Based Flight Control System, the proposed approach appears applicable to a large class of complex control problems. Author

**A88-27406**  
**FAILURE MODEL DETERMINATION IN A KNOWLEDGE-BASED CONTROL SYSTEM**

CHIEN Y. HUANG (Grumman Aerospace Corp., Bethpage, NY) and ROBERT F. STENGEL (Princeton University, NJ) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1643-1648. refs (Contract DAAG29-84-K-0048)

A technique for determining the most probable failure state of a restructurable control system is presented. The approach is to build a knowledge base that contains and makes use of inference mechanisms to deduce the most likely failures given the symptoms. The analysis is first carried out in a local sense, where only probabilistic information and causality are used to generate failure models, then in a global sense, where the models are grouped and heuristics are used to prune the number of candidate models. Procedures are illustrated using failure patterns of a generic database as well as a fault scenario for a hypothetical helicopter flight control system. It is concluded that the methods are potentially capable of handling generic failures and thus are useful in truly restructurable control systems. Author

**A88-27410**  
**EXPERIMENTAL IMPLEMENTATION AND EVALUATION OF THE RMI FAILURE DETECTION ALGORITHM**

D. T. HORAK and B. H. ALLISON (Bendix Aerospace Technology Center, Columbia, MD) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1803-1810. refs

This paper describes laboratory experiments with the Reachable Measurement Intervals (RMI) failure detection algorithm for systems with imperfect models. It was implemented on a multiprocessor computer system and used to detect and isolate failures in an aircraft simulator in the presence of modeling errors. The failure detection computer and the monitored system resembled a commercial system and provided a good vehicle for assessing the suitability of RMI for industrial applications. The algorithm performed very well with real hardware, matching its performance in simulations. It did so because it has been designed specifically to handle imperfect dynamic models. The algorithm is fast enough to monitor large industrial systems when implemented on a single-board computer. Its structure is suitable for parallel processing implementation which makes it fast enough for even very large systems. Author

**A88-27411**  
**EXPERT SYSTEM ALLOCATION FOR THE ELECTRONICALLY SCANNED ANTENNA RADAR**

ROBERT POPOLI and SAMUEL BLACKMAN (Hughes Aircraft Co., Radar Systems Group, El Segundo, CA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1821-1826. refs

The battle effectiveness of the next generation of fighter aircraft will rely on efficient deployment of modern electronically scanned antenna (ESA) radar. ESA requires the development of intelligent allocation algorithms. An expert systems approach for situation-driven sensor management is presented in this paper. The ESA allocation problem is defined, and a set of heuristic guidelines for a specific subset of the ESA allocation problem is presented. It is shown how to represent and reason with these heuristic guidelines using fuzzy sets, and simulation results demonstrating the operation of such an approach are presented. C.D.

## 15 MATHEMATICAL AND COMPUTER SCIENCES

**A88-27417**

### **CONTROL OF AN AXIAL PISTON PUMP USING A SINGLE-STAGE ELECTROHYDRAULIC SERVOVALVE**

A. AKERS (Iowa State University of Science and Technology, Ames) and S. J. LIN (Moorhead State University, MN) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1865-1870. Research supported by the Iowa State University of Science and Technology. refs

Optimal control theory is applied to the design of a pressure regulator for an axial piston pump and single-stage electrohydraulic valve combination. The control valve has been modeled and an optimal control law has been formulated. The time response curves due to a step input in flow rate and in current input to the servovalve have been obtained for the open loop and for the optimal control system. The results have been compared to those in which the supply valve to the swashplate actuators was not modeled. Controlled system modeling of the servovalve significantly improves the system's response frequency and pressure peaks. Author

**A88-27418**

### **PLACEMENT OF FAILURE-PRONE COMPONENTS ON FLEXIBLE STRUCTURES - A DEGREE OF CONTROLLABILITY APPROACH**

M. MARITON (CNRS, Laboratoire des Signaux et Systemes, Gif-sur-Yvette, France) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1883, 1884. refs

A suitable framework for the design of reliable flight control systems is discussed. The degree of controllability is proposed as a criterion for the choice of actuators and sensors. The placement of failure-prone actuators in order to maximize a degree of controllability is discussed in some detail. C.D.

**A88-27419**

### **ON ROBUST CONTROL OF WING ROCK USING NONLINEAR CONTROL**

HAROLD STALFORD (Virginia Polytechnic Institute and State University, Blacksburg) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1890-1899. refs

Nonlinear control theory of uncertain systems is applied to the high angle-of-attack flight dynamic phenomenon of wing rock. Wing rock, an unsteady aerodynamic effect, is an undamped oscillation primarily in the roll axis and is exhibited by many modern combat aircraft. It causes maneuver limitations ranging in severity from degradation in tracking effectiveness to loss of control. Robust control is investigated for a generic nonlinear wind tunnel model of a modern combat aircraft that exhibits wing rock. Feedback control is derived using the nonlinear control approach of uncertain systems. A typical example is presented. Author

**A88-27751**

### **AUTOMATIC SYSTEMS IN AERONAUTICS; NATIONAL COLLOQUIUM, PARIS, FRANCE, MAR. 17-19, 1986, PROCEEDINGS [L'AUTOMATIQUE POUR L'AERONAUTIQUE; COLLOQUE NATIONAL, PARIS, FRANCE, MAR. 17-19, 1986, ACTES]**

Colloquium sponsored by the Societe de Mathematiques Appliquees et Industrielles, Association Aeronautique et Astronautique de France, Delegation Generale pour l'Armement, et al. Toulouse, Cepadues-Editions, 1986, 552 p. In French. For individual items see A88-27752 to A88-27771.

Papers are presented on optimal control of a solar sail along the earth-moon trajectory, the application of singular perturbation techniques to aircraft trajectory optimization, the application of optimal feedback laws to satellite control, and CAD packages for control systems. Also considered are modelization and identification in helicopter science, the design of a helicopter automatic flight control system, the stability of helicopter blade motion in the case

of turbulent air flow, and nonlinear identification techniques for helicopter flight mechanics. Other topics include the identification and control of flexible structures, breakdown detection and flight control system reconfiguration, and problems related to the application of flight control systems to combat aircraft guidance. R.R.

R.R.

**A88-27752**

### **TECHNOLOGICAL LEAPS OCCURRING IN THE AERONAUTICAL AND SPACE FIELDS [SAUTS TECHNOLOGIQUES EN COURS DANS LES DOMAINES AERONAUTIQUE ET ESPACE]**

MARC J. PELEGRIN (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings Toulouse, Cepadues-Editions, 1986, p. 9-58. In French. refs

Recent advances in automation in the aeronautical and space fields are reviewed. Test results concerning the electrical transmission of signals for automated flight systems have been obtained during flight testing of the Concord and the A300. The Generalized Active Command system is designed to increase stability and maneuverability and to suppress buffeting and flutter effects. Other topics discussed include military aeronautical applications, the multicyclic control of helicopter blades, and the man-machine interface. Problems encountered during signal transmission, multisensor measurement, and signal processing are reviewed, in addition to problems involved with system flexibility. Advances in AI are also considered. R.R.

R.R.

**A88-27755**

### **ALPHA-DEGREE STABILITY AND ROBUSTNESS - APPLICATION TO THE DEVELOPMENT OF A REGULATOR [STABILITE ET ROBUSTESSE DE DEGRE ALPHA - APPLICATION A LA MISE AU POINT D'UN REGULATEUR]**

H. BOURLES (ESIEA, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 151-169. In French. refs

A general stability theory has been used to study the robustness of a regulator, with application to the problem of aircraft control. A method is first presented for analyzing the alpha-degree stability of a controlled-aircraft system which is governed by a differential equation. The method is then applied to the development of a regulator with the desired dynamics and degree of robustness, accurately predicting the gain margin and the regulator phase margin for a given structural perturbation. R.R.

R.R.

**A88-27756**

### **THEORY AND DEVELOPMENT OF DISCRETE MULTIVARIABLE REGULATORS ASSURING ROBUST TRACKING [THEORIE ET MISE AU POINT DE REGULATEURS MULTIVARIABLES DISCRETS ASSURANT UNE POURSUITE ROBUSTE]**

Y. JOANNIC (Matra, S.A., Velizy-Villacoublay, France) and O. MERCIER (Bertin et Cie., Plaisir, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 171-191. In French. DRET-supported research. refs

A discrete-time robust multivariable control law which enables asymptotic cancellation of tracking errors even under persistent exterior perturbations is presented. A solution to the problem of regulating the robust optimal tracking is given, in addition to the minimal, necessary, and sufficient conditions for the convergence towards zero of tracking errors. The intrinsic robustness and the excellent convergence properties of the control law are demonstrated for the multivariable problem of the lateral movement of a combat aircraft in the presence of model defects and applied perturbations. R.R.

R.R.

A88-27760

**MODELING AND IDENTIFICATION IN HELICOPTER SCIENCE [MODELISATION ET IDENTIFICATION DANS LA SCIENCE DE L'HELICOPTERE]**

MARCEL KRETZ (Giravions Dorand Industries, Suresnes, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 269-293. In French. refs

A generalized automatic control (GAC) technique for regulating helicopter functions which have not yet been subjected to automated control is discussed. GAC is applied to the example of multicyclic piloting via identification of a mathematical model, implementation of the model in a self-adaptive system, and optimization under physical constraints in order to achieve desired objectives such as vibration reduction. Examples given include the modeling of a hydrodynamic actuator, based on considerations of dynamical behavior, and the modeling of dynamic stalling. For the case of applying the GAC to the automated elimination of stalling, a divergence of solutions is found. R.R.

A88-27766

**REDUNDANT CONTROL SYSTEMS - FLEXIBILITY AND OPTIMALITY [LES SYSTEMES DE COMMANDE REDONDANTS - FIABILITE ET OPTIMALITE]**

M. MARITON and P. BERTRAND (CNRS, Laboratoire des Signaux et Systemes, Gif-sur-Yvette, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 417-430. In French. refs

Quadratic linear systems with Markovian jumps are considered, with application to achieving the high-performance and flexibility necessary for fault tolerance in aircraft. The present analysis leads to both a new derivation of optimal control laws, based upon automated control reconfiguration, and an integrated theory which globally accounts for the three stages performed in obtaining control systems: (1) the selection of components, (2) the selection of their position; and (3) the synthesis of the control system itself. Components such as sensors, actuators, and computers are taken into account, making possible the automated prediction of breakdowns and control system degradation. R.R.

A88-27771

**POINTS OF VIEW ON LINEAR AND NONLINEAR FILTERING IN AERONAUTICS [QUELQUES POINTS DE VUE SUR LE FILTRAGE LINEAIRE ET NON-LINEAIRE EN AERONAUTIQUE]**

J. LEVINE (Paris, Ecole des Mines, Fontainebleau, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings . Toulouse, Cepadues-Editions, 1986, p. 541-551. In French. refs

The advantages and disadvantages of the Kalman filter for linear systems, the extended Kalman filter for nonlinear systems, and other filtering methods for nonlinear systems are considered. Reference is given to aeronautical applications such as navigation and missile guidance. Difficulties encountered in the linear case include the regulation of noise levels, the compensation for biases due to modeling errors, and the selection of suboptimal filters. Two categories of linear filtering methods which are exact or approximate are discussed: (1) methods using the conditional law to obtain approximations of moments or the existence properties of finite-dimension filters; and (2) methods using an appropriate choice of coordinates to describe the system in a more agreeable form. R.R.

A88-28617#

**AN IMPROVEMENT ON THE ADAPTIVE MODEL FOLLOWING CONTROL**

YUN ZHANG and JIQIN PAN (Beijing Institute of Technology, People's Republic of China) Acta Automatica Sinica (ISSN 0254-4156), vol. 13, Nov. 1987, p. 401-407. In Chinese, with abstract in English. refs

In this paper, an improvement on adaptive model-following control (AMFC) is developed. Compared with AMFC, the improved AMFC (IAMFC) can be applied to a larger class of controlled

objects and has a larger class of adaptive control laws. An IAMFC system has been designed for flight roll stabilization. Simulation results indicate that the system satisfies requirements and that the IAMFC can overcome difficulties which AMFC cannot overcome. C.D.

N88-17218\*# Air Force Systems Command, Wright-Patterson AFB, Ohio.

**NEURAL NETWORK BASED ARCHITECTURES FOR AEROSPACE APPLICATIONS**

RICHARD RICART *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 85-91 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 09B

A brief history of the field of neural networks research is given and some simple concepts are described. In addition, some neural network based avionics research and development programs are reviewed. The need for the United States Air Force and NASA to assume a leadership role in supporting this technology is stressed. Author

N88-17253\*# Systems Research and Applications, Inc., Arlington, Va.

**SWAN: AN EXPERT SYSTEM WITH NATURAL LANGUAGE INTERFACE FOR TACTICAL AIR CAPABILITY ASSESSMENT**

ROBERT M. SIMMONS *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 341-348 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 09B

SWAN is an expert system and natural language interface for assessing the war fighting capability of Air Force units in Europe. The expert system is an object oriented knowledge based simulation with an alternate worlds facility for performing what-if excursions. Responses from the system take the form of generated text, tables, or graphs. The natural language interface is an expert system in its own right, with a knowledge base and rules which understand how to access external databases, models, or expert systems. The distinguishing feature of the Air Force expert system is its use of meta-knowledge to generate explanations in the frame and procedure based environment. Author

N88-17260\*# Worcester Polytechnic Inst., Mass. Intelligent Machines Group.

**REAL-TIME ARTIFICIAL INTELLIGENCE ISSUES IN THE DEVELOPMENT OF THE ADAPTIVE TACTICAL NAVIGATOR**

PETER E. GREEN, DOUGLAS P. GLASSON, JEAN-MICHEL L. POMAREDE, and NARAYAN A. ACHARYA (Analytic Sciences Corp., Reading, Mass.) *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 389-396 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 09B

Adaptive Tactical Navigation (ATN) is a laboratory prototype of a knowledge based system to provide navigation system management and decision aiding in the next generation of tactical aircraft. ATN's purpose is to manage a set of multimode navigation equipment, dynamically selecting the best equipment to use in accordance with mission goals and phase, threat environment, equipment malfunction status, and battle damage. ATN encompasses functions as diverse as sensor data interpretation, diagnosis, and planning. Real time issues that were identified in ATN and the approaches used to address them are addressed. Functional requirements and a global architecture for the ATN system are described. Decision making with time constraints are discussed. Two subproblems are identified; making decisions with incomplete information and with limited resources. Approaches used in ATN to address real time performance are described and simulation results are discussed. Author

## 15 MATHEMATICAL AND COMPUTER SCIENCES

**N88-17313\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**GENERAL ROTORCRAFT AEROMECHANICAL STABILITY PROGRAM (GRASP) VERSION 1.03: USER'S MANUAL**  
A. STEWART HOPKINS and DONALD L. KUNZ (Army Aviation Research and Development Command, Moffett Field, Calif.) Feb. 1988 64 p  
(NASA-TM-100043; A-88028; NAS 1.15:100043; USAAVSCOM-TR-87-A-12) Avail: NTIS HC A04/MF A01 CSCL 09B

The Rotorcraft Dynamics Division, Aeroflightdynamics Directorate, U.S. Army Aviation Research and Technology Activity has developed the General Rotorcraft Aeromechanical Stability Program (GRASP) to perform calculations that will assess the stability of rotorcraft in hovering flight and ground contact conditions. The program is designed to be state-of-the-art, hybrid, finite-element/multibody code that can be applied to all existing and future helicopter configurations. While GRASP was specifically designed to solve rotorcraft stability problems, its innovative structure and formulation allow for application to a wide range of structures. This manual describes the preparation of the input file required by Version 1.03 of GRASP, the procedures used to invoke GRASP on the NASA Ames Research Center CRAY X-MP 48 computer, and the interpretation of the output produced by GRASP. The parameters used by the input file are defined, and summaries of the input file and the job control language are included.

Author

**N88-17314#** Association Aeronautique et Astronautique de France, Paris.  
**METHODS FOR EVALUATING THE QUALITY AND RELIABILITY OF AERODYNAMIC SOFTWARE PROGRAMS**  
G. HECKMANN Nov. 1986 51 p In FRENCH Presented at the 23rd Colloque d'Aerodynamique Appliquee, Modane, France, 12-14 Nov. 1986 Sponsored by Direction des Recherches, Etudes et Techniques, Paris, France Prepared in cooperation with Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France (PB87-169793; NOTE-TECHNIQUE-86-02; ISBN-2-7170-0850-0) Avail: NTIS HC E04/MF E04 CSCL 09B

Industrial calculation codes in the sixties, seventies, and today; industrial needs; types and levels of needs; types and levels of programs; the reliability of conversational codes; and mesh programs are discussed. It is suggested that codes be evaluated by observing discrepancies between software calculations and data obtained during flight tests and wind tunnel trials of planes under development. Specific tests can also be developed for the express purpose of evaluating software and the data used in the same way as that obtained from ordinary wind tunnel tests.

Author

**N88-17363#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Abteilung Hubschrauber und Flugzeuge.  
**REDUCTION OF TIME DELAYS IN RUNGE-KUTTA INTEGRATION METHODS**  
S. NOWACK and FEIL 15 Apr. 1986 20 p (MBB/LKE-132/S/PUB/241/A; ETN-88-91438) Avail: NTIS HC A03/MF A01

A fourth order accurate Runge-Kutta (RK4) method for real time system simulation is proposed, where data must be sampled from input signals and incorporated into the numerical integration algorithms in order to evaluate the derivatives of the state variables. The method is compared to a standard RK4 for a flight simulation. Simulation of a one DOF-system with varying damping ratios shows that the accuracy of the proposed routine is equal (in the case of constant input function) or slightly superior (in the case of sinusoidal input) to the RK4 standard method. The results are for a system requiring no extrapolation. Simulation of a complex real time system (approach and touchdown of aircraft) shows that the proposed routine provides an increase in accuracy over the RK4 standard method even beyond decreasing the size of steps in output signals. This is particularly important when system variables change with high frequency and large increments.

ESA

**N88-18300\*#** Syracuse Univ., N. Y. Dept. of Mechanical and Aerospace Engineering.  
**COMPREHENSIVE ANALYSIS OF HELICOPTERS WITH BEARINGLESS ROTORS Status Report**  
V. R. MURTHY Mar. 1988 110 p  
(Contract NAG1-759)  
(NASA-CR-182537; NAS 1.26:182537) Avail: NTIS HC A06/MF A01 CSCL 09B

A modified Galerkin method is developed to analyze the dynamic problems of multiple-load-path bearingless rotor blades. The development and selection of functions are quite parallel to CAMRAD procedures, greatly facilitating the implementation of the method into the CAMRAD program. A software is developed implementing the modified Galerkin method to determine free vibration characteristics of multiple-load-path rotor blades undergoing coupled flapwise bending, chordwise bending, twisting, and extensional motions. Results are in the process of being obtained by debugging the software.

Author

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### PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

**N88-16646\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.  
**RECENT LANGLEY HELICOPTER ACOUSTICS CONTRIBUTIONS**  
HOMER G. MORGAN, S. P. PAO, and C. A. POWELL In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 1003-1044 Feb. 1988 Avail: NTIS HC A25/MF A01 CSCL 20A

The helicopter acoustics program at NASA Langley has included technology for elements of noise control ranging from sources of noise to receivers of noise. The scope of Langley contributions for about the last decade is discussed. Specifically, the resolution of two certification noise quantification issues by subjective acoustics research, the development status of the helicopter system noise prediction program ROTONET are reviewed and the highlights from research on blade rotational, broadband, and blade vortex interaction noise sources are presented. Finally, research contributions on helicopter cabin (or interior) noise control are presented. A bibliography of publications from the Langley helicopter acoustics program for the past 10 years is included.

Author

**N88-16648\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.  
**A DECADE OF AEROACOUSTIC RESEARCH AT NASA AMES RESEARCH CENTER**  
FREDERIC H. SCHMITZ, M. MOSHER, CAHIT KITAPLIOGLU, J. CROSS, and I. CHANG In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 1066-1090 Feb. 1988 Avail: NTIS HC A25/MF A01 CSCL 20A

The rotorcraft aeroacoustic research accomplishments of the past decade at Ames Research Center are reviewed. These include an extensive sequence of flight, ground, and wind tunnel tests that have utilized the facilities to guide and pioneer theoretical research. Many of these experiments were of benchmark quality. The experiments were used to isolate the inadequacies of linear theory in high-speed impulsive noise research, have led to the development of theoretical approaches, and have guided the emerging discipline of computational fluid dynamics to rotorcraft aeroacoustic problems.

Author

**N88-16649\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**AEROACOUSTIC RESEARCH PROGRAMS AT THE ARMY AVIATION RESEARCH AND TECHNOLOGY ACTIVITY**

YUNG H. YU, FREDRIC H. SCHMITZ, and H. ANDREW MORSE (Army Aviation Systems Command, Moffett Field, Calif.) In NASA, Washington, NASA/Army Rotorcraft Technology. Volume 2: Materials and Structures, Propulsion and Drive Systems, Flight Dynamics and Control, and Acoustics p 1091-1113 Feb. 1988 Avail: NTIS HC A25/MF A01 CSCL 20A

The Army rotorcraft aeroacoustic programs are reviewed, highlighting the theoretical and experimental progress made by Army researchers in the physical understanding of helicopter impulsive noise. The two impulsive noise sources addressed over this past decade are high-speed impulsive noise and blade-vortex interaction noise, both of which have had and will continue to have an increasing influence on Army rotorcraft design and operations. The advancements discussed are in the areas of in-flight data acquisition techniques, small-scale-model tests in wind tunnels, holographic interferometry/tomographic techniques, and the expanding capabilities of computational fluid dynamics in rotorcraft acoustic problems. Current theoretical prediction methods are compared with experimental data, and parameters that govern model scaling are established. The very successful cooperative efforts between the Army, NASA, and industry are also addressed Author

**N88-17440\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**MEASURED AND CALCULATED ACOUSTIC ATTENUATION RATES OF TUNED RESONATOR ARRAYS FOR TWO SURFACE IMPEDANCE DISTRIBUTION MODELS WITH FLOW**

TONY L. PARROTT, A. LOUIS ABRAHAMSON, and MICHAEL G. JONES (PRC Kentron, Inc., Hampton, Va.) Jan. 1988 51 p (NASA-TP-2766; L-16352; NAS 1.60:2766) Avail: NTIS HC A04/MF A01 CSCL 20A

An experiment was performed to validate two analytical models for predicting low frequency attenuation of duct liner configurations built from an array of seven resonators that could be individually tuned via adjustable cavity depths. These analytical models had previously been developed for high frequency aero-engine inlet duct liner design. In the low frequency application, the liner surface impedance distribution is unavoidably spatially varying by virtue of available fabrication techniques. The characteristic length of this spatial variation may be a significant fraction of the acoustic wavelength. Comparison of measured and predicted attenuation rates and transmission losses for both modal decomposition and finite element propagation models were in good to excellent agreement for a test frequency range that included the first and second cavity resonance frequencies. This was true for either of two surface impedance distribution modeling procedures used to simplify the impedance boundary conditions. In the presence of mean flow, measurements revealed a fine scale structure of acoustic hot spots in the attenuation and phase profiles. These details were accurately predicted by the finite element model. Since no impedance changes due to mean flow were assumed, it is concluded that this fine scale structure was due to convective effects of the mean flow interacting with the surface impedance nonuniformities. Author

**N88-17441\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ANNOYANCE CAUSED BY ADVANCED TURBOPROP AIRCRAFT FLYOVER NOISE: SINGLE-ROTATING PROPELLER CONFIGURATION**

DAVID A. MCCURDY Mar. 1988 43 p (NASA-TP-2782; L-16301; NAS 1.60:2782) Avail: NTIS HC A03/MF A01 CSCL 20A

Two experiments were conducted to quantify the annoyance of people to advanced turboprop (propfan) aircraft flyover noise. The objectives were to: (1) determine the effects on annoyance of various tonal characteristics; and (2) compare annoyance to advanced turboprops with annoyance to conventional turboprops

and jets. A computer was used to produce realistic, time-varying simulations of advanced turboprop aircraft takeoff noise. In the first experiment, subjects judged the annoyance of 45 advanced turboprop noises in which the tonal content was systematically varied to represent the factorial combinations of five fundamental frequencies, three frequency envelope shapes, and three tone-to-broadband noise ratios. Each noise was presented at three sound levels. In the second experiment, 18 advanced turboprop takeoffs, 5 conventional turboprop takeoffs, and 5 conventional jet takeoffs were presented at three sound pressure levels to subjects. Analysis indicated that frequency envelope shape did not significantly affect annoyance. The interaction of fundamental frequency with tone-to-broadband noise ratio did have a large and complex effect on annoyance. The advanced turboprop stimuli were slightly less annoying than the conventional stimuli. Author

**N88-17445#** Aeronautical Research Labs., Melbourne (Australia).

**LABORATORY STUDIES RELATED TO IN-FLIGHT ACOUSTIC EMISSION MONITORING**

S. R. LAMB Apr. 1987 23 p (AD-A186714; ARL-MAT-TM-393; DODA-AR-004-531) Avail: NTIS HC A03/MF A01 CSCL 20A

Programmed load testing of a structural member from a MACCHI aircraft was undertaken in an attempt to determine the source of the acoustic emission previously recorded during in-flight monitoring of the same component and to compare results obtained from different equipment. Although crack growth during laboratory testing appeared similar to in-flight crack growth, the pattern of recorded AE was markedly different. The laboratory tests are described and an explanation of the test results sought. GRA

**N88-17453#** National Aerospace Lab., Tokyo (Japan).

**AERODYNAMIC AND ACOUSTIC CHARACTERISTICS OF AN ADVANCED PROPELLER UNDER TAKE-OFF AND LANDING CONDITIONS**

HIDEO NISHIWAKI and KATSUMI TAKEDA 1987 13 p In JAPANESE; ENGLISH summary (NAL-TR-935; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Three configurations of six-bladed, 400 mm diameter, scale-model advanced propellers such as backward-, forward-, and back-forward alternately installed swept blades were tested in anechoic environments with an incoming main flow velocity up to 68 m/s. Under no incoming-flow conditions, the blade separated flow was also discussed from an academic point of view. The data for the advance ratio of 0.43 to 1.15 were obtained in the aeroacoustic aspects. The alternatively swept blades arrangement showed the best performance in spanwise load distribution among the three configurations. The forward swept blades did not exhibit any aeroacoustic advantage. The alternately swept configuration as a tandem rotation has the potential for decreasing the sound levels at the blade passage frequencies by the dispersion of sound with no sacrifice of aerodynamic performance and no additional mechanical complexity. Author

**N88-18373#** Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.

**SUPERSONIC AND SUBSONIC AIRCRAFT NOISE EFFECTS ON ANIMALS: A LITERATURE SURVEY Final Report, 15 Oct. 1985 - 15 Oct. 1986**

ROBERT C. KULL, JR. and ALAN D. FISHER 1 Dec. 1986 57 p. (AD-A186922; AAMRL-TR-87-032) Avail: NTIS HC A04/MF A01 CSCL 20A

We searched the literature concerning the effects of supersonic and subsonic aircraft noise on animals. Our search revealed many review papers of prior research accomplished, but few actual research papers. Out of all the reviews, Dufour's work is the most comprehensive. Many of the papers are anecdotal in nature and add little to our scientific knowledge - strictly circumstantial evidence. The literature reveals few effects on animals due to sonic booms. The effects of subsonic noise, however, needs much more investigation. One of the biggest problems with the research

## 16 PHYSICS

in this area is the lack of controls, lack of standardized ways of recording data and evaluating behaviors, and the number of variables involved. Specific recommendations to fill some of the technological gaps include a sonic boom study on a ground-nesting shorebird, effects of subsonic aircraft noise on endangered species, long term physiological effects causing immunosuppression, and noise versus visual aircraft stimuli effects. GRA

**N88-18376\*#** Purdue Univ., West Lafayette, Ind. School of Mechanical Engineering.

### **SOUND TRANSMISSION THROUGH THE WALLS OF LIGHT AIRCRAFT: AN INVESTIGATION OF STRUCTURE-BORNE NOISE IN A HANDLEY PAGE 137 JETSTREAM 3 AIRCRAFT**

R. J. BERNHARD and C. WOHLEVER Jan. 1988 164 p

(Contract NAG1-58)

(NASA-CR-182509; NAS 1.26:182509; REPT-0353-10; HL-88-5; PRF-520-1288-0353) Avail: NTIS HC A08/MF A01 CSCL 20A

This study indicates that the structureborne noise due to wing/vortex interaction for the Handley Page-137 Jetstream may be significant at frequencies above 500 Hz. It was found that by preventing such interaction, noise reductions between 1 to 3 dB were attainable. However, this study did not show any significant contribution due to this phenomena at the first blade passage tone. It is suspected that the wing/vortex interaction effect varies from plane to plane. Author

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## SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

**A88-25749#**

### **BECOME A CREATIVE FORCE FOR FUTURE AIRCRAFT**

JACK D. MATTINGLY AIAA Student Journal (ISSN 0001-1460), vol. 25, Fall 1987, p. 7-15.

AIAA, starting in 1988, will sponsor the Air-Breathing Propulsion Team Design Competition: for which, starting with a request-for-proposal for an aircraft system, a student team will determine the required aircraft configuration and such aspects of its propulsion system as the engine's size and cycle and its major components' design. This design competition is modeled after the three existing AIAA-sponsored undergraduate design competitions, with cash awards being given to first (\$1000), second (\$500), and third (\$250) place teams. Specific design tasks to be undertaken by students are a constraint analysis, a mission analysis, a cycle analysis, an engine cycle selection, engine sizing and performance projection, component design, and engine integration. O.C.

**A88-26183**

### **FREEDOM IN EUROPEAN AIR TRANSPORT - THE BEST OF BOTH WORLDS?**

EMILY E. TEGELBERG-ABERSON (Rijksluchtvaartdienst, The Hague, Netherlands) Air Law (ISSN 0165-2079), vol. 12, Dec. 1987, p. 282-295. refs

Consideration is given to the following features of the existing air transport system within Europe: (1) State sovereignty, as dictated by the Chicago Convention; (2) bilateralism, standardized according to the Bermuda agreements; and (3) interairline cooperation. The question of how to achieve a fully liberalized Europe without allowing the benefits of the existing system to slip away is examined. It is believed that, so long as the principle of State sovereignty is adhered to, there is no way of achieving a multilateral liberalization within the EEC. K.K.

**A88-26546**

### **SOMETHING SPECIAL IN THE AIR AND ON THE GROUND - THE POTENTIAL FOR UNLIMITED LIABILITY OF INTERNATIONAL AIR CARRIERS FOR TERRORIST ATTACKS UNDER THE WARSAW CONVENTION AND ITS REVISIONS**

H. L. SILETS Journal of Air Law and Commerce (ISSN 0021-8642), vol. 53, Winter 1987, p. 321-374. refs

**A88-26547**

### **THE ENVIRONMENTAL CONSEQUENCES OF MUNICIPAL AIRPORTS - A SUBJECT OF FEDERAL MANDATE?**

LEE L. BLACKMAN and ROGER P. FREEMAN. Journal of Air Law and Commerce (ISSN 0021-8642), vol. 53, Winter 1987, p. 375-400. refs

The allocation of authority over noise-based restrictions on access to the nation's airports is described in detail. The FAA's Chief Counsel believes that the FAA's refusal to adopt the proposal for complete preemption will permit a continuation of local restrictions which effectively raise the costs of interstate transportation. It is suggested in the present paper that these costs will inevitably be passed on to the traveling public, resulting in a system in which the cost of an airline ticket will more closely approach the true cost of air transportation by encompassing the economic and human burdens of noise together with the value of facilities, equipment, salaries, and fuel. K.K.

**N88-16699\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **LEWIS MATERIALS RESEARCH AND TECHNOLOGY: AN OVERVIEW**

SALVATORE J. GRISAFFE *In its* Aeropropulsion '87. Session 1: Aeropropulsion Materials Research 8 p Nov. 1987

Avail: NTIS HC A06/MF A01 CSCL 05A

The Materials Division at the Lewis Research Center has a long record of contributions to both materials and process technology as well as to the understanding of key high-temperature phenomena. An overview of the division staff, facilities, past history, recent progress, and future interests is presented. Author

**N88-17207\*#** Air Force Human Resources Lab., Wright-Patterson AFB, Ohio.

### **IMIS: INTEGRATED MAINTENANCE INFORMATION SYSTEM. A MAINTENANCE INFORMATION DELIVERY CONCEPT**

JOSEPH C. VONHOLLE *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 1-9 Oct. 1987

Avail: NTIS HC A23/MF A01 CSCL 05B

The Integrated Maintenance Information System (IMIS) will optimize the use of available manpower, enhance technical performance, improve training, and reduce the support equipment and documentation needed for deployment. It will serve as the technician's single, integrated source of all the technical information required to perform modern aircraft maintenance. Author

**N88-17634\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

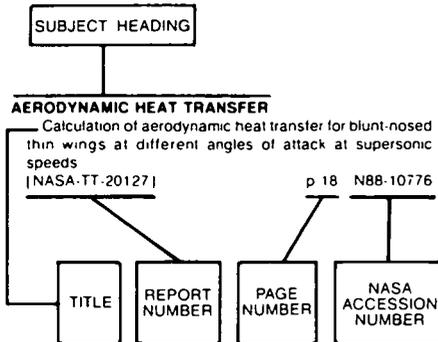
### **INFORMATION TRANSFER IN THE NATIONAL AIRSPACE SYSTEM**

ALFRED T. LEE *In* NASA. Langley Research Center, Airborne Wind Shear Detection and Warning Systems: First Combined Manufacturers and Technologists Conference p 507-515 Jan. 1988

Avail: NTIS HC A24/MF A01 CSCL 05B

An informal overview is given of the work in progress and the planned work in the area of information transfer that specifically addresses human factors issues in National Airspace System (NAS). The issues of how weather information will be displayed on the flight deck, the development of appropriate decision making technology, and digital datalink transmission are also briefly discussed. R.J.F.

### 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.

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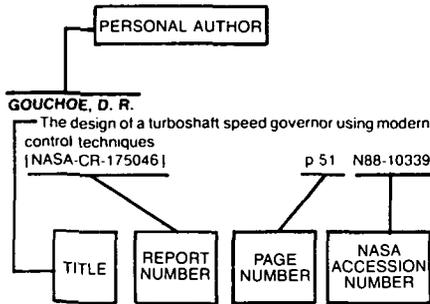
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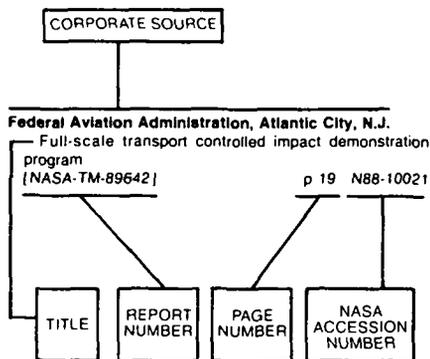
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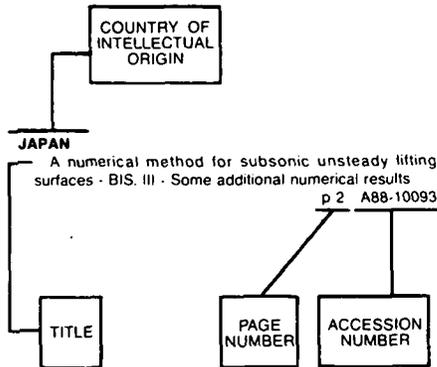
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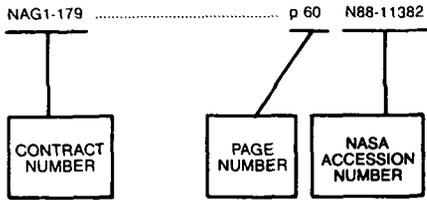
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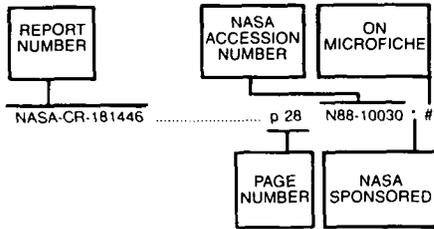


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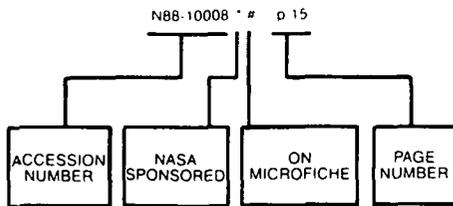
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