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A Continuing Bibliography with Indexes

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AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 245)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in October 1989 in

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

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INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 537 reports, journal articles and other documents originally announced in October 1989 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

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

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

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

An annual cumulative index will be published.

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

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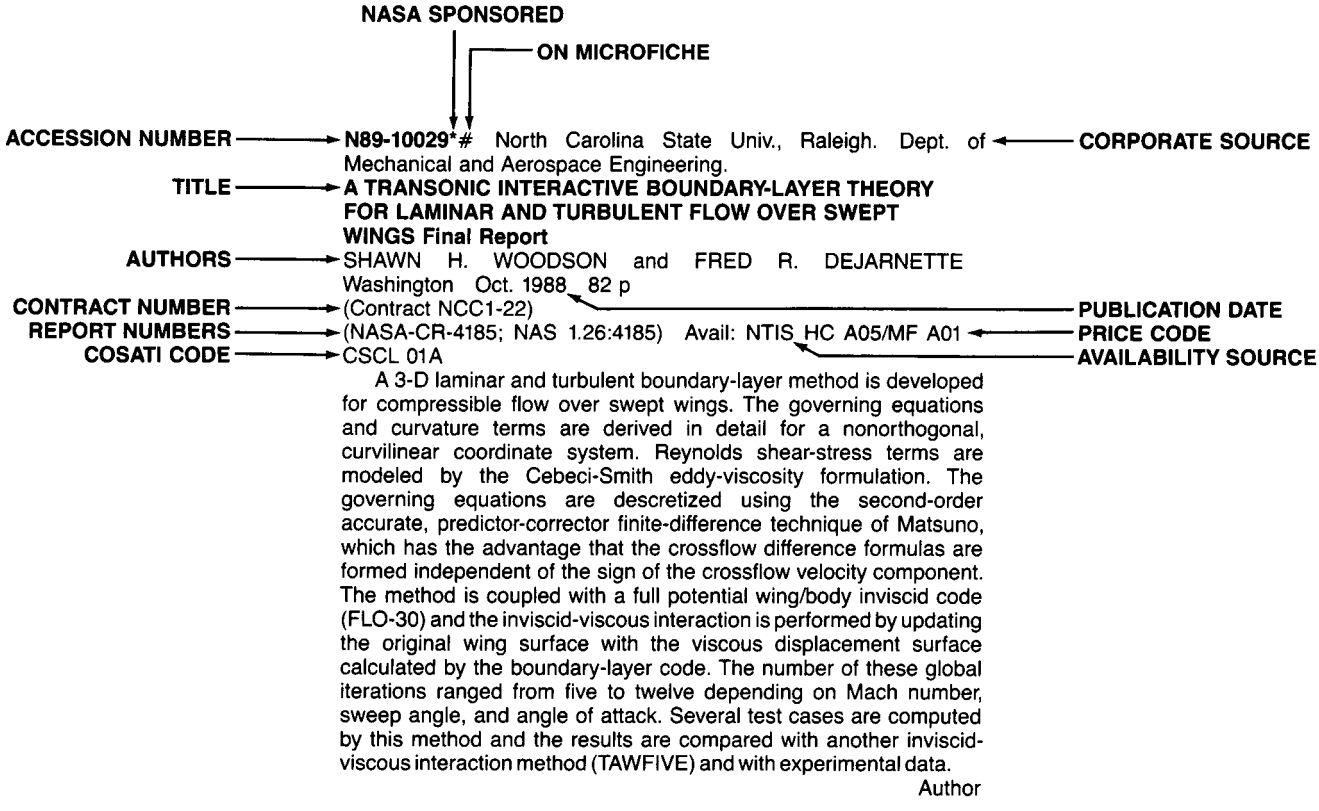
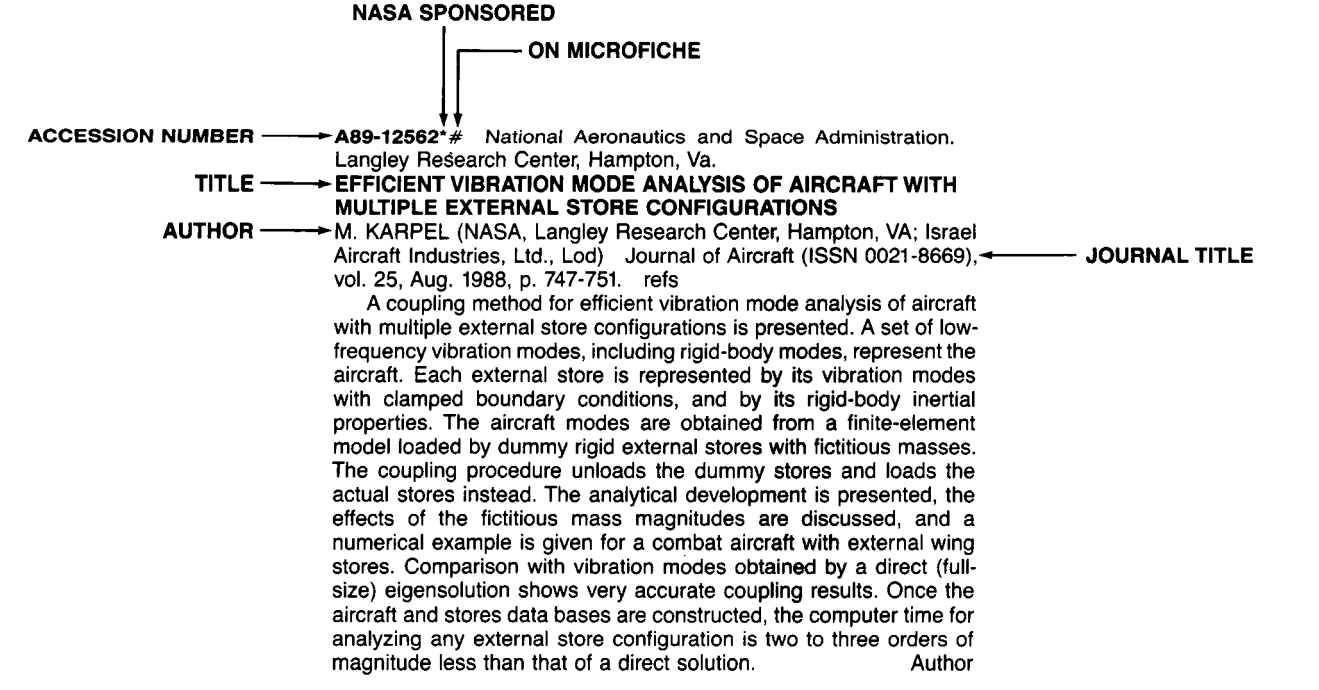
TYPICAL REPORT CITATION AND ABSTRACT



TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 245)

NOVEMBER 1989

01

AERONAUTICS (GENERAL)

A89-44641#
JET OR PROP REQUIRED FOR FUTURE REGIONAL TRANSPORTS?
JOSEPH SIMMERL Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 24, 25.

This article discusses the question whether a jet propulsion or prop propulsion system is more advantageous for a new generation of commuter aircraft. The issues addressed include comfort, safety, pollution, flexibility in the ATC environment, range, speed, and direct operating cost. The outlook for the commuter airline industry on this issue is considered. C.D.

A89-44642#
TECHNOLOGY OF STRUCTURES MAINTAINS HIGH STANDARDS
HERBERT KELLER, KARL FRIEDRICH SAHM, and HANS-WOLFGANG SCHROEDER Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 44-48.

Materials for new aircraft structure technologies are discussed. Aluminum-lithium alloys and superplastic forming and diffusion bonding technologies are described and their aircraft structure applications are examined. Advanced materials for corrosion and surface protection and metals for use at high temperatures are considered. The use of fiber-compound structures is discussed, and the use of nonmetals for extreme temperatures is addressed. Multifunctional structures are discussed. C.D.

A89-44643#
DORNIER'S ROLE IN THE 'EUROPEAN FIGHTER AIRCRAFT' EFA PROGRAM
Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 49-52.

This paper describes the required performances and system capabilities of the European Fighter Aircraft (EFA) which is to fulfill the harmonized requirements of the air forces of the German Federal Republic, Great Britain, Italy, and Spain, as expressed in the joint document 'the European Staff Requirements'. The industrial arrangements that have been made to develop the EFA are summarized, and Dornier's participation in that development is addressed. In particular, management and technical development aspects are considered. C.D.

A89-44644#
THE PHASED ESTABLISHMENT OF SUPPORT MATURITY FOR THE EUROPEAN FIGHTER AIRCRAFT (EFA)
JUERGEN KRAWCZAK Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 53-57.

A conceptual approach for a phased establishment of support maturity (ESM) for the European Fighter Aircraft is outlined. Packages of phased support options, on-call ordering of single interim support measures, and phased support management are discussed. Risk assessment and prognosis for full support maturity or phased support is shown along with an example of phased support planning and implementation. Experiences gained with ESM during the introduction of complex aircraft weapons systems are also reviewed. C.D.

A89-45032
AEROSPATIALE'S SHORT-TERM AND INTERMEDIATE-TERM PLACE IN THE INTERNATIONAL SCENE [PLACE D'AEROSPATIALE DANS LE CONTEXTE INTERNATIONAL A COURT ET MOYEN TERMES]
HENRI MARTRE (Aerospatiale, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 5-8. In French.

Aerospatiale's present and future place in the European and world-wide aeronautics industry is discussed. Cooperative French/European ventures include Concorde, Ariane, Airbus, ATR, the French/British helicopters Gazelle, Lynx, and Puma, and the French/German Hot, Milan, and Roland missiles. Special attention is given to the impact on the aeronautics industry of the conflicting European tendencies toward nationalization and international cooperation. The changing roles of the European countries in the production of military aircraft and missiles is discussed in detail. R.R.

A89-45033
DASSAULT, LEADER IN EUROPEAN MILITARY AND BUSINESS AIRCRAFT [DASSAULT, LEADER DES AVIONS D'ARMES ET DES AVIONS D'AFFAIRS EN EUROPE]
SERGE DASSAULT (Avions Marcel Dassault Breguet Aviation, S.A., Vaucresson, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 9-11. In French.

France's place in the international aeronautics industry in the past, present, and future is discussed. French contributions to the industry include the achievement of vertical take-off and prolonged Mach 2 flight, along with the development of variable-geometry vehicles, the ramjet engine, and the STS. Also considered are the Mirage 2000, Falcon 20, Falcon 50, Falcon 900, Rafale, and ATF aircraft. R.R.

A89-45034
THE SNECMA GROUP TODAY AND TOMORROW [LE GROUPE SNECMA AUJOURD'HUI ET DEMAIN]
BERNARD CAPILLON (SNECMA, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 12-14. In French.

Marketing aspects and characteristics of three French aerospace technologies are discussed: (1) the M88 engine, developed for Rafale; (2) the CFM56, developed for civil aircraft; and (3) Ariane 5. The Ariane 5 vehicle, to be used for Hermes, delivers 600 tons of thrust with its two solid-propellant boosters and 10 tens of thrust with its central cryogenic engine. French/American cooperation on such ventures as the CF6 engine and the development of a propfan is considered. R.R.

A89-45035
FROM AVIONICS TECHNOLOGY TO ARCHITECTURAL CONCEPTS [DE LA TECHNOLOGIE AUX CONCEPTS ARCHITECTURAUX DE L'AVIONIQUE]
ANDRE DERRE L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 15-18. In French.

The impact of recent digital electronic technological innovations

on aircraft systems is discussed, with emphasis on the development of integrated avionics systems for navigation, weapons control, and engine control. It is noted that the use of high-reliability high-flexibility VHSICs will overcome many of the problems encountered in present integrated systems. Also considered are the contributions of optoelectronics technologies (notably IR imaging) and composite and ceramic materials (including carbon-carbon composites) to avionics architectures. R.R.

A89-45037
AERONAUTICAL RESEARCH IN THE EUROPEAN FUTURE [LA RECHERCHE AERONAUTIQUE A L'HEURE EUROPEENNE]
PH. POISSON-QUINTON L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 28-41. In French.

The joint study of European Cooperative Measures for Aeronautical Research and Technology is discussed, covering such topics as the present European role in international aerospace research, the market potential for the next 25 years, and the advancement of European competitivity through the development of key (primarily civil) aircraft technologies. Emphasis is placed on the nèed for standardization in such areas of development as new materials, fabrication technologies, aerodynamics, acoustics, avionics systems, and integrated propulsion systems. R.R.

A89-45143
AIRCRAFT DEVELOPMENT TEST AND EVALUATION - AN OFFICE OF THE SECRETARY OF DEFENSE PERSPECTIVE
CHARLES E. ADOLPH (DOD, Washington, DC) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. VI-1.1 to VI-1.4.

The development of aircraft test and evaluation programs over the last two decades is reviewed. Aircraft flight test emphasis has recently shifted from airworthiness and aerodynamics testing to avionics subsystem test and integration. Technical problems involved with the integration of aircraft systems and test programs are considered. The impact of advances in weapon systems technology on the aircraft test process is examined. The importance of simulators and other hardware-in-the-loop ground test facilities for the evaluation of software-intensive systems is emphasized. R.R.

A89-46078
THE EEC SUPPORTS AIR TRANSPORT RESEARCH [EG FOERDERT LUFTFAHRTFORSCHUNG]
STEPHAN VON WELCK Luft- und Raumfahrt (ISSN 0173-6264), vol. 10, 2nd Quarter, 1989, p. 28-30. In German.

The report of the Ministry for European Community on the air transport industry is discussed. The preparations surrounding the study which led to the report are reviewed, and the proposals made by the report are critically examined. The essential elements of the research program proposed by the report are summarized, and the requirements which need to be met to carry out the program are discussed. C.D.

A89-46496
HORNET MAINTENANCE
HERBERT A. CHASE (McDonnell Aircraft Co., Saint Louis, MO) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 405-408. refs

A step toward life-cycle-cost reduction was the introduction of a Flight Incident Recording and Aircraft Monitoring Set (FIRAMS) in the F/A-18 Hornet. FIRAMS provides onboard nonvolatile storage of operational flight information and maintenance parameters. It also integrates fuel and engine displays and performs the fuel gaging and transfer functions. FIRAMS also promotes the concept of using onboard computers for air vehicle system management. This concept was implemented into a large portion of the F/A-18C/D fuel system. The FIRAMS subsystem uses a complex correlation of data for fuel control. Future applications of the experience gained in the FIRAMS program include onboard fault detection and fault isolation. I.E.

A89-47326
AEROSPACE BEHAVIORAL TECHNOLOGY CONFERENCE AND EXPOSITION, 7TH, ANAHEIM, CA, OCT. 3-6, 1988, PROCEEDINGS
Conference and Exposition sponsored by SAE. Warrendale, PA, Society of Automotive Engineers, Inc. (SAE P-216), 1989, 183 p. For individual items see A89-47327 to A89-47342.
(SAE P-216)

Topics discussed in these proceedings include those on the cockpit, space, workload, crew awareness, air transport system automation, fitness for duty, concerns of the international pilots, training technologies, and graphic tools for cockpit design. Papers are presented on display requirements for a threat response system; flight crew displays for Space Station proximity operations; EVA design integration for Space Station assembly; an assessment of crew workload procedures in full fidelity; the definition, measurement, and enhancement of the situational awareness in the commercial flight deck; and current and future trends in automation in transport aircraft. Attention is also given to the design of crew rest quarters, airline operations and the contaminated runway, the role of flight planning in aircrew decision performance, requirements for rapid prototyping of crew station displays, and human factors engineering workstation for model-based cockpit design. I.S.

N89-25113# Federal Aviation Administration, Washington, DC. Office of Management Systems.
FAA STATISTICAL HANDBOOK OF AVIATION: CALENDAR YEAR 1987
1987 212 p
(AD-A200917) Avail: NTIS HC A10/MF A01 CSCL 01/3

Statistical information is presented pertaining to the Federal Aviation Administration, the National Airspace System, Airports, Airport Activity, U.S. Civil Air Carrier Fleet, U.S. Civil Air Carrier Operating Data, Airmen, General Aviation Aircraft, Aircraft Accidents, Aeronautical Production and Imports/Exports. A Glossary of the terms used in this publication is contained. GRA

N89-25948# Federal Aviation Administration, Washington, DC. Office of Aviation Policy and Plans.
FAA (FEDERAL AVIATION ADMINISTRATION) AVIATION FORECASTS: FISCAL YEARS 1989-2000
Mar. 1989 252 p
(AD-A206716; FAA-APO-89-1) Avail: NTIS HC A12/MF A01 CSCL 01/2

This report contains forecasts of aviation activity at FAA facilities. These include airports with FAA control towers, air route traffic control centers, and flight service stations. Detailed forecasts were made for the four major users of the NAtional Aviation System: air carriers, air taxi/commuters, general aviation and the military. The forecasts were prepared to meet the budget and planning needs of the constituent units of the FAA and to provide information that can be used by state and local authorities, by the aviation industry, and by the general public. The overall outlook for the forecast period is for continued economic growth, rising real fuel prices, and moderate inflation. Based upon these assumptions, aviation activity by fiscal year 2000 is forecast to increase by 31.0 percent at towered airports (commuters, 51.8 percent; air carriers, 34.6 percent; general aviation, 27.5 percent; military, 0.0 percent), 32.0 percent at air route traffic control centers (commuters, 55.2 percent; air carriers, 33.7 percent; general aviation, 30.0 percent military, 0.0 percent, and 7.8 percent in flight services performed. Hours flown by general aviation are forecast to increase 14.9 percent and helicopter hours flown, 82.6 percent. Scheduled domestic revenue passenger miles (RPM's) are forecast to increase 73.6 percent, with scheduled international RPM's forecast to increase by 104.9 percent; and regionals/ commuters RPM's forecast to increase by 158.7 percent. GRA

N89-25949# Logistics Management Inst., Bethesda, MD.
AIRCRAFT SUSTAINABILITY MODEL VERSION 1.5: USERS MANUAL

FRANK L. EICHORN Mar. 1989 45 p
(Contract MDA903-85-C-0139)
(AD-A207015; LMI-AF801R2) Avail: NTIS HC A03/MF A01
CSCL 15/5

The Aircraft Sustainability Model (ASM) is an item-specific inventory model that relates investments for spares to aircraft sortie generation capability during a conflict. An important advantage of the ASM is its ability to produce an entire curve relating a wide range of investment levels to the resulting sortie generation capability, allowing Air Force planners to trade off spares investment and capability. Moreover, the algorithm that builds the curve explicitly trades off investment in line replaceable units installed directly on aircraft versus their constituent shop replaceable unit subassemblies. These features, together with the computational efficiency of the code, have led to rapid acceptance of the ASM within the Air Force Logistics Command (AFLC). AFLC is now incorporating the ASM into the Requirements Execution Availability Logistics Module (REALM) of the Weapon System Management Information System (WSMIS). The ASM is being used in WSMIS/REALM to compute item requirements and to execute the Air Force budget for the reparable spares portion of War Reserve Materiel (WRM). This users manual explains the use of the PC-version of the ASM, Version 1.5. GRA

02

AERODYNAMICS

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

A89-43722
THE MIXING OF THREE-DIMENSIONAL TURBULENT WAKES IN BOUNDARY LAYERS
A. MOGHADAM and L. C. SQUIRE (Cambridge, University, England) Aeronautical Journal (ISSN 0001-9240), vol. 93, May 1989, p. 153-161. refs

The three-dimensional aspects of the wake/boundary layer interaction (particularly, slat-wake/wing boundary layer interaction) are investigated with reference to measurements of mean velocity and Reynolds stress tensor components obtained by using a specially developed digital system with a triple-wire hot probe. An important finding of the study is the rapid decay of the crossflow downstream of the trailing edge. For nominally two-dimensional and quasi-three-dimensional flows, comparisons are made between experimental results and theoretical predictions using the two-dimensional form of the K-epsilon model and algebraic stress models of turbulence. Tests on an isolated wake are also reported. V.L.

A89-43724
LOPAN - A LOW-ORDER PANEL METHOD FOR SUBSONIC AND SUPERSONIC FLOWS
T. D. RUBIN (Israel Aircraft Industries, Ltd., Lod) Aeronautical Journal (ISSN 0001-9240), vol. 93, May 1989, p. 177-182. refs

LOPAN, a low-order panel method for calculating subsonic or supersonic linear flow about general configurations, is presented. In common with other internal Dirichlet methods, LOPAN allows for a condition on the outward conormal component of the flow velocity. LOPAN makes it possible to implement, during the same computer run, either the conormal or the normal condition without the need for an expanded matrix. This is achieved using a simple iterative procedure which should be easily applicable to any code using the internal Dirichlet formulation. V.L.

A89-44112#
MULTI-STAGE COMPRESSOR AIRFOIL AERODYNAMICS. I - AIRFOIL POTENTIAL FLOW ANALYSIS
H. D. JOSLYN and R. P. DRING (United Technologies Research Center, East Hartford, CT) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 457-468. Research supported by United Technologies Corp. Previously cited in issue 20, p. 2917, Accession no. A86-42822. refs
(Contract N00014-84-C-0354)

A89-44114#
TRANSONIC CASCADE FLOW SOLVED BY THE COMBINED SHOCK-CAPTURING AND SHOCK-FITTING METHOD
JIANZHONG XU and WENYAN NI (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 476-481. Previously cited in issue 18, p. 2804, Accession no. A87-42333. refs

A89-44116#
HYPERSONIC VEHICLE PROPULSION - A COMPUTATIONAL FLUID DYNAMICS APPLICATION CASE STUDY
THOMAS J. BARBER (United Technologies Research Center, East Hartford, CT) and G. B. COX, JR. (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 492-501. Research supported by United Technologies Corp. and USAF. Previously cited in issue 07, p. 936, Accession no. A88-22350. refs

A89-44319#
SOLUTION OF EULER EQUATIONS BY A FINITE ELEMENT METHOD APPLICATION TO SUPERSONIC FLOWS
DANIEL KALFON and DOMINIQUE VOLPERT (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 6, 1988, p. 1-11. Research supported by CEA. refs

An attempt was made to obtain a finite element code capable of computing complex flows around axisymmetrical bodies. The results reveal that Galerkin's continuous method with adaptive meshes is very promising. The stiff shocks are captured without oscillation and the computation times per iteration are acceptable. K.K.

A89-44322#
GENERALIZATION OF THE ROE SCHEME FOR COMPUTING FLOWS OF MIXED GASES WITH VARIABLE CONCENTRATIONS
REMI ABGRALL (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 6, 1988, p. 31-43. refs

A generalization of the Roe scheme is presented for computing flows by solution of the Euler equations, in the case of a mixture of inviscid gases having spatially variable concentrations. The mixture is taken to be an ideal gas, but with variable specific heats. The problem of automatically capturing the contact surfaces between two nonreactive ideal gases with different specific heat ratios is considered. The method is tested on the Riemann problem and an application to a jet problem is presented. Author

A89-44390
INVISCID TRANSONIC FLOW OVER A WAVY WALL DECAYING DOWNSTREAM
JEONG-JOO PARK and KEUN-SHIK CHANG (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) Communications in Applied Numerical Methods (ISSN 0748-8025), vol. 5, May 1989, p. 219-228. refs

Inviscid transonic flow over a wavy wall with either subsonic or supersonic freestream speeds is studied by solving the Euler equations numerically. The streamwise flow development through a series of shock waves and entropy production are investigated in depth. In the case of supersonic freestream, isentropy contours of both horseshoe and staircase forms are found. The limitations and validity of this inviscid rotational flow model are discussed by comparing the results with those for viscous turbulent flow calculated previously. Author

A89-44637
PREDICTION OF THE STABILITY LIMIT OF MULTISTAGE AXIAL COMPRESSORS [PREDICTION DE LA LIMITE DE STABILITE DES COMPRESSEURS AXIAUX MULTI-ETAGES]
P. GILLANT (Societe Bertin et Cie., Plaisir, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 47-53. In French.
(Contract DRET-80-098; DRET-82-096; DRET-84-307)

The calculation method presented intends to predict the stability limit of a multistage axial compresor, starting from the knowledge of its complete geometry and from the aerodynamical characteristics of the blading of each stage. The stability of the flow is studied on each stream surface by applying the Liapunov theory to the partial differential equations system established from the continuity, momentum, and energy unsteady equations and linearized around the steady state running point under consideration. Satisfactory results are obtained and the short calculation delay involved in the numerical model allows thorough parametrical studies to be performed during the early phase of development of new jet engines. Author

A89-44638
PREDICTION OF TURBOMACHINERY PERFORMANCE - APPLICATION TO A CENTRIFUGAL PUMP, A CENTRIFUGAL COMPRESSOR, AND A RADIAL INFLOW TURBINE [PREVISION DES CARACTERISTIQUES DES TURBOMACHINES - APPLICATION A UNE POMPE CENTRIFUGE, UN COMPRESSEUR CENTRIFUGE ET UNE TURBINE CENTRIPETE]
M. FRIBERG, M. MAHIEDDINE, M. TOUSSAINT, and M. FRELIN (Conservatoire National des Arts et Metiers, Paris, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 55-66. In French.

A simple method for pump and compressor performance evaluation is presented. This method only requires a knowledge of the geometry of the machine. The pressure/mass flow characteristic and the efficiency are computed. The torque is derived by using Euler's equation. Losses taken into account are due to friction, flow separation, off design angles of attack, and leakage between rotor and stator. In the case of a radial turbine, operated at high temperature, evaluation of the performance can be deduced from measurements obtained during cold flow operation. Author

A89-44639
THEORETICAL AND EXPERIMENTAL STUDY OF TURBINE AERODYNAMICS [ETUDE THEORIQUE ET EXPERIMENTALE DE L'AERODYNAMIQUE DES TURBINES]
P. BRY (SNECMA, Moissy-Cramayel, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 67-80. In French. refs

Theoretical and experimental techniques employed in the design of jet engine turbines are reviewed. Optimization of the shape of the inner and outer casings is performed analytically. Turbomachinery design is based upon flow calculations which take into account the radial variations of losses and angular momentum. Blade profiles are developed using an iterative procedure based upon inverse and direct two-dimensional and three-dimensional calculation codes for subsonic, transonic, or supersonic flows. These design methods also include boundary layer calculations. Experimental techniques are used to validate the predicted turbine performance characteristics and to calibrate the various theoretical methods. R.R.

A89-44640
DESIGN OF VANE TIPS IMPROVING AXIAL COMPRESSOR PERFORMANCE [DESSIN D'EXTREMITES D'AUBES AMELIORANT LES PERFORMANCES DES COMPRESSEURS AXIAUX]
MARIUS GOUTINES (SNECMA, Moissy-Cramayel, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 109, 110. In French.

Since several years SNECMA has developed a numerical model which provides secondary flow predictions along flow-path walls of axial compressors. This model has been validated with detailed measurements of experimental compressors and used to design blade rows with ends adapted to the actual flow. The high pressure compressor for the THR/GE 36 engine includes such a design for stators, and test results have confirmed the advantages of this technique. Author

A89-44898
CALCULATION OF THE TOTAL PRESSURE LOSS COEFFICIENT WITH THREE MODELS FOR FOUR SUPERSONIC AXIAL-FLOW COMPRESSORS [BERECHNUNG DES TOTALDRUCK-VERLUSTKOEFFIZIENTEN MIT DREI MODELLEN FUER VIER TRANSSCHALL-AXIALVERDICHTER]
HORST STOFF and RENE WAELCHLI (Asea Brown Boveri AG, Baden, Switzerland) Forschung im Ingenieurwesen (ISSN 0015-7899), vol. 55, May 1989, p. 77-79. In German. refs

Three semiempirical numerical models are evaluated in computations of the total pressure loss in four commercial axial-flow compressors. The theoretical bases of the models are briefly reviewed, and the results are compared with measurement data in graphs. Best agreement is obtained with the simplest of the models applied, the subsonic model of Messenger and Kennedy (1972); it is pointed out, however, that the more elaborate model of Strinning and Dunker (1977) permits selective variation of the design parameters to achieve an optimum configuration. T.K.

A89-44972#
EXPERIMENTAL STUDY ON AERODYNAMIC CHARACTERISTICS OF HYPERSONIC TRANSPORT CONFIGURATION
NORIKAZU SUDANI, SHIGEAKI NOMURA, KOICHI HOZUMI, AKIRA MURAKAMI, and YASUHIKO AIHARA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 423, 1989, p. 178-185. In Japanese, with abstract in English. refs

An experimental study has been carried out on aerodynamics of a cruising type hypersonic transport (HST) configuration, assuming to cruise at a height of 30 km at Mach number 7. The hypersonic flow over the double-delta wing, which is a basic wing shape of HST, has been investigated. The results of the flow visualization and the quantitative measurements (static pressure and heat transfer) show that the vortices of the leeward side of the double-delta wing influence aerodynamic forces, and that they are associated with the intense local heating along the center line. From the wind tunnel test of the HST model at Mach number 7, it is confirmed that the geometry of the model almost satisfies the requirements of aerodynamic characteristics under hypersonic cruising. In parallel with the experiments, a basic study on aerothermodynamic control of the performance has been performed. The results show that the static pressure rises with heat addition to the stream beneath the afterbody of the HST, and suggest possibility of improving lift-to-drag ratio. Author

A89-45045
HELICOPTER BLADES [LES PALES D'HELICOPTERE]
RENE MOUILLE (Aerospatiale, Division Helicopteres, Marignane, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 109-115. In French.

The aerodynamics, optimization, and fabrication of helicopter blades are reviewed. It is noted that the efficiency in steady flight, as indicated by figures of merit, for modern helicoptor rotors (such as the AS 365 N and the AS 332) has approached 0.80, and that power requirements have been reduced by close to 20 percent over the past 30 years. The use of composite materials has permitted the optimization of blade aerodynamics, along with the minimization of blade vibration. Flight load estimations are used to calculate the static and dynamic stresses in order to determine the operating life of the blades. R.R.

A89-45187#
A NEW VARIATIONAL METHOD FOR THE GENERATION OF TWO- AND THREE-DIMENSIONAL ADAPTED GRIDS IN COMPUTATIONAL FLUID DYNAMICS
OLIVIER-PIERRE JACQUOTTE and JEAN CABELLO (ONERA, Chatillon-sous-Bagneux, France) (International Conference on Finite Element Method in Flow Problems, 7th, Huntsville, AL, Apr. 3-7, 1989) ONERA, TP no. 1989-31, 1989, 7 p. refs
(ONERA, TP NO. 1989-31)

A variational method for the optimization and adaptation of structured grids is presented. This method is applicable to two- or three-dimensional structured mesh as well as to surface mesh. It relies upon the introduction of a proper measure of a cell deformation that is derived form basic principles of continuum mechanics. Several properties are prescribed, which guarantee the well-posedness of the mesh optimization problem and the efficiency of the solution algorithm. The ability of the method for the mesh adaptation is also described. Examples of two- and three-dimensional grids are shown and illustrate the success of the presented method. Author

A89-45260*# Vigyan Research Associates, Inc., Hampton, VA.
STUDIES OF VORTEX FLOW AERODYNAMICS USING CFD FLOW VISUALIZATIONS
C.-H. HSU, P.-M. HARTWICH (Vigyan Research Associates, Inc., Hampton, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) Asian Congress of Fluid Mechanics, 4th, Hong Kong, Aug. 21-25, 1989, Paper. 5 p. refs

Navier-Stokes computations of three-dimensional vortical flows over a round-edged double-delta wing and a tangent-ogive forebody are performed using an implicit upwind finite-difference scheme. Computed particle traces are compared with experimental oil-flow streaks. Author

A89-45262*# High Technology Corp., Hampton, VA.
WIND-TUNNEL INVESTIGATIONS OF WINGS WITH SERRATED SHARP TRAILING EDGES
P. M. H. W. VIJGEN (High Technology Corp., Hampton, VA), C. P. VAN DAM (California, University, Davis), B. J. HOLMES, and F. G. HOWARD (NASA, Langley Research Center, Hampton, VA) Conference on Low-Reynolds Number Aerodynamics, University of Notre Dame, IN, June 5-7, 1989, Paper. 20 p. refs
(Contract NAG1-345; NAS1-18240)

Exploratory wind-tunnel force measurements are presented for two wing geometries with small-scale planar and nonplanar serrated trailing-edge devices (chord-Reynolds numbers ranged from 1.0 to 3.7 million). The planar serrated trailing-edge extensions reduced the drag at conditions when trailing-edge separation occurred at low angles of attack. The introduction of serrations reduced or eliminated the drag penalty, due to the small (1-2 percent of the chord length) nonplanar trailing-edge flaps, while maintaining the effects of increase in camber. The presence of streamwise vortices immediately downstream of the serrated trailing edges is believed to have favorably affected the boundary-layer flow approaching the trailing edge and the near-wake development, resulting in reduced pressure (form) drag. Author

A89-45355* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CFD FOR HYPERSONIC AIRBREATHING AIRCRAFT
AJAY KUMAR (NASA, Langley Research Center, Hampton, VA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 40-56. refs

A general discussion is given on the use of advanced computational fluid dynamics (CFD) in analyzing the hypersonic flow field around an airbreathing aircraft. Unique features of the hypersonic flow physics are presented and an assessment is given of the current algorithms in terms of their capability to model hypersonic flows. Several examples of advanced CFD applications are then presented. Author

A89-45359
A FLOW-FIELD SOLVER USING OVERLYING AND EMBEDDED MESHES TOGETHER WITH A NOVEL COMPACT EULER ALGORITHM
C. M. ALBONE and GAYNOR JOYCE (Royal Aerospace Establishment, Farnborough, England) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 106-110. refs

Two-dimensional flow problems involving complex multielement airfoils are solved numerically using a novel mesh-generation procedure and the explicit split-coefficient-matrix upwind Euler algorithm of Chakravarthy et al. (1980). The discretization combines a Cartesian main mesh (density controlled by embedding) with curvilinear meshes aligned with configuration or flow features; information is exchanged between the two meshes to establish the boundary conditions. Results for a three-element airfoil at Mach 0.2 and angle of attack 20 deg are presented in graphs and briefly discussed. T.K.

A89-45360
MULTIDIMENSIONAL ADAPTIVE EULER SOLVER
RENZO ARINA (CNR, Centro di Studio sulla Dinamica dei Fluidi, Turin, Italy), BERNARDO FAVINI (Roma I, Universita, Rome, Italy), and LUCA ZANNETTI (Torino, Politecnico, Turin, Italy) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 111-115. refs

The fundamental principles of the Euler solver proposed by Favini and Zannetti (1987) are summarized and illustrated with sample results. The shock-capture method combines Lambda and flux-vector splitting, and the adaptive-grid-generation method is that of Arina (1988). Results for regular shock reflection at a wall and supersonic flow past a circular cylinder are presented graphically and briefly characterized. It is shown that the grid adaptation affects the ability of the upwind scheme to model the flowfield. T.K.

A89-45363
NUMERICAL STUDY OF THE 3D SEPARATING FLOW ABOUT OBSTACLES WITH SHARP CORNERS
NOBUHIRO BABA and HIDEAKI MIYATA (Tokyo, University, Japan) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 126-130. refs

The formation and evolution of vortices in incompressible flows around structures with sharp corners are investigated by means of numerical simulations based on the finite-difference Navier-Stokes solver of Baba and Miyata (1987). The treatment of flow over a double step and over a rectangular cylinder is outlined, and the numerical results are presented graphically and compared with experimental flow visualizations. It is shown that counterrotating streamwise vortices are superimposed on the spanwise-organized vortical structure and affect the transition to turbulence. Also discussed are the significant effects of numerical errors arising from the nonlinear terms; a rotational formulation with kinetic-energy and momentum conservation is found to be most robust in this regard. T.K.

A89-45366* Scientific Research Associates, Inc., Glastonbury, CT.
SOLUTION OF THE INCOMPRESSIBLE NAVIER-STOKES EQUATIONS USING ARTIFICIAL COMPRESSIBILITY METHODS
W. R. BRILEY, R. C. BUGGELN, and H. MCDONALD (Scientific Research Associates, Inc., Glastonbury, CT) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 156-160. Research supported by NASA. refs

A modified artificial compressibility formulation is derived from a preconditioned low Mach number compressible formulation, and these two methods are compared on a two-dimensional laminar

leading edge flow using a LBI/ADI solution algorithm. The two methods are essentially equivalent with appropriate preconditioning parameters and have the same convergence rates and efficiency, giving 4 orders of residual reduction in about 75 iterations with a vectorized CRAY-XMP run time of 20 seconds for 3000 grid points. Author

A89-45368
COMPUTATION OF HYPERSONIC VORTEX FLOWS WITH AN EULER MODEL
CHARLES-HENRI BRUNEAU, JACQUES LAMINIE (Paris XI, Universite, Orsay, France), and JEAN-JACQUES CHATTOT (Aerospatiale, Les Mureaux, France) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 177-181. Research supported by DRET and Ecole Polytechnique. refs

A least-squares formulation of the energy equation is used to extend the variational Euler solver of Bruneau et al. (1986) to supersonic and hypersonic flow problems. The derivation and numerical implementation are outlined, and results are presented graphically for a thin delta wing at freestream Mach numbers 0.7 or 2.0 and angle of attack 10 deg. The solution for 80,000 unknowns at Mach 0.7 converges in 50 iterations and required about 30 min on one processor of a Cray 2 supercomputer; in a test computation for Mach 5.0, however, a 200,000-point computation required 100,000 megawords of storage and 8 h of CPU time. T.K.

A89-45369
A HIGH RESOLUTION FINITE VOLUME SCHEME FOR STEADY EXTERNAL TRANSONIC FLOW
D. M. CAUSON (Manchester Polytechnic, England) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 182-186. Research supported by the Ministry of Defence Procurement Executive. refs

An improved Euler solver is presented for computing steady external transonic flows around projectiles and aircraft forebodies. The method solves the unsteady Euler equations by time-marching using operator-splitting in conjunction with a finite volume formulation. The resolution of captured shock waves is improved by the use of a total variation diminishing (TVD) version of the well-known MacCormack scheme and artificial compression techniques. Existing production code implementations of MacCormack's method can be updated easily, as described, to reflect recent advances in one-dimensional schemes. Author

A89-45370
DEVELOPMENT OF A HIGHLY EFFICIENT AND ACCURATE 3D EULER FLOW SOLVER
H. C. CHEN and N. J. YU (Boeing Commercial Airplanes, Seattle, WA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 187-191. refs

The theoretical basis and performance of a cell-centered out-of-core multigrid solution algorithm for the Euler equations (Yu et al., 1988) are reviewed. The method incorporates a finite-volume spatial discretization, successive mesh refinement and multigrid acceleration, and a Runge-Kutta time integration; the hardware implementation involves block-by-block computation of flowfield data stored on a solid-state disk, with conservation of fluxes across interblock boundaries. Results for a wing-body/winglet configuration at freestream Mach number M = 0.7 and alpha = 2.08 deg and an NLR7301 airfoil at Mach 0.721 and alpha = -0.194 deg are presented graphically and discussed in detail. It is demonstrated that the solution method is insensitive to grid quality and dissipation parameters and converges well with respect to mesh refinement. T.K.

A89-45374
AN IMPLICIT TIME-MARCHING METHOD FOR SOLVING THE 3-D COMPRESSIBLE NAVIER-STOKES EQUATIONS
HISAAKI DAIGUJI and SATORU YAMAMOTO (Tohoku University, Sendai, Japan) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 210-214. refs

The implicit time-marching finite-difference method developed by Daiguji et al. (1986) for the Euler equations of steady three-dimensional compressible flow is extended to solve the Navier-Stokes equations, with diffusion terms accounted for. The derivation for the case of relative flow through the impeller of a turbomachine in general curvilinear coordinates is outlined, and results for two-dimensional and three-dimensional cascade flows are presented in graphs and briefly characterized. It is shown that the important features of the flows are captured despite the use of relatively coarse grids. T.K.

A89-45375
LOW-STORAGE IMPLICIT UPWIND-FEM SCHEMES FOR THE EULER EQUATIONS
A. DERVIEUX, L. FEZOUI, H. STEVE (Institut National de Recherche en Informatique et en Automatique, Valbonne, France), J. PERIAUX, and B. STOUFFLET (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 215-219. refs

New versions of the linearized implicit scheme are presented. Among others, there are the following improvements: (1) at most, only the block-diagonal terms of the matrix are stored, and (2) nonrecurrent solution algorithms are applied, making it possible to adapt the schemes to supercomputers. The convergence to the steady solution is fast and mesh adaptation is combined without losing efficiency in the solution. K.K.

A89-45378
COMPUTATION OF VISCOUS UNSTEADY COMPRESSIBLE FLOW ABOUT AIRFOILS
K. DORTMANN (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 230-234. refs

The formation of vortices near the trailing edge of a NACA 4412 airfoil in unsteady subsonic flow with time-dependent inflow conditions is investigated analytically. An explicit five-step Runge-Kutta time-stepping scheme is adopted to resolve the time scales required for characterization of the inflow, the gasdynamic regime, and the wake flow. Near the trailing edge, the inviscid and viscous forces are treated using a cell-vertex discretization and a node-centered scheme, respectively, and particular attention is given to the preservation of spatial and temporal accuracy in the application of numerical damping. The results are presented graphically and shown to be in good general agreement with published experimental data. T.K.

A89-45381
COMPUTER SIMULATION OF SOME TYPES OF FLOWS ARISING AT INTERACTIONS BETWEEN A SUPERSONIC FLOW AND A BOUNDARY LAYER
T. G. ELIZAROVA and B. N. CHETVERUSHKIN (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 245-250. refs

Numerical simulation results obtained for nonstationary periodic flows with front separation zones arising in a supersonic flow around a spiked cylinder are presented. Both the stationary and oscillatory regimes of the first and second kind were calculated as a function of the free stream velocity and the geometry of the body. Numerical results obtained for a supersonic gasdynamic flow around a

cylindrical tube closed from one end and mounted by its open end toward a supersonic free stream are presented as well. K.K.

A89-45384* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ACCURATE SIMULATION OF VORTICAL FLOWS
KOZO FUJII (NASA, Ames Research Center, Moffett Field, CA; Institute of Space and Astronautical Science, Sagamihara, Japan) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 268-272. refs

Even with recent supercomputers having a large memory, Navier-Stokes simulations for vortical flows do not provide satisfactory results because of the lack of grid resolution to accurately simulate the strength of separation vortices. To overcome this problem, a zonal method is proposed to increase the number of grid points locally. Interface scheme which is critical for an efficient and stable zonal method is based on the Fortified Navier-Stokes concept. Application to both two-dimensional conical and three-dimensional delta wing problems indicates this simple zonal method can improve the accuracy of vortical flow simulations. Author

A89-45390
NUMERICAL SIMULATION OF THE FLOW ABOUT A WING WITH LEADING-EDGE VORTEX FLOW
J. M. J. W. JACOBS, H. W. M. HOEIJMAKERS, J. I. VAN DEN BERG, and J. W. BOERSTOEL (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 311-317. Research supported by the Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs

The compressible flow about a cropped 65-deg swept sharp-edged delta wing featuring leading-edge vortex flow is computed. Numerical results are experimental data are compared for a transonic and for a subsonic case. Attention is given to the influence of grid density and grid point distribution. C.D.

A89-45391
MULTIGRID CALCULATIONS FOR CASCADES
ANTONY JAMESON and FENG LIU (Princeton University, NJ) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 318-325. refs

A finite volume method with a multistage time-stepping scheme is used here to calculate two-dimensional cascade flow. The stability limit of the explicit scheme is extended to using implicit residual averaging. Convergence is accelerated by using locally varying time steps, enthalpy damping, and an effective multigrid method. Adaptive numerical dissipation is used for capturing shocks. Results for the NACA 0012 cascade, the Hobson shock-free cascade, and the supersonic wedge cascade show excellent accuracy and convergence in comparison to results by other investigators. C.D.

A89-45392
UNSTEADY AND TURBULENT FLOW USING ADAPTATION METHODS
JOHN G. KALLINDERIS and JUDSON R. BARON (MIT, Cambridge, MA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 326-330. refs

Previous adaptation methodology and numerical schemes are applied here to complex flows such as those involving airfoils in turbulent flow. A detection procedure is used which tracks both flow features and their directionality and defines embedding patches which act as filters to reduce the number of randomly embedded cells. A new and general way for implementing an algebraic turbulence model for unstructured grids is described and its accuracy is evaluated. For unsteady simulations, it is shown how a spatial variation of the time steps can be allowed while simultaneously maintaining time accuracy. A conservative interface treatment is presented and compared with a nonconservative treatment for steady state problems in both subsonic and supersonic flow. C.D.

A89-45393
RNS SOLUTIONS FOR THREE-DIMENSIONAL STEADY INCOMPRESSIBLE FLOWS
P. K. KHOSLA, S. G. RUBIN, and A. HIMANSU (Cincinnati, University, OH) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 331-336. refs
(Contract F49620-85-C-0027)

Laminar, three-dimensional, separated-flow reduced Navier-Stokes (RNS) solutions are obtained for a trough and a parabolic-arc airfoil. A sparse-matrix solver is combined with a marching or relaxation procedure. Comparisons are made with two-dimensional solutions and a finite recirculation bubble is found for the three-dimensional cases. C.D.

A89-45394* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL STUDY OF UNSTEADY VISCOUS HYPERSONIC BLUNT BODY FLOWS WITH AN IMPINGING SHOCK
G. H. KLOPFER (NEAR, Inc., Mountain View, CA), H. C. YEE, and P. KUTLER (NASA, Ames Research Center, Moffett Field, CA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 337-343. refs

A complex two-dimensional, unsteady, viscous hypersonic shock wave interaction is numerically simulated by a high-resolution, second-order fully implicit shock-capturing scheme. The physical model consists of a nonstationary oblique shock impinging on the bow shock of a blunt body. Studies indicate that the unsteady flow patterns are slightly different from their steady counterparts. However, for the sample cases investigated the peak surface pressures for the unsteady flows seem to occur at very different impingement locations than for the steady flow cases. Author

A89-45402
ASYMMETRIC SEPARATED FLOWS ABOUT SHARP CONES IN A SUPERSONIC STREAM
F. MARCONI (Grumman Corporate Research Center, Bethpage, NY) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 395-402. refs
(Contract F49620-84-C-0036)

The inviscid flow separation model is used to investigate whether lateral instability in slender-nosed aircraft flying at high angle of attack is a viscous or inviscid phenomenon. The geometries considered are slender right circular cones. The Euler code, used in conjunction with a flow-separation model, indicates that the phenomenon is inviscid in nature. Preliminary results indicate that the asymmetry of the vortex flow is caused by mutual interference of the starboard and port vortices. C.D.

A89-45404
INVERSE METHOD FOR THE DETERMINATION OF TRANSONIC BLADE PROFILES OF TURBOMACHINERIES
B. MICHAUX (Indiana University, Bloomington) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 408-412. Research supported by SNECMA and Indiana University.
(Contract AF-AFOSR-88-103)

A new numerical method allowing the computation of transonic blade profile geometry for turbomachineries is presented. An

equivalence of the constraints by Lighthill (1945) is investigated in order to obtain the existence of a closed profile. An extension of the method by Stanitz for a fluid verifying the exact isentropicity law is developed. C.D.

A89-45405
INTERACTION OF AN OBLIQUE SHOCK WAVE WITH SUPERSONIC TURBULENT BLUNT BODY FLOWS
YOUNG J. MOON and MAURICE HOLT (California, University, Berkeley) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 418-423. refs

A numerical study of shock-on-shock interactions near a cylindrical body, representative of the engine inlet cowl of the National Aerospace Plane (NASP), is presented. Among the six principal shock interference patterns depending upon the intersection point, noted by Edney, the most critical cases, of types III and IV, are considered in the present study. In these cases, anomalous amplifications of peak pressure and heat flux occur at the shear layer and supersonic jet impingement points, respectively. The primary goal of this study is to calculate the entire flow field numerically, capturing all the interacting shocks and complicated shock-layer flows. The finite volume formulation of Van Leer's flux-vector splitting MUSCL scheme, in generalized coordinates, is used to solve the full Navier-Stokes equations in strong conservative form. Author

A89-45413* University Coll. of Swansea (Wales).
ADAPTIVE NUMERICAL SOLUTIONS OF THE EULER *EQUATIONS IN 3D USING FINITE ELEMENTS*
J. PERAIRE, J. PEIRO, L. FORMAGGIA, and K. MORGAN (Swansea, University College, Wales) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 469-473. Research supported by the Research Corp. refs
(Contract NAGW-478; SERC-GR/E/61762)

The development of an adaptive mesh solution for a flow involving shock interaction on a swept cylinder and an initial solution for a flow past a complex fighter configuration is reported. The finite element solution algorithm, the mesh generation, and the adaptivity of the solution are described. Sample results for the flow past an F-18 configuration at Mach 0.9 and alpha of 3 deg and for shock interaction on a swept cylinder at Mach 8.04 are summarized. C.D.

A89-45414
SIMULATION OF INVISCID HYPERSONIC REAL GAS FLOWS
M. PFITZNER, C. WEILAND, and G. HARTMANN (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 479-483. refs

Two-dimensional and three-dimensional calculations of inviscid supersonic and hypersonic flows about a variety of configurations, including orbiters and missiles, as well as flows through nozzles, are presented. Equilibrium real gas and ideal gas results are compared and the differences are discussed. The supersonic part of the flow field is calculated with a pseudospace marching method which uses the algorithm for the unsteady Euler equations as a relaxation procedure. Shock-fitting and shock-capturing capabilities for the ideal and real gas cases are demonstrated. C.D.

A89-45415
SIMULATION OF UNSTEADY FLOW PAST SHARP SHOULDERS ON SEMI-INFINITE BODIES
R. RAMAMURTI, U. GHIA, and K. N. GHIA (Cincinnati, University, OH) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 494-500. refs
(Contract AF-AFOSR-87-0074)

A Navier-Stokes analysis has been developed for simulating unsteady flows using general clustered conformal coordinates and a three-level multigrid procedure for the stream-function equation. The mathematical formulation is outlined and the numerical procedure is described. The leading edge separation encountered in high-incidence flows is examined by considering a model problem of the flow past a semiinfinite body with finite thickness and a sharp shoulder. C.D.

A89-45419
TRANSONIC ANALYSIS OF ARBITRARY CONFIGURATIONS USING LOCALLY REFINED GRIDS
SATISH S. SAMANT (Boeing Commercial Airplanes, Seattle, WA), JOHN E. BUSSOLETTI, FORRESTER T. JOHNSON (Boeing Advanced Systems, Seattle, WA), ROBIN G. MELVIN, and DAVID P. YOUNG (Boeing Computer Services, Seattle, WA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 518-522.

An approach is presented to solve the full potential equation about arbitrary configurations. A hierarchical refinement of a globally uniform rectangular grid is superimposed over a boundary described by networks of panels. The finite element method is used to obtain discrete operators for irregularly shaped regions near the boundary. The implementation of grid refinement and some results obtained using this approach are described. Author

A89-45422
NAVIER-STOKES SIMULATION OF TRANSONIC FLOW ABOUT WINGS USING A BLOCK STRUCTURED APPROACH
D. SCHWAMBORN (DFVLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 533-537.

An explicit finite volume method for the integration of the Navier-Stokes equations is presented. The method is cast into a very flexible block-structured approach. Results are presented for the simulation of the DFVLR-F5 experiment which has been designed to serve as a well defined boundary value problem for transonic viscous flow computations. Author

A89-45425
INVISCID AND VISCOUS FLOW SIMULATIONS AROUND THE ONERA-M6 BY TVD SCHEMES
YOKO TAKAKURA (Fujitsu, Ltd., Scientific Systems Dept., Tokyo, Japan), SATORU OGAWA, and TOMIKO ISHIGURO (National Aerospace Laboratory, Chofu, Japan) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 553-557. refs

The flow around the Onera-M6 wing poses significant aerodynamical problems, involving interaction between shock waves, between shock waves and boundary layers, and between two-wall boundary layers and the wing tip vortex. The extent to which TVD schemes can treat these phenomena is examined here using inviscid and viscous flow simulations. The results indicate that the TVD schemes are applicable to both inviscid and viscous flow problems. The solutions of the Euler equations in the low attack angle case are excellent. Improvements of the left-hand-side operators and the practicalization of large eddy simulation are also reported. C.D.

A89-45428* Mississippi State Univ., Mississippi State.
TRANSONIC FLOW SOLUTIONS ON GENERAL 3D REGIONS USING COMPOSITE-BLOCK GRIDS
JOE F. THOMPSON and DAVID L. WHITFIELD (Mississippi State University, Mississippi State) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June

27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 568-572. Research supported by USAF. refs
(Contract NAG3-767)

The construction of computational fluid dynamics (CFD) codes for complicated regions is greatly simplified by a composite-block grid structure since, with the use of a surrounding layer of points on each block, a flow code is then only required basically to operate on rectangular computational regions. The necessary correspondence of points on the surrounding layers (image points) with interior points (object points) is set up by the grid code and made available to the CFD solution code. Author

A89-45434
NONISENTROPIC POTENTIAL CALCULATION FOR 2-D AND 3-D TRANSONIC FLOW
ZI-QIANG ZHU and XUE-SONG BAI (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 618-622. refs

A shock point operator is introduced to account for the entropy change across a shock wave. The operator satisfies conservation relations which are consistent with the shock jump condition. A full potential code with such a nonisentropic formulation allows more accurate flow computations around airfoils and wings. Numerical calculations indicate that the present formulation yields results that are close to the Euler solution and experimental data. The computation time required is only a fraction of that required using the Euler code. C.D.

A89-45437* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A NATURAL LOW-FREQUENCY OSCILLATION OF THE FLOW OVER AN AIRFOIL NEAR STALLING CONDITIONS
K. B. M. Q. ZAMAN, D. J. MCKINZIE (NASA, Lewis Research Center, Cleveland, OH), and C. L. RUMSEY (NASA, Langley Research Center, Hampton, VA) Journal of Fluid Mechanics (ISSN 0022-1120), vol. 202, May 1989, p. 403-442. refs

An experimental and computational study of the low-frequency oscillation observed in the flow over an airfoil at the onset of static stall is presented. Wind-tunnel results obtained with two-dimensional airfoil models show that this phenomena takes place only with a transitional state of the separating boundary layer. It is noted that the flowfield does not involve a Karman vortex street. The experimental results agree well with the results of a two-dimensional Navier-Stokes code. The present study demonstrates that the low-frequency oscillations produce intense flow fluctuations which impart much larger unsteady forces to the airfoil than experienced by bluff-body shedding and which may represent the primary aerodynamics of stall flutter of blades and wings. R.R.

A89-45458
PRESSURE FLUCTUATIONS ON AN OSCILLATING TRAILING EDGE
THOMAS STAUBLI and DONALD ROCKWELL (Lehigh University, Bethlehem, PA) Journal of Fluid Mechanics (ISSN 0022-1120), vol. 203, June 1989, p. 307-346. Research supported by SNSF, U.S. Navy, NSF, and Stiftung Volkswagenwerk. refs

The surface loading and near-wake flow structure that are inherent to vortex formation from both blunt trailing edges and cylindrical bodies are investigated. Turbulent boundary layers separating from a blunt trailing edge are shown to give rise to organized vortical structures in the downstream wake, and the perturbation of this inherent flow instability by controlled oscillations of the edge produces corresponding organized components of unsteady surface pressure along the edge. Flow visualizations are performed in order to determine the phasing of the organized vortical structures shed from the trailing edge relative to the edge displacement. R.R.

A89-45468* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A NEWTON/UPWIND METHOD AND NUMERICAL STUDY OF SHOCK WAVE/BOUNDARY LAYER INTERACTIONS
MENG-SING LIOU (NASA, Lewis Research Center, Cleveland, OH) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 9, July 1989, p. 747-761. refs

The objective of the paper is two-fold. First, an upwind/central differencing method for solving the steady Navier-Stokes equations is described. The symmetric line relation method is used to solve the resulting algebraic system to achieve high computational efficiency. The grid spacings used in the calculations are determined from the triple-deck theory, in terms of Mach and Reynolds numbers and other flow parameters. Thus the accuracy of the numerical solutions is improved by comparing them with experimental, analytical, and other computational results. Secondly, the shock wave/boundary layer interactions are studied numerically, with special attention given to the flow separation. The concept of free interaction is confirmed. Although the separated region varies with Mach and Reynolds numbers, it is found that the transverse velocity component behind the incident shock, which has not been identified heretofore, is also an important parameter. A small change of this quantity is sufficient to eliminate the flow separation entirely. Author

A89-45560#
INVESTIGATION ON UNSTEADY FLOW FIELD AND ENDWALL BOUNDARY LAYER IN AXIAL FLOW COMPRESSOR WITH HOT-WIRE ANEMOMETER
QIXUN LIN, NINGFANG GUO, YAPING LI, and NINGFANG XIAO (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 141-144, 195. In Chinese, with abstract in English.

The measurement method for rotating stall is presented. The time difference between two signals and its frequency are determined correctly on the basis of cross-correlation and spectrum analysis. Then, the rotating stall regime, its spread velocity, and its form are obtained. The methods of the two-dimensional unsteady flow measurement are described. The velocity distribution of the unsteady flow, for example a rotating-stall cell, is obtained. A rotating single wire method is applied to measuring the two-dimensional boundary layer. The results measured behind a single rotor and a stator are shown in the paper. The contamination from dirt, the influence of air flow temperature, and the boundary layer flow field disturbance caused by probe hole, are considered. Author

A89-45565#
EFFECTS OF AXIAL VELOCITY DENSITY RATIO ON CASCADE PERFORMANCES
QIANZHI LIU and RUQUN YAN (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 161-164, 196. In Chinese, with abstract in English. refs

In turbomachinery cascade flows, the effects of Axial Velocity Density Ratio (AVDR) on cascade performances are very important. The theoretical and experimental studies of the problem are presented in this paper. The theoretical correlations of major cascade performances with AVDR are obtained. The comparisons of calculations and experiments are in good agreement. Author

A89-45906* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INTERACTION OF AN OSCILLATING VORTEX WITH A TURBULENT BOUNDARY LAYER
R. V. WESTPHAL (NASA, Ames Research Center, Moffett Field, CA) and R. D. MEHTA (Stanford University, CA) Experiments in Fluids (ISSN 0723-4864), vol. 7, no. 6, June 1989, p. 405-411. refs
(Contract NCC2-294)

An oscillating vortex embedded within a turbulent boundary layer was generated experimentally by forcing a periodic lateral translation of a half-delta wing vortex generator. The objective of

the experiment was to investigate the possibility that a natural oscillation, or meander, might be responsible for flattened vortex cores observed in previous work, which could also have contaminated previous turbulence measurements. The effect of this forced oscillation was characterized by comparison of measurements of the mean velocities and Reynolds stresses at two streamwise stations, for cases with and without forcing. The Reynolds stresses were affected significantly by the forced oscillation, mainly through contributions from the individual production terms, provided that the vortex was not too diffuse. Author

A89-46198
DIFFERENCE METHODS FOR INITIAL-BOUNDARY-VALUE PROBLEMS AND FLOW AROUND BODIES (REVISED EDITION)
YOU-LAN ZHU, XI-CHANG ZHONG, BING-MU CHEN, and ZUO-MIN ZHANG (Chinese Academy of Sciences, Computing Center, Beijing, People's Republic of China) Berlin and New York, Springer-Verlag, 1988, 608 p. Translation. refs

This book presents a detailed description of a new difference method for quasi-linear hyperbolic systems of partial differential equations. The method is highly accurate, even for problems with singularities such as shocks, contact discontinuities, rarefaction waves, and detonations. The mathematical foundation of the method and the method's application to supersonic flow around bodies are discussed. C.D.

A89-46256#
AN INTEGRATED DESIGN COMPUTATIONAL METHOD FOR THE WING OPTIMIZATION CAMBER AND TWIST AT SUBSONIC AND SUPERSONIC FLOW
DEHUA LIO, CHANGYOU HUANG, GOLIN ZHU (China Aerodynamic Research and Development Centre, Sichuan, People's Republic of China), YUPU LI, and GUANGMING SHE (611 Aircraft Design Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 192-199. In Chinese, with abstract in English. refs

An integrated design computational method based on an element solution method is presented for the wing optimization camber and twist at subsonic and supersonic flow. A wing design was selected by choosing the design points in subsonic and supersonic flow. K.K.

A89-46259#
EXPERIMENTAL STUDY OF VORTEX AND AERODYNAMIC CHARACTERISTICS OF STACK WINGS WITH SIDESLIP
GUOHUA BAO (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 215-219. In Chinese, with abstract in English.

Experimental results on stack wings are presented. The effect of the bursting and twisting of vortices on the aerodynamic characteristics is analyzed. The results show that sideslip delays twisting of the vortices on the upwind side but accelerates it on the backwind side. K.K.

A89-46260#
FLOW CHARACTERISTICS IN AN S-SHAPED RECTANGULAR-ROUND DIFFUSER AT HIGH INCIDENCE
QI LIN and RONGWEI GUO (Nanjing Aeronautical Institute, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 220-226. In Chinese, with abstract in English.

The flow in an S-shaped rectangular-round diffuser in the 0 to 85 deg incidence range is studied experimentally. The diffuser was tested in the working section of a blowdown tunnel. The study reveals that, with increasing incidence, the average total pressure coefficient and swirl coefficient increase and the air flow coefficient decreases continuously. K.K.

A89-46262#
DESIGN AND ANALYSIS OF AIRFOILS IN TRANSONIC VISCOUS FLOW
PING LIU and SHIJUN LUO (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 235-239. In Chinese, with abstract in English. refs

A numerical method has been employed to design and analyze airfoils in transonic viscous flow. The results show that the agreement of present method and the wind tunnel experiment is good both for weak interaction cases of shock wave/boundary layer and for strong cases. When the separation occurs, however, the agreement is poor downstream of the shock wave. Author

A89-46263#
RADIATIVE CHARACTERISTICS OF HYPERSONIC CONE WAKE
XUEHUA ZHOU and GUOYING CHAO (Chinese Academy of Sciences, Institute of Mechanics, Beijing, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 240-244. In Chinese, with abstract in English. refs

A finite explicit difference method was applied to the axisymmetric boundary layer equations of a hypersonic air wake in the chemical nonequilibrium behind a hypersonic cone. A two-dimensional distribution of the temperature, density, concentration, and electron density was obtained. The radiation intensity and quantity were calculated for the species which are the source of the wake radiation. K.K.

A89-46266#
THE COMPUTED RESULTS OF AIRFOIL NEAR THE FREESTREAM MACH NUMBER ONE
LONGDE HE (Chinese Academy of Sciences, Institute of Mechanics, Beijing, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 255-257. In Chinese, with abstract in English. refs

The range of freestream Mach numbers over which the local Mach number is frozen for a NACA0012 airfoil at alpha = 0 and 2 deg is determined. The distances between the detached shock and airfoil leading edge are determined at Mach numbers in the range of 1.05 to 1.30. K.K.

A89-46267#
THE INDUCED POWER BASED ON LEADING EDGE SUCTION FOR A HELICOPTER IN HOVERING
ZHENHAO LI (Chinese Helicopter Research and Development Institute, Chinese Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 258-261. In Chinese, with abstract in English.

A new formula for induced power based on the leading edge suction for a helicopter in hovering is derived in this paper. A simple example shows its applicability. This formula can be used for aerodynamic optimization of rotor blade. Author

A89-46694#
BEHAVIOR OF VORTEX STREET IN THE WAKE BEHIND A CIRCULAR CYLINDER UNDER CONTROLLED EXCITATION
MUNESHIGE OKUDE and TATSUYA MATSUI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 424, 1989, p. 228-237. In Japanese, with abstract in English. refs

The behavior of vortex street in the wake behind a circular cylinder under controlled excitation was investigated with the techniques both of hot-wire and of flow visualization at the Reynolds numbers lower than 160 in the pure Karman vortex street range. The response frequencies of the velocity fluctuation indicated the nonlinear interaction among the disturbances of the frequency of primary vortex street, of the most amplified frequency in the wake and of the forcing frequency. When the wake flow is forced with the disturbance of the intermediate frequency lower than that of the primary vortex street, the velocity fluctuation at far downstream location had two modes of the frequency caused by the nonlinear effect. One of them led to merging of two vortices in the primary

vortex street, and the other led to merging of three vortices, i.e., merging of two vortices followed by joining of another vortex afterward. The width of the wake was rapidly increased by the vortex merging. Author

A89-46763*# Applied and Theoretical Mechanics, Inc., Oakland, CA.
MODELING OF TURBULENCE FOR COMPRESSION CORNER FLOWS AND INTERNAL FLOWS
J. M. CHAMPNEY (Applied and Theoretical Mechanics, Inc., Oakland, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(Contract NAS2-12778)
(AIAA PAPER 89-2344)

A compressible Reynolds averaged Navier-Stokes code is applied to examine the performances of basic turbulence models for unseparated and separated flows. The turbulence models considered are a zero-equation model and several two-equation models, including a new k-epsilon model with an eddy viscosity damping function depending upon the Reynolds number and the distance from the wall. The turbulence models are assessed using the following experimental flows: a channel flow, a backward facing step, and a two-dimensional compression corner at Mach 2.8. Discussions and comparisons of the experimental and numerical results are given. Mesh refinement is shown to have a significant beneficial effect on free shear layer flow results obtained with two-equation turbulence models. The results illustrate the usefulness of several turbulence models as a design tool for fluid engineering systems. Author

A89-46769*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MACH 5 INLET CFD AND EXPERIMENTAL RESULTS
LOIS J. WEIR (NASA, Lewis Research Center, Cleveland, OH), D. R. REDDY, and GEORGE D. RUPP (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. refs
(AIAA PAPER 89-2355)

An experimental research program was conducted in the NASA Lewis Research Center 10 ft. by 10 ft. supersonic wind tunnel. The two-dimensional inlet model was designed to study the Mach 3.0 to 5.0 speed range for an 'over-under' turbojet plus ramjet propulsion system. The model was extensively instrumented to provide both analytical code validation data as well as inlet performance information. Support studies for the program include flow field predictions with both three-dimensional parabolized Navier-Stokes (PNS) and three-dimensional full Navier-Stokes (FNS) analytical codes. Analytical predictions and experimental results are compared. Author

A89-46771*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RECTANGULAR NOZZLE PLUME VELOCITY MODELING FOR USE IN JET NOISE PREDICTION
U. H. VON GLAHN (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 21 p. Previously announced in STAR as N89-22577. refs
(AIAA PAPER 89-2357)

A modeling technique for predicting the axial and transverse velocity characteristics of rectangular nozzle plumes is developed. In this technique, modeling of the plume cross section is initiated at the nozzle exit plane. The technique is demonstrated for the plume issuing from a rectangular nozzle having an aspect ratio of 6.0 and discharging into quiescent air. Application of the present procedures to a nozzle discharging into a moving airstream (flight effect) are then demonstrated. The effects of plume shear layer structure modification on the velocity flowfield are discussed and modeling procedures are illustrated by example. Author

A89-46839#
A VALIDATION OF A NAVIER-STOKES 2D SOLVER FOR TRANSONIC TURBINE CASCADE FLOWS
S. COLANTUONI, A. TERLIZZI (Alfa Romeo Avio S.p.A., Naples, Italy), and F. GRASSO (Roma I, Universita, Rome, Italy) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2451)

In the present work a solver for the solution of the compressible Navier Stokes equations for transonic turbine cascade flows is validated. The model here presented employs a finite volume 3-stage Runge-Kutta algorithm with symmetric discretization of both inviscid and viscous terms. Test cases are presented for the computation of flows through three different cascades for which experimental data are available. Author

A89-46840*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TWO-DIMENSIONAL COMPUTATIONS OF MULTI-STAGE COMPRESSOR FLOWS USING A ZONAL APPROACH
KAREN L. GUNDY-BURLET, MAN MOHAN RAI (NASA, Ames Research Center, Moffett Field, CA), and ROBERT P. DRING (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2452)

A clear understanding of the fluid dynamics associated with rotor/stator configurations can be very helpful when optimizing the performance of turbomachinery. In this study, a two-dimensional, implicit, thin-layer, Navier-Stokes zonal approach has been used to investigate the flow within a 2 1/2-stage compressor. Relative motion between the rotor and stator airfoils is made possible with the use of systems of patched and overlaid grids that move with respect to each other. The treatment of multistage turbomachines with arbitrary numbers of airfoils per row is made possible by the use of a flexible database system. Results in the form of instantaneous pressure and entropy contours and time-averaged pressures are presented for the 2 1/2-stage compressor. Time-averaged pressures and pressure amplitudes for a single-stage turbine configuration are also presented. The numerical results compare well with experimental data. Author

A89-46842#
COMPUTATIONAL AND EXPERIMENTAL STUDY OF STALL PROPAGATION IN AXIAL COMPRESSORS
S. JONNAVITHULA, S. THANGAM, and F. SISTO (Stevens Institute of Technology, Hoboken, NJ) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(Contract N00014-86-K-0315; N62271-87-M-0204)
(AIAA PAPER 89-2454)

The paper presents a numerical and experimental study of stall propagation in axial compressors. In the numerical study, the compressor blades are represented as an isolated linear cascade of airfoils and the stall propagation is simulated using a vortex tracking method. This method involves the use of periodic vortex arrays to simulate infinite cascades, the use of a vortex merging algorithm to allow computations for large times, the imposition of the no slip and the impenetrability boundary conditions in an integral sense, the use of integral boundary layer methods to locate the separation points and the use of Fourier analysis techniques to compute the velocities of the propagating stall. Detailed parametric studies of the influence of flow parameters like the inflow angle and stall wavelength, and geometric parameters like cascade solidity, blade camber and stagger have been performed. The experimental investigations were conducted in a single stage axial compressor test-rig. The occurrence of rotating stall in this research compressor was demonstrated, and some experimental studies on the effect of various flow parameters on the stall propagation were conducted. The computational and experimental results are compared and are shown to be in qualitative agreement. Author

A89-46843*# Pennsylvania State Univ., University Park.
AN EXPERIMENTAL STUDY OF THE EFFECT OF STREAMWISE VORTICITY ON SUPERSONIC MIXING ENHANCEMENT
J. W. NAUGHTON, L. N. CATTAFESTA, and G. S. SETTLES (Pennsylvania State University, University Park) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 24 p. refs
(Contract NAG1-872)
(AIAA PAPER 89-2456)

An initial experimental study of the effect of streamwise vorticity on supersonic turbulent mixing has been carried out. A Mach 3 streamwise vortex is generated using a strutmounted swirl injector and is injected into a Mach 3.5 freestream. The resulting flowfield is investigated using both five-hole angularity probe and total temperature probe surveys. The results are compared to identical experiments with a baseline, swirl-free Mach 3 jet. Laser Light Sheet (LLS) images are used to observe the mixing phenomena. The entrainment of energy and mass is used to evaluate the degree of mixing between the two streams for both the vortex and jet cases. The results reveal that streamwise vorticity does lead to a modest mixing enhancement of about 34 percent for the conditions tested. Author

A89-46845#
EXPERIMENTAL STUDY OF SPREADING RATE ENHANCEMENT OF HIGH MACH NUMBER TURBULENT SHEAR LAYERS
D. S. DOLLING (Texas, University, Austin) and Y. R. SHAU AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(Contract N00014-89-J-1221)
(AIAA PAPER 89-2458)

The effects of initial conditions on the spreading rate of a high Reynolds number compressible turbulent shear layer have been experimentally investigated in a Mach 5 blowdown tunnel. The results show that a shock incident on the shear layer has no measureable effect on the local thickness or spreading rate, or on the spreading rate further downstream. Changes in the initial conditions due to the shock impinging on the plate boundary layer are found to provide a significant increase in the spreading rate near the shear layer origin. Cross-correlations of fluctuating pitot pressures reveal little evidence of any changes in the shear layer large-scale structure orientation under disturbed conditions. R.R.

A89-46847*# Ohio State Univ., Columbus.
COMPRESSIBILITY AND SHOCK WAVE INTERACTION EFFECTS ON FREE SHEAR LAYERS
M. SAMIMY (Ohio State University, Columbus), D. E. ERWIN, and G. S. ELLIOTT AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs
(Contract N00014-87-K-0169; NAG3-764)
(AIAA PAPER 89-2460)

Two compressible free shear layers with convective Mach numbers of .51 and .86 were studied as baseline configurations to investigate the effects of compressibility on the turbulence characteristics. These shear layers were then disturbed by the placement of an obstruction in the shear layer in an attempt to enhance the shear layer growth rate. These models produced a curved shock in the supersonic side of the shear layer. The results indicate a significant reduction in turbulence levels with increased compressibility. However, there are not any significant changes due to the bow shock interaction with the shear layer. Author

A89-46848*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
LOW ANGLE INJECTION INTO A SUPERSONIC FLOW
R. B. MAYS, R. H. THOMAS, and J. A. SCHETZ (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. Research supported by NASA. refs
(AIAA PAPER 89-2461)

A study of helium jets injected into a Mach 3 airflow through circular sonic nozzles angled downstream at 15 and 30 deg is presented. An aspirating hot-film probe was employed to measure helium concentrations. The results of Schlieren and nonoshadowgraph photography show the presence of large-scale turbulent structures in the high pressure jets. Concentration data reveal some asymmetries both in the cross section of the jet and in the trajectory of the jet relative to the centerline of the jet. Plotting the decay of maximum concentration with axial distance, it is found that the mixing rate can be increased significantly by increasing the pressure ratio. These low angle jets display good cross-stream penetration. R.R.

A89-46924#
COMPUTATIONAL ANALYSIS OF TURBOMACHINERY FLOWS USING FLOFIVE
LINDA M. RINK (Morton Thiokol, Inc., Brigham City, UT) and MARK A. CARROLL (U.S. Navy, Naval Ocean Systems Center, San Diego, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. Research supported by Sundstrand Turbomach, NSF, and San Diego Supercomputer Center. refs
(AIAA PAPER 89-2559)

A three-dimensional compressible Navier-Stokes solver, FLOFIVE, is evaluated. Simulation results have been compared to five-hole spherical total probe experimental results for a straight-walled two-dimensional diffuser, along with LDV measurements for a curved duct and a centrifugal compressor impeller. FLOFIVE is shown to accurately predict the boundary layer growth and pressure recovery coefficient for the case of the diffuser, and to reproduce the experimentally observed secondary flows and gapwise and spanwise velocity values for the case of the curved duct. Although the code could reproduce the strong wakes in the impellar, the computational pressure ratio values overpredicted the experimental value by 10 percent. R.R.

A89-46933*# Purdue Univ., West Lafayette, IN.
L2F & LDV VELOCIMETRY MEASUREMENT AND ANALYSIS OF THE 3-D FLOW FIELD IN A CENTRIFUGAL COMPRESSOR
JOHN R. FAGAN, JR. and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. Research supported by NASA. refs
(AIAA PAPER 89-2572)

The flow field in the Purdue Research Centrifugal Compressor is studied using a laser two-focus (L2F) velocimeter. L2F data are obtained which quantify: (1) the compressor inlet flow field; (2) the steady-state velocity field in the impeller blade passages; and (3) the flow field in the radial diffuser. The L2F data are compared with both laser Doppler velocimetry (LDV) data and predictions from three-dimensional inviscid and viscous flow models. In addition, a model is developed to calculate the effect on the measurement volume geometry of refraction by curved windows. Finally, the advantages and disadvantages of using the L2F for turbomachinery measurements is discussed in terms of measurement accuracy, ease of use, including sample time per correlated event and the ability to make measurements in regions of high noise due to stray radiation from wall reflections. Author

A89-46935#
APPLICATION OF SIMPLE WAVE THEORY TO THE RADIATIVE BOUNDARY CONDITIONS REQUIRED FOR AN INTERNAL FLOW EULER SOLVER
MARK A. DRIVER (USAF, Institute of Technology, Wright-Patterson AFB, OH) and ROBERT E. GRAY (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. refs
(AIAA PAPER 89-2577)

A numerical algorithm is developed with the capability of capturing shocks in the internal blade passages of a modern gas turbine. The algorithm uses MacCormack's explicit finite difference scheme to solve the two-dimensional form of the Euler equations.

Simple wave theory is rigorously developed for application to the radiative boundary value problem. The computed solution is compared with experimental data for a high-work low aspect ratio turbine. The ability to obtain a reasonably accurate blade loading diagram within a practical execution time is demonstrated. Two oblique shocks, typical of those formed at the trailing edge of a transonic rotor blade, are captured. These shocks are smeared over several grid points, as expected with a shock capturing scheme, but their influence on the blade loading diagram is evident. Author

A89-47003#
PERFORMANCE AND FLOW FIELD OF A DUCTED PROPELLER
R. GANESH RAJAGOPALAN and ZHAOXING ZHANG (Iowa State University of Science and Technology, Ames) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. Research supported by the Iowa State University of Science and Technology. refs
(AIAA PAPER 89-2673)

The steady incompressible laminar Navier-Stokes equations have been solved in an axisymmetric coordinate system in order to analyze the performance and flowfield of a ducted propeller. In the method, the duct and nacelle are considered as axisymmetric solid bodies and are represented by blocked off regions in the flow with all three velocity components set to zero. Results are presented for propellers with several advance ratios. The flow through the duct alone is calculated in order to assess changes in the the surface pressure distribution of the shroud due to the propeller. The present method takes into account all the interference effects between the duct, the propeller, and the nacelle, and it can be used to optimize blade tip-clearance and lip shape. R.R.

A89-47004#
COMPUTATIONAL MODELING OF AXISYMMETRIC PROPELLER-HULL INTERACTION IN SLENDER LOW DRAG BODIES
R. DECHER (Washington, University, Seattle), J. C. HERMANSON (United Technologies Research Center, East Hartford, CT), and P. Y. HO AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(Contract N00014-81-K-0095)
(AIAA PAPER 89-2674)

Computational approaches to modeling the propeller-hull interaction for low drag hull shapes are examined. Inviscid interaction effects is modeled as a simple combination of sources/sinks and an actuator disk. A full Navier-Stokes equations is deemed necessary to include viscous effects. Unreliable results obtained from the axial source technique are discussed. The solution of the full Navier-Stokes equations is seen to be sensitive to grid nonorthogonality when the grid is concentrated near the surface of the low drag body. This phenomenon needs to be better understood before this technique can be successfully applied to model the propeller-hull interaction on low drag bodies.
Author

A89-47008#
BOW SHOCK MATCHING WITH VISCOUS EFFECTS ON HYPERSONIC FOREBODIES
MARK J. LEWIS (Maryland, University, College Park) and DANIEL E. HASTINGS (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 16 p. Research supported by the Charles Stark Draper Laboratory, Inc. refs
(AIAA PAPER 89-2678)

The desire to match the bow shock of a hypersonic vehicle to the lip of the engine cowl provides for a design constrain on the hypersonic forebody. For inviscid flow, it is shown that there is one particular wedge angle which provides for shock matching which is insensitive to steady-state changes in vehicle angle of attack, though it is not possible to match against changes in flight Mach number. The angle of attack sensitivity of a hypersonic boundary layer makes this matching process more difficult. Design rules for cowl matching with secondary shocks are presented, though it is never possible to fix them against changes in angle of attack. It is also shown that dynamic motion effects are less significant in affecting shock position and associated thermodynamic properties than the steady-state effects. Author

A89-47009#
NUMERICAL AND EXPERIMENTAL INVESTIGATION OF AIRFRAME-INTEGRATED INLET FOR HIGH VELOCITIES
V. A. VINOGRADOV, V. A. STEPANOV (Tsentral'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR), and E. V. ALEKSANDROVICH (Tsentral'nyi Aerogidrodinamicheskii Institut, Zhukovski, USSR) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2679)

Godunov's (1976) steady state scheme is the basis of the present numerical investigation of airframe-integrated, three-dimensional fixed-geometry inlets for hypersonic operation to Mach 6. The inlet configurations examined are similar to Trexler's (1975) designs, with and without struts; two of these three-dimensional inlet configurations, one possessing struts and the other without these, were experimentally tested in the freestream Mach 2-6 range. Experimental results are compared with those obtained numerically. O.C.

A89-47010#
MACH 4 TESTING OF SCRAMJET INLET MODELS
TAKESHI KANDA, TOMOYUKI KOMURO, GORO MASUYA, KENJI KUDO, ATSUO MURAKAMI (National Aerospace Laboratory, Kakuda, Japan) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2680)

Six scramjet inlet models were tested in a Mach 4 wind tunnel. Wall pressure was measured, pitot pressure was measured at the throat, and schlieren photographs were taken. Parameters of these models are side plate sweep angle, contraction ratio, and cowl geometry. The shock pattern inside one of the models as shown by schlieren photographs coincides with calculations. Both mass capture ratio and total pressure recovery are 50 - 70 percent. There seems to be an optimum sweep angle and an optimum cowl length for maximum total pressure recovery. Author

A89-47011#
INVISCID ANALYSIS OF A DUAL MODE SCRAMJET INLET
Y.-C. HSIA, BEN GROSS, and J. PAUL ORTWERTH (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p.
(AIAA PAPER 89-2681)

A three-dimensional inviscid flow computation was made on the Marquardt dual mode scramjet inlet which was tested for Air Force Aero-Propulsion Laboratory in 1966. An Euler solver based on high accuracy TVD scheme was used to carry out the analysis. The objective was to establish three-dimensional scramjet inlet CFD capability and to evaluate the applicability of Euler solutions for inlet performance calculation. The computations were made for freestream Mach numbers 2 and 5. A post-processor was developed to calculate the inlet performance. Comparison between computed and available test data showed that Euler analysis was able to predict the trend of the inlet performance and provide insight of the flow field. Author

A89-47013#
SURGE AND ROTATING STALL IN AXIAL COMPRESSORS
H. ISHII and Y. KASHIWABARA (Hitachi, Ltd., Mechanical Engineering Research Laboratory, Tsuchiura, Japan) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2683)

This paper briefly summarizes the features of surge and rotating

stall in multistage compressors based on test results, and describes a numerical method for representing both surge and rotating stall in axial compressors for practical application. The test results show possibilities of simultaneous occurrence of surge and rotating stall. The present method, expanding on a theoretical model by Moore (1985) which assumes inlet distortion, aims to represent unsteady behaviors observed in real machines. The method deals with the fluid equations of two-dimensional unsteady incompressible flow in the axial and circumferential directions. A set of differential equations is solved by Galerkin's method with circumferential flow distortion expressed in the form of a high-order Fourier series to take into account the nonlinearity of the equations about the angular variable. The method is used to evaluate various relations, including that between compressor parameters and unsteady behavior modes, and that between inlet distortion and onset point. Finally, the usefulness of the method is examined by comparisons with test results obtained from a 3-stage axial compressor. Author

A89-47014#
ROTATING STALL PERFORMANCE AND RECOVERABILITY OF A HIGH-SPEED 10-STAGE AXIAL-FLOW COMPRESSOR
W. W. COPENHAVER (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) and T. H. OKIISHI (Iowa State University of Science and Technology, Ames) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 17 p. Research supported by USAF. refs
(AIAA PAPER 89-2684)

A high-speed, 10-stage compressor component was tested while operating in-stall to investigate parameters that affect the overall recoverability of a multistage compressor. The compressor was tested at different in-stall operating conditions by varying compressor shaft speed, discharge throttle, and variable geometry settings to determine the effect of each variable on rotating-stall performance and recoverability. Test results suggest that the stall cell may not extend the full length of the compressor but instead can be confined to a portion, here the rear stages, of the compressor. Author

A89-47016#
MODEL PREDICTIONS OF FAN RESPONSE TO INLET TEMPERATURE TRANSIENTS AND SPATIAL TEMPERATURE DISTORTION
CONSTANCE A. DOWLER, KEITH M. BOYER, and NORMAN POTI (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2686)

A three-stage axial flow fan model was used to study the effects of inlet temperature transients (with and without distortion), steady-state spatial temperature distortion, and instantaneous temperature drop on fan performance. When circumferential distortion was present, the critical temperature rise (the face-averaged temperature rise just prior to system instability) was found to be greater for larger circumferential extents and lower magnitudes of distortion. Larger circumferential extents and lower magnitudes were also shown to result in less loss in stall margin. The results have been used to derive procedures for the safe and efficient operation of a hydrogen fueled burner. R.R.

A89-47017#
MODEL PREDICTIONS FOR IMPROVED RECOVERABILITY OF A MULTISTAGE AXIAL-FLOW COMPRESSOR
KEITH M. BOYER (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) and WALTER F. O'BRIEN (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs
(AIAA PAPER 89-2687)

A ten-stage axial flow compressor rig recently tested at Wright-Patterson AFB Compressor Research Facility can be represented by means of a one-dimensional stage-by-stage model employing a control-volume approach to the simulation of steady state and transient system operation, including surge and rotating stall. Overall and individual stage performance comparisons between model and experimental results exhibit excellent agreement. Both sets of results have indicated extensive compressor-recovery hysteresis in part-speed operation, largely influenced by staging effects. The model predicts improved recoverability and hysteresis reduction through enlargement of the rear stage flowpath, and the addition of a bleed outflow downstream of the middle stages. O.C.

A89-47026*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LARGE SCALE ADVANCED PROPELLER BLADE PRESSURE DISTRIBUTIONS - PREDICTION AND DATA
M. NALLASAMY, O. YAMAMOTO, S. WARSI (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH), and L. J. BOBER (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 22 p. refs
(AIAA PAPER 89-2696)

Two Euler analysis techniques, finite difference and finite volume, are employed to predict the blade surface pressure distributions of a large scale advanced propeller. The predicted pressure distributions are compared with wind tunnel data. Both techniques produced blade pressure distributions which are in fairly good agreement with the data over the range of test Mach numbers of 0.2 to 0.78. However, the numerical simulations fail to predict correctly the measured pressure distributions for the low Mach number, high power case which seem to have a leading edge vortex. A discussion of the compressibility effects is also presented. Author

A89-47027#
HOT WIRE MEASUREMENTS DOWNSTREAM OF A PROP-FAN
T. G. TILLMAN, J. C. SIMONICH, and J. H. WAGNER (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 20 p. Research supported by United Technologies Corp. refs
(AIAA PAPER 89-2698)

The present analysis of a propfan's near-field aerodynamics examined the wake structure of a contrarotating propfan model operating in the single-rotation mode, in order to obtain benchmark data defining the rotor-synchronized downstream flowfield for simulated cruise conditions. Three components of blade-synchronized periodic velocity were obtained at various radial locations over the course of blade passage, using high frequency response hot-wire anemometry; attention was given to the blade-tip region and the leading-edge vortex features. The existence of a vortex core axial-velocity defect is documented. O.C.

A89-47028#
NAVIER-STOKES SIMULATIONS AROUND A PROPFAN USING HIGHER-ORDER UPWIND SCHEMES
CHUICHI ARAKAWA (Tokyo, University, Japan), SHIGERU SAITO, HIROSHI KOBAYASHI, and YUICHI MATSUO (National Aerospace Laboratory, Chofu, Japan) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2699)

Viscous transonic flows around a typical single-rotation Propfan are simulated by solving time-averaged Navier-Stokes equations. An implicit finite-difference code based on a higher-order upwind TVD formulation with a practical two-equation model of turbulence is developed and applied. Computations are performed at cruise conditions of Mach number of 0.8. Viscous flow field structures around the propeller are made clear in detail. Predicted aerodynamic performances show good agreement with experimental data. Author

A89-47156*# Toledo Univ., OH.
RAREFIED GAS FLOW THROUGH TWO-DIMENSIONAL NOZZLES
KENNETH J. DE WITT, DUEN-REN JENG, THEO G. KEITH, JR.

(Toledo, University, OH), and CHAN-HONG CHUNG AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(Contract NAG3-577)
(AIAA PAPER 89-2893)

A kinetic theory analysis is made of the flow of a rarefied gas from one reservoir to another through two-dimensional nozzles with arbitrary curvature. The Boltzmann equation simplified by a model collision integral is solved by means of finite-difference approximations with the discrete ordinate method. The physical space is transformed by a general grid generation technique and the velocity space is transformed to a polar coordinate system. A numerical code is developed which can be applied to any two-dimensional passage of complicated geometry for the flow regimes from free-molecular to slip. Numerical values of flow quantities can be calculated for the entire physical space including both inside the nozzle and in the outside plume. Predictions are made for the case of parallel slots and compared with existing literature data. Also, results for the cases of convergent or divergent slots and two-dimensional nozzles with arbitrary curvature at arbitrary knudsen number are presented. Author

A89-47160*# Analytical Services and Materials, Inc., Hampton, VA.
THE APPLICATION OF 3D MARCHING SCHEME FOR THE PREDICTION OF SUPERSONIC FREE JETS
KHALED S. ABDOL-HAMID (Analytical Services and Materials, Inc., Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(Contract NAS1-18599)
(AIAA PAPER 89-2897)

A modified version of the upwind flux-difference scheme of Roe for supersonic flow solution is described. This efficient iterative Space Marching Scheme (SMS) is used to solve the three-dimensional, Reynolds-averaged Navier-Stokes equations, for underexpanded and overexpanded supersonic free jet with a single time sweep. Comparisons with experimental data and the Parabolized Navier-Stokes (PNS) solutions are presented. These results show that the present scheme gives good agreement with experimental data in less computer time and the convergence history of the SMS is much faster than the PNS solution. Author

A89-47177#
REDUCTION OF 1-P AERODYNAMIC LOADS ON TRACTOR AIRCRAFT ENGINE INSTALLATIONS
F. L. GATES and A. A. SMAILYS (Pratt and Whitney Canada, Mississauga) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2924)

Sources of asymmetry in the flow of air through a propeller are reviewed, and the flight conditions giving rise to high once-per-revolution (1P) cyclic loads are investigated. An algorithm for the prediction of 1-P moments and forces for any composition of wings and nacelles is proposed. The predictions agree well with inflow angles and 1-P moments at low speeds determined experimentally in a wind tunnel, but are somewhat compromised at moderate and high speeds due to cross-flow deficiencies in the algorithm. It is pointed out that this shortcoming can be overcome by introducing the effect of cross flow induced by span-wise loading and its mutually-dependent effect on the presence and placement of nacelles into the algorithm. R.R.

A89-47183#
SURVEY AND ASSESSMENT OF VALIDATION DATA BASE FOR SHOCKWAVE BOUNDARY LAYER INTERACTIONS IN SUPERSONIC INLETS
A. HAMED (Cincinnati, University, OH) and J. S. SHANG (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 17 p. Research supported by UES. refs
(AIAA PAPER 89-2939)

A comprehensive critical evaluation of extant experimental data concerning the control of shock boundary layer interactions in supersonic inlets by means of boundary-bleed has extablished that surface and pitot pressure data support the possibility of boundary layer separation control. Contradictions are noted, however, between several different investigations' results on the effectiveness of bleed configurations at the shock, upstream of the shock, or downstream of the shock, in controlling separation. Turbulence measurements indicate significant changes in turbulence across the shock boundary layer interaction, especially if the flow separates. O.C.

A89-47184#
BLOCK-STRUCTURED SOLUTION OF TRANSONIC FLOWS AROUND WING/PYLON/NACELLE CONFIGURATIONS
A. ECER, J. T. SPYROPOULOS (Purdue University, Indianapolis, IN), R. K. ROUT, and S. S. BADESHA (GE Aircraft Engines, Cincinnati, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p. Research supported by IBM Corp. refs
(AIAA PAPER 89-2940)

Block-structured finite element grid generation is combined with Euler solution schemes to analyze the flows around isolated and installed nacelles at incidence. In the present method, the solution domain is divided in a structured distribution of subdomains, and the geometry of each block is then approximated by a finite element superelement of mixed order in order to generate grids of second-order continuity in each block. Geometric irregularities such as void blocks, slits, or coupled surfaces are included at the block boundaries. Following a Clebsch transformation of the velocity field, the equations for the conservation of mass and entropy are solved in each block, relaxing boundary conditions at the interblock boundaries at every iteration. R.R.

A89-47185#
STEADY-STATE AND TIME-DEPENDENT AERODYNAMICS IN AN ANNULAR TURBINE CASCADE OPERATING AT HIGH SUBSONIC MACH NUMBERS
A. EZZAT, T. H. FRANSSON, and F. JOLLES (Lausanne, Ecole Polytechnique Federale, Switzerland) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 17 p. Research supported by Ansaldo Componenti S.p.A. and Franco Tosi Industriale S.p.A. refs
(AIAA PAPER 89-2941)

An experimental investigation has been conducted of the steady-state and time-dependent aerodynamic characteristics of a low-pressure steam turbine blade's two-dimensional section, where the section in question is from the upper part of the blade, where the nominal flow conditions are subsonic at the inlet and supersonic at the outlet. The experimental steady-state and time-dependent aerodynamic data presented correspond to three steady-state loadings, with a total inlet flow angle variation of 14 deg. The results obtained indicate that the blading, in its present form, is susceptible to blade flutter in the first bending mode. The leading-edge form of the blade is identified as one of the primary reasons for the undesirable unsteady flow effects. O.C.

A89-47187*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AVERAGE-PASSAGE SIMULATION OF COUNTER-ROTATING PROPFAN PROPULSION SYSTEMS AS APPLIED TO CRUISE MISSILES
RICHARD A. MULAC (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH), JON C. SCHNEIDER (McDonnell Douglas Astronautics Co., Saint Louis, MO), and JOHN J. ADAMCZYK (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. Previously announced in STAR as N89-23416. refs
(AIAA PAPER 89-2943)

Counter-rotating propfan (CRP) propulsion technologies are currently being evaluated as cruise missile propulsion systems. The aerodynamic integration concerns associated with this application are being addressed through the computational

modeling of the missile body-propfan flowfield interactions. The work described in this paper consists of a detailed analysis of the aerodynamic interactions between the control surfaces and the propfan blades through the solution of the average-passage equation system. Two baseline configurations were studied, the control fins mounted forward of the counter-rotating propeller and the control fins mounted aft of the counter-rotating propeller. In both cases, control fin-propfan separation distance and control fin deflection angle were varied. Author

A89-47351*# Loral Defense Systems, Akron, OH.
ANALYSIS OF LOW REYNOLDS NUMBER SEPARATION BUBBLES USING SEMIEMPIRICAL METHODS
GORDON S. SCHMIDT (Loral Corp., Akron, OH) and THOMAS J. MUELLER (Notre Dame, University, IN) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 993-1001. Research supported by the University of Notre Dame. refs
(Contract NSG-1419)

The formation and growth of transitional separation bubbles can significantly affect boundary-layer development on airfoils operating at low chord Reynolds numbers. Of primary concern is the change in boundary-layer thickness between laminar separation and turbulent reattachment. This can be estimated using semiempirical methods, such as the one devised by Horton (1968), which are based on solutions to the integral forms of the boundary-layer equations. The applicability of these methods at low Reynolds numbers was investigated using hot-wire measurements of bubbles formed on an NACA 66(3)-018 airfoil at chord Reynolds numbers of 50,000-200,000. The momentum thickness growth between separation and transition was found to be similar to that predicted for a laminar half-jet and appears to be influenced by the momentum thickness Reynolds number at separation. This parameter also was found to have a noticeable effect on the Reynolds number based on the length of a bubble's laminar portion. Author

A89-47352#
FLOW STRUCTURE AND SCALING LAWS IN LATERAL WING-TIP BLOWING
C. S. LEE, D. TAVELLA, N. J. WOOD, and L. ROBERTS (Stanford University, CA) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1002-1007. Previously cited in issue 17, p. 2462, Accession no. A86-37831. refs

A89-47356#
VISCOUS AERODYNAMIC ANALYSIS OF AN OSCILLATING FLAT-PLATE AIRFOIL
LINDA M. SCHROEDER and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1021-1022. Abridged. Research sponsored by USAF. Previously cited in issue 07, p. 928, Accession no. A88-22092.

A89-47357*# Washington Univ., Seattle.
FURTHER EXPERIMENTS ON SUPERSONIC TURBULENT FLOW DEVELOPMENT IN A SQUARE DUCT
D. O. DAVIS and F. B. GESSNER (Washington, University, Seattle) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1023-1030. Previously cited in issue 18, p. 2806, Accession no. A87-42362. refs
(Contract NCA2-IR-850-401)

A89-47358*# Old Dominion Univ., Norfolk, VA.
UNSTEADY TRANSONIC AIRFOIL COMPUTATION USING IMPLICIT EULER SCHEME ON BODY-FIXED GRID
OSAMA A. KANDIL and H. ANDREW CHUANG (Old Dominion University, Norfolk, VA) (Developments in theoretical and applied mechanics. Volume 14; Proceedings of the Fourteenth Southeastern Conference on Theoretical and Applied Mechanics, Biloxi, MS, Apr. 18, 19, 1988, p. 37-46) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1031-1037. Previously cited in issue 01, p. 0006, Accession no. A89-11153. refs
(Contract NAG1-648)

A89-47360#
INVESTIGATION OF THE FLOW STRUCTURE AROUND A RAPIDLY PITCHING AIRFOIL
MIGUEL R. VISBAL and J. S. SHANG (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1044-1051. Previously cited in issue 19, p. 2942, Accession no. A87-44951. refs

A89-47372*# San Diego State Univ., CA.
AERODYNAMICS OF HIGH-LIFT, LOW-ASPECT-RATIO UNSWEPT WINGS
JOSEPH KATZ (San Diego State University, CA) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1123, 1124. refs
(Contract NCC2-458)

It is presently demonstrated that highly cambered, low aspect ratio airfoil configurations can be neither experimentally nor numerically developed on the basis of two-dimensional methods; the strong dependency of airfoil shape on aspect ratio requires the definition of a planform to be conducted first, in order to serve as input for three-dimensional optimization methods. It is found that even the simplified three-dimensional computational method presently employed can accelerate a multielement-airfoil wing development. O.C.

A89-47373#
DIFFUSER PERFORMANCE OF TWO-STREAM SUPERSONIC WIND TUNNELS
DIMITRI PAPAMOSCHOU (California Institute of Technology, Pasadena) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1124-1127. Research supported by the Rockwell International Foundation Trust. refs
(Contract N00014-85-K-0646)

A theoretical model has been developed which determines the inviscid, steady-state diffuser performance of a wind tunel having two plane parallel supersonic streams that come into contact downstream of a splitter plate to form an infinitely thin interface. Model predictions are applicable to the design and operation of both two-stream supersonic wind tunnels and aircraft engines in which flow mixing occurs at supersonic speeds. The calculations presented reflect idealized conditions under which the shear-layer and boundary layer growth rates are taken to be zero. O.C.

A89-47376#
UNSTEADY TRANSITION LOCATION
KENNETH F. STETSON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 27, Aug. 1989, p. 1135-1137. refs

Results were obtained in the USAF Flight Dynamics Laboratory Mach 6 wind tunnel which furnish additional evidence of nosetip threshold conditions that determine when a nosetip will generate low frustum transition Reynolds numbers. The example treated also illustrates a case of unsteady transition location for this early frustum transition condition. Transition moved steadily rearward with increasing time; in 2.5 sec, both sides of the model has a completely laminar boundary layer. O.C.

N89-25117*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF MILLING MACHINE ROUGHNESS AND WING DIHEDRAL ON THE SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A HIGHLY SWEPT WING
CHRISTINE M. DARDEN Washington Aug. 1989 88 p
(NASA-TP-2918; L-16546; NAS 1.60:2918) Avail: NTIS HC A05/MF A01 CSCL 01/1

An experimental investigation was conducted to assess the effect of surface finish on the longitudinal and lateral aerodynamic characteristics of a highly-swept wing at supersonic speeds. A study of the effects of wing dihedral was also made. Included in the tests were four wing models: three models having 22.5 degrees of outboard dihedral, identical except for surface finish, and a zero-dihedral, smooth model of the same planform for reference. Of the three dihedral models, two were taken directly from the milling machine without smoothing: one having a maximum scallop

height of 0.002 inches and the other a maximum scallop height of 0.005 inches. The third dihedral model was handfinished to a smooth surface. Tests were conducted in Test Section 1 of the Unitary Plan Wind Tunnel at NASA-Langley over a range of Mach numbers from 1.8 to 2.8, a range of angle of attack from -5 to 8 degrees, and at a Reynolds numbers per foot of 2 x 10(6). Selected data were also taken at a Reynolds number per foot of 6 x 10(6). Drag coefficient increases, with corresponding lift-drag ratio decreases were the primary aerodynamic effects attributed to increased surface roughness due to milling machine grooves. These drag and lift-drag ratio increments due to roughness increased as Reynolds number increased. Author

N89-25119*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

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

DENNIS L. HUFF and T. S. R. REDDY (Toledo Univ., OH.) 1989 18 p *Presented at the 25th Joint Propulsion Conference*, Monterey, CA, 10-12 Jul. 1989; cosponsored by the AIAA, ASME, SAE and ASEE

(NASA-TM-102053; E-4805; NAS 1.15:102053; AIAA-89-2805) Avail: NTIS HC A03/MF A01 CSCL 01/1

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

N89-25121*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

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

CHRISTOPHER E. HUGHES and JOHN A. GAZZANIGA (Sverdrup Technology, Inc., Cleveland, OH.) 1989 47 p Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; cosponsored in part by AIAA, ASME, SAE, and ASEE

(NASA-TM-102292; E-4883; NAS 1.15:102292; AIAA-89-2583) Avail: NTIS HC A03/MF A01 CSCL 01/1

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

N89-25122*# Kansas Univ. Center for Research, Inc., Lawrence.

SPANWISE LIFT DISTRIBUTIONS AND WAKE VELOCITY SURVEYS OF A SEMI-SPAN WING WITH A DISCONTINUOUS TWIST

HIROYUKI KUMAGAI May 1989 208 p

(Contract NCC2-175)

(NASA-CR-177532; NAS 1.26:177532) Avail: NTIS HC A10/MF A01 CSCL 01/1

A wind tunnel test was conducted in the NASA-Ames 7 x 10 ft wind tunnel to investigate the lift distribution on a semispan wing with a discontinuous change in spanwise twist. The semispan wing had a tip with an adjustable pitch angle independent on the inboard section pitch angle simulating the free tip rotor blade when its free tip is at a deflected position. The spanwise lift distribution over the wing and the tip were measured and three component velocity surveys behind the wing were obtained with a 3-D laser Doppler velocimeter (LV) with the wing at one angle of attack and the tip deflected at different pitch angles. A six-component internal strain gage balance was also used to measure total forces and moments on the tip. The 3-D lift was computed from the 2-D lift distributions obtained from the LV and from the strain gage balance. The results from both experimental methods are shown to be in agreement with predictions made by a steady, 3-D panel code, VSAERO. Author

N89-25125# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Abteilung Instationaere Aerodynamik.

TWO-DIMENSIONAL ELLIPTIC GRID GENERATION FOR AIRFOILS AND CASCADES

VOLKER CARSTENS Dec. 1988 77 p

(DFVLR-FB-88-52; ISSN-0171-1342; ETN-89-94638) Avail: NTIS HC A05/MF A01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Fed. Republic of Germany, DM 28.50

Based on the solution of two coupled transformed Poisson equations, a method to generate two-dimensional grids for airfoils and cascades is presented. With the method it is possible to control line spacing and intersection angle of the grid lines at the physical boundaries by a particular choice of inhomogeneous terms in the Poisson equations. The numerical solution of the grid generating equations is performed by a Newton relaxation algorithm which significantly improves stability and convergence of the numerical solution compared to the classical SLOR method. Examples of airfoil and cascade grids demonstrate the efficiency of the existing procedure. ESA

N89-25126# Technische Hochschule, Aachen (Germany, F.R.). Sonderforschungsbereich 25.

VORTEX FLOWS IN FLYING TECHNIQUE [WIRBELSTROEMUNGEN IN DER FLUGTECHNIK]

1988 378 p In GERMAN IUTAM Symposium: On Fundamental Aspects of Vortex Motion held in 1987

(ETN-89-94428) Avail: NTIS HC A17/MF A01

Flows with free vortices were investigated by the integration of the conservation equations. The mechanisms leading to vortex breakdown were clarified. Velocity fields in vortex structures were measured. Strongly unsteady vortex fields at elastic helicopter rotor blades were studied. The interaction between compression shocks and vertical flows, the dissipation of vortex power in longitudinal flow on wings, and vortex structures in the wake of transonic flow about profiles were investigated. Flow field changes of wing profiles in unsteady flow and unsteady flow on profiles in a liquid tunnel are treated. The effect of winglets on the loading mechanics and wing assembly reactions and the reduction of the adverse effects of wing tip vortices by modifying the wing tips were studied.

ESA

N89-25129# Technische Hochschule, Aachen (Germany, F.R.).
UNSTEADY PHENOMENA ON DELTA WINGS WITH PARTIALLY BROKEN-DOWN VORTEX REGIONS [INSTATIONAERE VORGAENGE AN DELTAFLUEGELN MIT TEILWEISE AUFGEPLATZTEN WIRBELBEREICHEN]
BERND STECKEMETZ *In its* Vortex Flows in Flying Technique p 41-68 1988 In GERMAN
Avail: NTIS HC A17/MF A01

Delta wings were investigated in water and wind tunnels to clarify unsteady flow phenomena in the vortex system of the delta wing occurring during wing maneuvers and in gust fields. The investigations in the water tunnel concentrated on the visualization of the leading vortex; the pictures show the temporal shift of the vortex and breakdown positions for the different test parameters. The pressure distribution measurements in the subsonic wind tunnel can be directly compared with the water tunnel test data, while the force and moment measurements in steady flow provide data on the total wing. Assuming quasi-stationarity, the effects of breakdown and heading phenomena on the force and moment balance of the wing were assessed using the coupled water and wind tunnel data, and verified by unsteady force and moment measurements. ESA

N89-25131# Technische Hochschule, Aachen (Germany, F.R.).
STRONGLY UNSTEADY VORTEX FIELDS AT ELASTIC HELICOPTER ROTOR BLADES [STARK INSTATIONAERE WIRBELFELDER AN ELASTISCHEN HUBSCHRAUBERROTORBLAETTERN]
K. GRUENSPAHN *In its* Vortex Flows in Flying Technique p 89-113 1988 In GERMAN
Avail: NTIS HC A17/MF A01

Unsteady flow phenomena at helicopter rotor blades during forward flight were studied in the framework of two-dimensional profile theory. The flow medium was assumed to be compressible, inviscid, and heat-conduction free. Starting from the Euler equations, a numerical bicharacteristic method of a second order for the calculation of two-dimensional, unsteady, compressible flow was developed, allowing the simulation of flow about accelerating profiles. Fast angle-of-attack oscillations of a profile and profile motions with translatory acceleration were analyzed; the results are in good agreement with the Jameson stationary transonic potential method. ESA

N89-25134# Technische Hochschule, Aachen (Germany, F.R.).
VORTEX STRUCTURES IN THE WAKE OF TRANSONIC FLOW ABOUT PROFILES [WIRBELNSTRUKTUREN IM NACHLAUF SCHALLNAH ANGESTROEMTER PROFILE]
H.-J. ROMBERG *In its* Vortex Flows in Flying Technique p 143-157 1988 In GERMAN
Avail: NTIS HC A17/MF A01

Measurements were performed on wing profiles in transonic and supersonic wind tunnels with a view to the investigation of the mechanisms responsible for the formation of vortex structures. The measuring chambers of the wind tunnels are equipped with adaptive walls to minimize wall interferences. The pressure distributions with and without adaptive walls were measured and compared with Navier-Stokes calculations. Pressure distribution and pressure variations in the wake were also measured. The measurements were correlated with the numerical evaluation of Mach-Zehnder recordings, which clarifies the mechanisms and the quantities affecting the formation of vortex structures. ESA

N89-25135# Technische Hochschule, Aachen (Germany, F.R.).
FLOW ABOUT TRAILING EDGES IN UNSTEADY FLOW [HINTERKANTENUMSTROEMUNG IN INSTATIONAERER ANSTROEMUNG]
B. SCHWEITZER and K. DORTMANN *In its* Vortex Flows in Flying Technique p 159-182 1988 In GERMAN
Avail: NTIS HC A17/MF A01

The flow field changes at wing profiles in an unsteady flow and constant angle of attack were investigated experimentally as well as numerically. Water tunnel experiments show clearly that the profile flow and especially the separation domain are affected by flow velocity changes. Unsteady pressure distributions and boundary layer profiles were measured in a wind tunnel. Despite the different test conditions, the fundamental similarity between the flow in the wind and the water tunnel was demonstrated. The measurement of the unsteady pressure distributions allows the determination of the unsteady lift coefficient. A force and moment measurement was performed to determine the aerodynamic forces on the profile. ESA

N89-25137# Technische Hochschule, Aachen (Germany, F.R.).
EFFECT OF WINGLETS ON LOADING MECHANICS AND WING ASSEMBLY REACTIONS [EINFLUSS VON WINGLETS AUF DIE BELASTUNGS MECHANIK UND TRAGWERKSREAKTIONEN]
GRAHAM BUTT and ATHANASSIOS DAFNIS *In its* Vortex Flows in Flying Technique p 223-260 1988 In GERMAN
Avail: NTIS HC A17/MF A01

The structural mechanical effects of winglets on the lifting structure of wings were investigated on the laboratory aircraft Morane Rallye. The pressure distribution on the Morane wing was calculated. A six-component force measurement was performed on the Morane model with and without winglets. The structural data of the Morane wings were obtained. Flutter calculations with three degrees of freedom were made. The unsteady aerodynamic forces were measured on the vibration test stand in the wind tunnel. ESA

N89-25138# Technische Hochschule, Aachen (Germany, F.R.).
DAMPING OF WING TIP VORTEX SYSTEMS BY THE MODIFICATION OF THE WING TIPS [ABSCHWAECHUNG VON RANDWIRBELSYSTEMEN DURCH MODIFIKATION DER FLUEGELSPITZEN]
T. SCHERER and T. VITTING *In its* Vortex Flows in Flying Technique p 261-287 1988 In GERMAN
Avail: NTIS HC A17/MF A01

The reduction of the adverse effects of wing tip vortices by the design of wing tips and by active and passive control of the evolution of the vortex orbit, was investigated. The aim was to prevent the formation of single vortices or the perturbation of ordered wortex structures by self-induction. The vortex behavior was described using water tunnel experiments and simulation calculations. The results show that the highest circumferential velocity in the wing tip vortex can be reduced by more than 60 percent if the vortex formation process can be hindered or if the ordered vortex structures can be perturbed by self-induction. Experiments and simulations show that behind semi-delta winglets with small angle of attack, double vortices are built which lead to strongly reduced circumferential velocities. Winglets were developed for the Dromedar aircraft, providing a clearly improved spray distribution. ESA

N89-25139# Technische Hochschule, Aachen (Germany, F.R.).
MECHANICAL REACTION OF WINGS MOVING THROUGH A VORTEX REGION [MECHANISCHE REAKTIONEN VON FLUEGELN, DIE DURCH EIN WIRBELGEBIET BEWEGT WERDEN]
DIETER HOLZDEPPE and HANS-WERNER LINDERT *In its* Vortex Flows in Flying Technique p 289-312 1988 In GERMAN
Avail: NTIS HC A17/MF A01

The dynamic reactions of rotor blades on loading by vortex perturbations were investigated. The principal item in the structural dynamic calculations is the reconstruction of the exciting functions from a few measured structural responses such as cutting moments, displacements, and accelerations. By modelling the rotor blade as a beam structure, the distribution of the resulting aerodynamic forces over the rotor blade length can be reconstructed. The reconstruction of the aerodynamic moments from simultaneously measured torsion torques also provide the position of the resulting aerodynamic forces with respect to the profile depth. The results can also be used to improve the analytical unsteady aerodynamic force models. ESA

N89-25198*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FINITE ELEMENT FLOW-THERMAL-STRUCTURAL ANALYSIS OF AERODYNAMICALLY HEATED LEADING EDGES
PRAMOTE DECHAUMPHAI, ALLAN R. WIETING, and AJAY K. PANDEY (Planning Research Corp., Hampton, VA.) *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 971-990 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/1

Hypersonic vehicles operate in a hostile aerothermal environment which has a significant impact on their aerothermostructural performance. Significant coupling occurs between the aerodynamic flow field, structural heat transfer, and structural response creating a multidisciplinary interaction. A long term goal of the Aerothermal Loads Branch at the NASA Langley Research Center is to develop a computational capability for integrated fluid, thermal and structural analysis of aerodynamically heated structures. The integrated analysis capability includes the coupling between the fluid and the structure which occurs primarily through the thermal response of the structure, because: (1) the surface temperature affects the external flow by changing the amount of energy absorbed by the structure, and (2) the temperature gradients in the structure result in structural deformations which alter the flow field and attendant surface pressures and heating rates. In the integrated analysis, a finite element method is used to solve: (1) the Navier-Stokes equations for the flow solution, (2) the energy equation of the structure for the temperature response, and (3) the equilibrium equations of the structure for the structural deformation and stresses. Author

N89-25950# National Aerospace Lab., Tokyo (Japan).
A NUMERICAL SOLUTION OF TRANSONIC FLOW USING DISCONTINUOUS SHOCK WAVE RELATIONSHIP
MASAYOSHI NAKAMURA Sep. 1988 18 p In JAPANESE; ENGLISH summary
(NAL-TR-997; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

It is the purpose of this study to obtain solutions, which contain complete discontinuities of shock waves, of the potential equations for transonic airfoils using numerical techniques. For iterative calculations, the potential equations are transformed into a more convenient form of simultaneous equations having two variables, velocity potential and Mach number. The solutions with the complete discontinuities of shock waves satisfying shock wave relationship are obtained by the iterative calculations without divergencies or high frequencies under a grid system in the physical plane. Numerical results of the present techniques, and of another method for the transonic flow over an airfoil of NACA0012 with shock wave, are used as test cases for comparison. Author

N89-25951*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STEADY-STATE AND TRANSITIONAL AERODYNAMIC CHARACTERISTICS OF A WING IN SIMULATED HEAVY RAIN
BRYAN A. CAMPBELL and GAUDY M. BEZOS Washington Aug. 1989 95 p
(NASA-TP-2932; L-16576; NAS 1.60:2932) Avail: NTIS HC A05/MF A01 CSCL 01/1

The steady-state and transient effects of simulated heavy rain on the subsonic aerodynamic characteristics of a wing model were determined in the Langley 14- by 22-Foot Subsonic Tunnel. The 1.29 foot chord wing was comprised of a NACA 23015 airfoil and had an aspect ratio of 6.10. Data were obtained while test variables of liquid water content, angle of attack, and trailing edge flap angle were parametrically varied at dynamic pressures of 10, 30, and 50 psf (i.e., Reynolds numbers of .76x10(6), 1.31x10(6), and 1.69x10(6)). The experimental results showed reductions in lift and increases in drag when in the simulated rain environment. Accompanying this was a reduction of the stall angle of attack by approximately 4 deg. The transient aerodynamic performance during transition from dry to wet steady-state conditions varied between a linear and a nonlinear transition. Author

N89-25952# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
FLOW CHARACTERISTICS ABOUT A TRAILING EDGE Ph.D. Thesis
DWAYNE S. SMITH Mar. 1989 112 p
(UTIAS-TN-270; ISSN-0082-5263) Avail: NTIS HC A06/MF A01

The mandate was to determine the mean and turbulent flow quantities of an attached, fully-developed boundary layer of an aft-loaded airfoil. The steady, two-dimensional flow characteristics of the near and far wake were also studied. This was done to gain an understanding of the viscous effects near the trailing edge of the airfoil in the hope of providing accurate data for airfoil performance models. Tests were conducted at a Reynolds number of 1.7 million based on chord and a Mach number of 0.14. The airfoil model on loan from Boeing of Canada's deHavilland Division was restricted to zero incidence and the boundary layer was artificially tripped at 0.075c. Artificial tripping was employed to provide a well-defined transition location over that of free transition for numerical analysis. The hot-wire anemometer measurements taken in the boundary layer and wake near the trailing edge reveal that a complex interaction takes place just aft of the airfoil where the upper and lower surface flows combine. The boundary layer thickness was found to increase quickly over the last few percent chord with a corresponding increase in turbulence intensity. The extreme asymmetry in the near wake profile was seen to transform into an essentially symmetric profile by approximately X/C= 1.075. such as, skin friction coefficients, displacement Author

N89-25953*# Eloret Corp., Sunnyvale, CA.
EXPERIMENTAL AND COMPUTATIONAL FLOW-FIELD RESULTS FOR AN ALL-BODY HYPERSONIC AIRCRAFT Technical Progress Report, 1 Oct. 1988 - 31 Mar. 1989
JOSEPH W. CLEARY 7 Jun. 1989 30 p Presented at the 6th National Aero-Space Plane Technology Symposium, 24-28 Apr. 1989
(Contract NCC2-416)
(NASA-CR-185347; NAS 1.26:185347) Avail: NTIS HC A03/MF A01 CSCL 01/1

A comprehensive test program is defined which is being implemented in the NASA/Ames 3.5 foot Hypersonic Wind Tunnel for obtaining data on a generic all-body hypersonic vehicle for computational fluid dynamics (CFD) code validation. Computational methods (approximate inviscid methods and an upwind parabolized Navier-Stokes code) currently being applied to the all-body model are outlined. Experimental and computational results on surface pressure distributions and Pitot-pressure surveys for the basic sharp-nose model (without control surfaces) at a free-stream Mach number of 7 are presented. K.C.D.

N89-25954*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE ACOUSTICS OF A SMALL-SCALE HELICOPTER ROTOR IN HOVER
CAHIT KITAPLIOGLU Apr. 1989 96 p
(NASA-TM-101058; A-89015; NAS 1.15:101058) Avail: NTIS HC A05/MF A01 CSCL 01/1

A 2.1 m diameter, 1/6-scale model helicopter main rotor was tested in hover in the test section of the NASA Ames 40- by 80-foot wind tunnel. Performance and noise data on a small-scale rotor at various thrust coefficients and tip Mach numbers were obtained for comparison with existing data on similar full-scale helicopter rotors. These data form part of a data base to permit the estimation of scaling effects on various rotor noise mechanisms. Another objective was to contribute to a data base that will permit the estimation of facility effects on acoustic testing. Acoustic 1/3-octave-band spectra are presented, together with variations of overall acoustic levels with rotor performance, microphone distance, and directivity angle. Author

N89-25957*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INFLUENCE OF THICKNESS AND CAMBER ON THE AEROELASTIC STABILITY OF SUPERSONIC THROUGHFLOW FANS: AN ENGINEERING APPROACH
JOHN K. RAMSEY Jun. 1989 22 p
(NASA-TM-101949; E-4642; NAS 1.15:101949) Avail: NTIS HC A03/MF A01 CSCL 01/1

An engineering approach was used to include the nonlinear effects of thickness and camber in an analytical aeroelastic analysis of cascades in supersonic acial flow (supersonic leading-edge locus). A hybrid code using Lighthill's nonlinear piston theory and Lanes's linear potential theory was developed to include these nonlinear effects. Lighthill's theory was used to calculate the unsteady pressures on the noninterference surface regions of the airfoils in cascade. Lane's theory was used to calculate the unsteady pressures on the remaining interference surface regions. Two airfoil profiles was investigated (a supersonic throughflow fan design and a NACA 66-206 airfoil with a sharp leading edge). Results show that compared with predictions of Lane's potential theory, for flat plates, the inclusion of thickness (with or without camber) may increase or decrease the aeroelastic stability, depending on the airfoil geometry and operating conditions. When thickness effects are included in the aeroelastic analysis, inclusion of camber will influence the predicted stability in proportion to the magnitude of the added camber. The critical interblade phase angle, depending on the airfoil profile and operating conditions, may also be influenced by thickness and camber. Compared with predictions of Lane's linear potential theory, the inclusion of thickness and camber decreased the aerodynamic stifness and increased the aerodynamic damping at Mach 2 and 2.95 for a cascade of supersonic throughflow fan airfoils oscillating 180 degrees out of phase at a reduced frequency of 0.1. Author

N89-25958*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PERFORMANCE AND LOADS DATA FROM AN OUTDOOR HOVER TEST OF A LYNX TAIL ROTOR
DAVID B. SIGNOR, GLORIA K. YAMAUCHI, CHARLES A. SMITH, and MARTIN J. HAGEN Jun. 1989 63 p
(NASA-TM-101057; A-89014; NAS 1.15:101057) Avail: NTIS HC A04/MF A01 CSCL 01/1

A Lynx tail rotor was tested in hover at the Outdoor Aerodynamic Research Facility at NASA Ames Research Center. The test objectives were to measure the isolated rotor performance to provide a baseline for subsequent testing, and to operate the rotor throughout the speed and collective envelope before testing in the NFAC 40- by 80-Foot Wind Tunnel. Rotor forces and blade bending moments were measured at ambient wind conditions from zero to 6.23 m/sec. The test envelope was limited to rotor speeds of 1550 to 1850 rpm and minus 13 deg to plus 20 deg of blade collective pitch. The isolated rotor performance and blade loads data are presented. Author

N89-25964# Ohio Univ., Athens. Dept. of Mechanical Engineering.
AN EXPERIMENTAL INVESTIGATION OF HIGH LIFT/HIGH RATE AERODYNAMICS OF AN UNSTEADY AIRFOIL Final Report, 1 Sep. 1987 - 31 Dec. 1988
G. M. GRAHAM Mar. 1989 49 p
(Contract AF-AFOSR-0312-87; AF PROJ. 2307)
(AD-A206964; AFOSR-89-0438TR) Avail: NTIS HC A03/MF A01 CSCL 01/1

An experimental study of a two dimensional NACA 0015 airfoil undergoing both positive and negative constant pitch rate motions at high angles of attack was conducted in the Ohio University tow tank facility. Nondimensional pitch rates in the range of 0.1 greater than K greater than 0.7 and Reynolds numbers in the range of 141,000 greater than Re greater than 342,000 were considered. Test results consist of lift and drag force coefficients and flow visualizations. The results of this study provide insight into the airfoil-dynamic stall vortex interaction during the pitch down motion and the cessation of aerodynamic stall. These data may be useful in high angle of attack applications such as the enhanced maneuverability concept for fighter aircraft. GRA

N89-25965# Winzen International, Inc., San Antonio, TX.
LONG DURATION BALLOON TECHNOLOGY SURVEY, PHASE 1 Final Report, 11 Aug. 1988 - 28 Feb. 1989
PAMELA G. SCOTT, THOMAS M. LEW, JAMES S. WILBECK, JAMES L. RAND, and RICHARD H. BREZINSKY 17 Mar. 1989 66 p
(Contract DAAH01-88-C-0715; ARPA ORDER 5916)
(AD-A206975; WII-9942-01-TR-01) Avail: NTIS HC A04/MF A01 CSCL 01/3

This feasibility study addresses the design and fabrication of a long endurance balloon vehicle capable of supporting 50 pounds at 120,000 feet for up to one year. The concept makes use of the experience gained by the scientific community over the past two decades in flying smaller payloads for long periods of time. The result of the effort is a prototype balloon which has a better lift to weight ratio than previous designs. This was achieved by the use of a novel shape (multiple intersecting spheres) and the use of a material new in the area of ballooning (Emblem, a biaxially oriented Nylon 6). This film demonstrates very high strength without displaying the susceptibility of prior films to pinholing. Other results of the effort are two analytical tools and specialized fabrication techniques. The analytical tools are a heat transfer model for predicting maximum and minimum super-temperatures of the balloon gas, and mechanical model to design the superpressure balloons for particular flight scenarios. GRA

N89-25966# Institut Franco-Allemand de Recherches, Saint-Louis (France).
VORTICES AND PRESSURE WAVES AT PLATES, CYLINDERS AND WIND PROFILES [WIRBEL UND DRUCKWELLEN AN PLATTEN, ZYLINDERN UND TRAGFLUEGELPROFILEN]
F. SEILER, J. SRULIJES, and A. GEORGE 19 Jan. 1988 37 p In GERMAN
(ISL-R-102/88; ETN-89-94853) Avail: NTIS HC A03/MF A01

Vortex behavior and Karman vortex street formation behind wing profiles in a shock tube are studied and visualized by differential interferometry. Precise image quality flow visualization allows observation of recompression shock waves together with pressure waves. For a wing profile in a hard incident subsonic flow an asymmetric vortex distribution around the wings is observed. Pressure waves are determined on the underside of the wing; the upward side is free of shock and pressure waves. ESA

N89-25969# Manchester Univ. (England). Aeronautical Group.
AN INITIAL ASSESSMENT OF THE IMPACT OF BOUNDARY LAYER CONTROL ON SST
D. I. A. POLL and S. R. BUNTING 1988 17 p
(AERO-REPT-8802; ETN-89-94953) Avail: NTIS HC A03/MF A01

The implications of establishing laminar flow on a vehicle traveling at supersonic speed are considered. A simple analysis is used to estimate the magnitudes of the different components which make up the total aircraft drag and to determine how the relative importance of each component changes with increasing flight Mach number. Special consideration is given to the effect of laminarization on the equilibrium surface temperatures and an attempt is made to assess the impact of the observed changes on the vehicle design. Results indicate that substantial improvements in performance are available for vehicles flying at up to Mach 4. ESA

N89-25970# Manchester Univ. (England). Dept. of Aeronautical Engineering.
AN INTRODUCTION TO THE PROBLEM OF AERODYNAMIC HEATING
D. I. A. POLL 1989 17 p
(AERO-REPT-8901; ETN-89-94956) Avail: NTIS HC A03/MF A01

Aerodynamic heat transfer to a body travelling at high speed

is reviewed. The various sources of thermal energy which act upon the outer surface are identified and their relative importance is examined. Special consideration is given to the convective heat transfer from the body boundary layer. The complete boundary layer problem is described and an approximate solution method is presented. A generalized evaluation of the heating loads is developed and the results suggest that, for high speed devices flying at low altitude, the boundary layer convective heat load is the dominant term. This suggests that the surface temperatures and heat loads can only be evaluated by a simultaneous solution of the boundary layer flow and internal unsteady heat conduction problems. ESA

N89-25972# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Abteilung Trans-Ueberschall-Entwuresaerodynamik.
A LIFTING SURFACE METHOD FOR THE CALCULATION OF STEADY AND UNSTEADY, INCOMPRESSIBLE PROPELLER AERODYNAMICS Ph.D. Thesis - Technische Univ., Brunwsick
JUERGEN SCHOENE Jan. 1989 120 p In GERMAN; ENGLISH summary
(DFVLR-FB-89-04; ISSN-0171-1342; ETN-89-94980) Avail: NTIS HC A06/MF A01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Fed. Republic of Germany, DM 40

A lifting surface method for steady and unsteady propeller aerodynamics which allows the calculation of the lift distribution of single and counter-rotating propellers in axial onflow is described. The integral equation for lifting surfaces with time dependent lift distribution is derived, based on the acceleration potential of Prandtl. A solution method for this equation is developed. The lifting surfaces of the propeller blades are subdivided into panels. On a panel, doublets are located along a line. The doublet strength is developed into a Fourier series. A set of linear algebraic equations has to be solved. Calculations for wings, for single propellers with steady and unsteady lift distributions and for counter-rotating propellers are shown. ESA

N89-25973*# Continuum Dynamics, Inc., Princeton, NJ.
FEASIBILITY OF PREDICTING PERFORMANCE DEGRADATION OF AIRFOILS IN HEAVY RAIN Final Report
A. J. BILANIN, T. R. QUACKENBUSH, and A. FEO Jun. 1989 44 p
(Contract NAS1-18302)
(NASA-CR-181842; NAS 1.26:181842; CDI-89-04) Avail: NTIS HC A03/MF A01 CSCL 01/1

The heavy rain aerodynamic performance penalty program is detailed. This effort supported the design of a fullscale test program as well as examined the feasibility of estimating the degradation of performance of airfoils from first principles. The analytic efforts were supplemented by a droplet splashback test program in an attempt to observe the physics of impact and generation of ejecta. These tests demonstrated that the interaction of rain with an airfoil is a highly complex phenomenon and this interaction is not likely to be analyzed analytically with existing tools. Author

03

AIR TRANSPORTATION AND SAFETY

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

A89-45129
SLED TESTING OF U.S. AIR FORCE ESCAPE SYSTEMS
C. D. GRAGG (USAF, Holloman AFB, NM) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. II-1.1 to II-1.7. refs

Tests to verify the safety of escape systems are conducted at the High Speed Test Track at Holloman Air Force Base, New Mexico. A brief description is given of the facility and the techniques used in escape system testing. An explanation is given of the test analysis philosophy and procedures. The testing described includes most of the escape systems now in the Air Force inventory as well as some presently in use by other governmental agencies and foreign governments. Ejection seats, crew modules, and extraction seat escape systems have been tested. Author

A89-45296#
AGING AIRCRAFT
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 27, July 1989, p. 38-42.

The first 290 B737 airliners built employed a cold-bonding adhesive where the skin running along the top of the fuselage overlaps the adjacent skin panel; subsequent aircraft were hot-bonded in an autoclave; investigators have found that surface preparation before application of the cold-bonding adhesive failed to ensure adequate bonding to the skin. As a result, bonds degraded and shifted all shear loads to the countersunk rivets which pass through the lap joint to attach the panels to a stringer, overstressing the adjacent skin and leading to extensive crack formation and growth. These factors are held responsible for the peeling off of a B737's upper fuselage in flight on April 28, 1988. An account is presently given of additional, corrosion-related fatigue failures in older aircraft. O.C.

A89-45337
AN AIR PHOTO ANALYSIS OF AN AIRPLANE CRASH
J. N. RINKER, J. H. GARSTANG, D. EDWARDS, and J. J. DEL VECCHIO (U.S. Army, Engineer Topographic Laboratories, Fort Belvoir, VA; Canadian Aviation Safety Board, Ottawa, Canada) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, July 1989, p. A6-A15. refs

Crash patterns such as cut and damaged vegetation, gouges, debris scatter and burn areas, and their spatial relations can be effectively evaluated by the analysis of stereo aerial photographs. Results from the Canadian Aviation Safety Board's use of aerial photography in the Gander, Nfld., crash of December 12, 1985, show that the technique can lend direct support to an investigation in several ways. It provides an overall perspective view of the regional relations of the crash patterns and helps direct ground activities. In tree-covered areas, it can help establish aircraft attitude and orientation. When combined with debris plots and attitude determinations, it can help establish the breakup sequence. And, when coupled to photogrammetric procedures,it can assign dimensional values to attitude, descent path, areas and lengths. Author

A89-46593
FAST BRAKE
JAKE PAGE Air and Space (ISSN 0886-2257), vol. 4, Aug.-Sept. 1989, p. 46-51.

The development of high-performance parachutes is discussed, focusing on the F-111 parachute system. Computer models, wind tunnel tests, rocket sled tests, and air drops from a B-52 are used in the design and testing of the parachute system. The requirements for the F-111 system include carrying a module load of 3,300 pounds with a rate of descent of about 25 ft/s. The design is based on a cluster of three light-weight parachutes with a central disreef system to ensure that the cluster disreefs simultaneously so that none of the three parachutes is subjected to excessive loads. R.B.

A89-47334
AUTOMATION IN TRANSPORT AIRCRAFT - CURRENT AND FUTURE TRENDS
A. G. LIDDLE (British Air Line Pilots Association, Harlington, England) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 73-77.
(SAE PAPER 881468)

Current automation technology for transport aircrafts, from the

design stage to the operational use, is discussed together with human factors involved. Recently introduced automation systems AB757/767 and A320 are assessed with respect to their instrumentation, and the advantages and disadvantages of these aircraft are discussed and compared with those of older systems. The danger of overautomation is emphasized. I.S.

A89-47339
AIRLINE OPERATIONS AND THE CONTAMINATED RUNWAY
KNUT ANFINDSEN (International Federation of Air Line Pilots' Associations, Egham, England) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 119, 120.
(SAE PAPER 881460)

Problems related to airline operations on a runway contaminated by hard-packed snow overlaid with glazed ice and water are highlighted, and methods that can be used for reducing risk on a slippery runway are discussed. It is often suggested that the ICAO standard for the aircraft performance operating limitations (5.2.6) cannot be strictly implemented because it is difficult to measure friction by ground measuring equipment and then use these measurements to predict the aircraft-stopping performance. However, experience shows that a reliable runway friction-measuring equipment can significantly contribute to improved safety of winter operations. I.S.

N89-25142# Federal Aviation Administration, Atlantic City, NJ.
NOTICE TO AIRMEN (NOTAM) SYSTEM OPERATIONAL CONCEPT Final Report
BETTY K. FALATO Dec. 1988 56 p
(DOT/FAA/CT-TN89/10; DOT/FAA/DS-89/05) Avail: NTIS HC A04/MF A01

A requirement for the National Airspace System (NAS) to provide timely knowledge to users of information which is essential to safety of flight is identified in the NAS System Requirement Specification, NAS-SR-1000. The primary method of providing timely aeronautical information is via the Notice to Airmen (NOTAM) system. A concept of operations is presented for the NOTAM system. It describes NOTAM system capabilities and shows the relationships between subsystems, facilities, information, and operators/users. It is intended to provide a common perspective for personnel involved in NOTAM-related activities, assist in determining whether the NOTAM system meets formal requirements, and support coordination among the organizations involved with the NOTAM system. Author

N89-25143 Civil Aviation Authority, London (England).
UK AIRMISSES INVOLVING COMMERCIAL AIR TRANSPORT
Dec. 1988 73 p
(CAA-3/88; ISSN-0951-6301; ETN-89-94326) Avail: Civil Aviation Authority, Greville House, 37 Gratton Road, Cheltenham, England, 5 sterling pounds

Statistics on commercial air transport airmisses in United Kingdom airspace from 1978 to Apr. 1988 are presented. Numbers of incidents; aircraft involved; and airmisses related to flying hours are shown. Incident reports for the period Jan. to Apr. 1988 are reproduced. During this period, there were 21 incidents, involving a total of 31 aircraft, giving an average 3.8 commercial air transport aircraft in risk-bearing airmisses per 100,000 hr flown. ESA

N89-25144# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Abteilung Glaechenflugzeuge.
CONTRIBUTIONS TO THE IMPROVEMENT OF FLIGHT SAFETY IN WIND SHEAR Ph.D. Thesis - Technische Univ., Brunswick
REINHARD KOENIG Dec. 1988 186 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1141)
(DFVLR-FB-88-49; ISSN-0171-1342; ETN-89-94635) Avail: NTIS HC A09/MF A01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Fed. Republic of Germany, DM 65.50

From the description of the wind shear effects on the energy state of the aircraft, measures are derived in order to define a controller that improves flight safety. In comparison to a conventional flight control system, this approach presents advantages for reducing windshear effects. The actual windshear problem stems from neither the controlled flight nor the limited aircraft performance, but rather from manual flight. The pilot is unable to perform with conventional instrumentation the necessary measures, such as setting the thrust at the right time and level. Indicating the energy and power loss via signals sent into modified instruments leads to an improvement in flight performance during windshear. It is therefore shown that through suitable instrumentation modifications the effects of wind shear can be reduced. ESA

N89-25974# National Transportation Safety Board, Washington, DC.
GENERAL AVIATION ACCIDENTS INVOLVING VISUAL FLIGHT RULES FLIGHT INTO INSTRUMENT METEOROLOGICAL CONDITIONS
8 Feb. 1989 39 p
(PB89-917001; NTSB/SR-89/01) Avail: NTIS HC A03/MF A01 CSCL 01/3

A statistical compilation is presented of data from the National Transportation Safety Board's Aviation Accident Data System. The data includes 361 general aviation accidents that occurred between 1983 and early 1987. In all of these accidents, visual flight rule flight into instrument meteorological conditions was listed as a probable cause or a related factor. There were 276 fatal accidents which resulted in 583 fatalities. Ninety-four percent of the aircraft involved in these accidents were airplanes; the remainder were helicopters. Author

N89-25976# Boeing Co., Seattle, WA. Commercial Airplanes.
AIRPLANE TESTS OF ENHANCED EMERGENCY SMOKE VENTING Final Report
ELLIOTT L. MAYLOR Mar. 1989 60 p
(Contract DTFA03-88-C-00056)
(D218N301; DOT/FAA/CT-89/9) Avail: NTIS HC A04/MF A01

This airplane test program evaluated the capability of certain air conditioning (environmental control) system modifications to enhance the venting of neutral or buoyant smoke that may be continuously injected into the passenger cabin during an inflight fire emergency. The program used a Boeing 757 airplane modified by adding an outflow valve in the forward upper lobe fuselage and changing to high-flow control valves in both air conditioning packs. Artificially generated smoke, neutral and with helium added to simulate buoyancy, was released at various passenger cabin locations. Data from the ground tests showed that an upper lobe outflow valve controls either neutral or buoyant smoke. Cruise/descent/land test results showed that neutral smoke can be controlled with either an upper or lower lobe outflow valve if the outflow valve and the smoke source are at the same end of the passenger cabin; this capability is not changed significantly by a 30 percent increase to the current pack flow rate. The results also showed that maintaining pack flow while doors are open for passenger evacuation causes an undesirable increase in the rate of smoke spreading into the smoke free portions of the cabin. Author

N89-25977*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF SEVERE ATMOSPHERIC DISTURBANCES FROM AIRLINE FLIGHT RECORDS
R. C. WINGROVE, R. E. BACH, JR., and T. A. SCHULTZ Jun. 1989 10 p Presented at the AGARD Flight Mechanics Panel Symposium-Flight in Adverse Environmental Conditions, Gol, Norway, 8-11 May 1989
(NASA-TM-102186; A-89111; NAS 1.15:102186) Avail: NTIS HC A02/MF A01 CSCL 01/3

Advanced methods were developed to determine time varying winds and turbulence from digital flight data recorders carried aboard modern airliners. Analysis of several cases involving severe

clear air turbulence encounters at cruise altitudes has shown that the aircraft encountered vortex arrays generated by destabilized wind shear layers above mountains or thunderstorms. A model was developed to identify the strength, size, and spacing of vortex arrays. This model is used to study the effects of severe wind hazards on operational safety for different types of aircraft. The study demonstrates that small remotely piloted vehicles and executive aircraft exhibit more violent behavior than do large airliners during encounters with high-altitude vortices. Analysis of digital flight data from the accident at Dallas/Ft. Worth in 1985 indicates that the aircraft encountered a microburst with rapidly changing winds embedded in a strong outflow near the ground. A multiple-vortex-ring model was developed to represent the microburst wind pattern. This model can be used in flight simulators to better understand the control problems in severe microburst encounters. Author

N89-25979# Test Wing (4950th), Wright-Patterson AFB, OH. Aeronautical Systems Div.
EC-18B/BOEING 707 SMOKE VENTING FLIGHT TEST Final Report, Jan. - Jul. 1988
DANIEL J. MOKRIS 27 Mar. 1989 75 p
(AD-A206601; REPT-4950/FTR-88-05-03) Avail: NTIS HC A04/MF A01 CSCL 01/2

This report presents the results of the smoke venting flight test on a USAF C-18, and a modified B-707 aircraft. A 3-in. x 4-in. smoke elimination valve (SEV) was installed in a metal window plug in a fuselage window forward of the wing's leading edge. The SEV consisted of a hinged flat plate that extended out into the slipstream. The local airflow accelerated around the plate, decreasing pressure in the area, and creating a draw that pulled smoke from the cabin of the aircraft. The objective of the test was to prove the feasibility of the SEV for venting smoke. The aircraft was instrumented with smoke density detecting light meters and a computerized data collection system. First, a baseline test of the aircraft's pressurization and air conditioning system was conducted. Then the SEV was opened to assess its smoke clearing capabilities. Smoke clearing time constants were developed to gauge the system's performance and ranged from 57 to 555 seconds, depending on the test condition. While the SEV did exhaust smoke, complex airflow within the cabin appeared to cause air stagnation in certain areas. This in turn forced the time constants to increase when the SEV was opened, a trend exactly opposite of what was expected. Recommendations were made to re-accomplish the tests using a more realistic scenario, repeat runs to increase reliability of data collected, and use some means to visualize local flow patterns in certain key areas around the cabin. GRA

N89-25981*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONTROLLER EVALUATIONS OF THE DESCENT ADVISOR AUTOMATION AID
LEONARD TOBIAS, UWE VOLCKERS (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.), and HEINZ ERZBERGER Jun. 1989 13 p Presented at the AIAA American Control Conference, Pittsburgh, PA, Jun. 1989
(NASA-TM-102197; A-89150; NAS 1.15:102197) Avail: NTIS HC A03/MF A01 CSCL 01/3

An automation aid to assist air traffic controllers in efficiently spacing traffic and meeting arrival times at a fix has been developed at NASA Ames Research Center. The automation aid, referred to as the descent advisor (DA), is based on accurate models of aircraft performance and weather conditions. The DA generates suggested clearances, including both top-of-descent point and speed profile data, for one or more aircraft in order to achieve specific time or distance separation objectives. The DA algorithm is interfaced with a mouse-based, menu-driven controller display that allows the air traffic controller to interactively use its accurate predictive capability to resolve conflicts and issue advisories to arrival aircraft. This paper focuses on operational issues concerning the utilization of the DA, specifically, how the DA can be used for prediction, intrail spacing, and metering. In order to evaluate the DA, a real time simulation was conducted using both current and retired controller subjects. Controllers operated in teams of two, as they do in the present environment; issues of training and team interaction will be discussed. Evaluations by controllers indicated considerable enthusiasm for the DA aid, and provided specific recommendations for using the tool effectively. Author

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

A89-43827#
DEVELOPMENT AND VERIFICATION OF SOFTWARE FOR FLIGHT SAFETY CRITICAL STRAPDOWN SYSTEMS
WOLFGANG HASSENPFLUG and HOSSEIN AFZALI (LITEF GmbH, Freiburg, Federal Republic of Germany) IN: Symposium Gyro Technology 1988; Proceedings of the Symposium, Stuttgart, Federal Republic of Germany, Sept. 20, 21, 1988. Stuttgart/Duesseldorf, Universitaet Stuttgart/Deutsche Gesellschaft fuer Ortung und Navigation, 1988, p. 2.0-2.12.

A software-development methodology is described which was proven to work satisfactorily to produce highly reliable software for flignt safety critical strapdown systems. Present in-service results indicate that the design goal of less than or equal to 10 to the -9th failures per flying hour can be achieved with a very high degree of confidence. The methodology was approved by most of the civil aviation agencies of the Western world and was accepted by military agencies to reach flight clearance for an inherently unstable fighter aircraft demonstrator. I.S.

A89-43828#
NEW KALMAN FILTER ALGORITHMS FOR HYBRID NAVIGATION, FLIGHTPATH COMPUTATION AND INERTIAL GEODESY
H.-J. HOTOP (DFVLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) IN: Symposium Gyro Technology 1988; Proceedings of the Symposium, Stuttgart, Federal Republic of Germany, Sept. 20, 21, 1988. Stuttgart/Duesseldorf, Universitaet Stuttgart/Deutsche Gesellschaft fuer Ortung und Navigation, 1988, p. 3.0-3.19. refs

A new numerically stable Kalman filter algorithm, based on orthogonal transformations, is developed and verified by an application to a laser strapdown inertial navigation system. A comparison of simulation results obtained with the new Kalman filter to those of the conventional algorithm, the Joseph algorithm, and the Bierman algorithm (executed using the IBM 4381, IBM 3090, and GRAY-XMP) showed that the new Kalman algorithm is superior with regard to the speed of computing process and the ability to handle correlated measurements without the need for additional transformations. It is suggested that the new algorithm will find applications in long-duration hybrid navigation, flight guidance, and inertial geodesy. I.S.

A89-43891
NAVIGATION AIDS TO AIRCRAFT ALL-WEATHER LANDING
JOHN CHARNLEY (Royal Institute of Navigation, London, England) (Royal Institute of Navigation, Annual General Meeting, 42nd, London, England, Oct. 26, 1988) Journal of Navigation (ISSN 0373-4633), vol. 42, May 1989, p. 161-186. refs

Progress made in aids to aircraft all-weather operation is reviewed, starting from early attempts made during World War I to the current capability in which the safe landing of modern civil transport aircraft in very low visibility is regarded as a relatively routine operation. Particular attention is given to various fail-safe techniques for the protection against the effects of failure in the critical landing period, improvements in the instrument landing

system, and the subject of software integrity. Finally, future developments are discussed with emphasis on the microwave landing system. V.L.

A89-43893
OMEGA NAVIGATION IN THE SHADOW OF ANTARCTICA
R. BARR (Department of Scientific and Industrial Research, Physics and Engineering Laboratory, Wellington, New Zealand) and K. B. YOUNG (Royal New Zealand Air Force, Whenuapai) Journal of Navigation (ISSN 0373-4633), vol. 42, May 1989, p. 236-247. refs

A series of measurements are examined to determine the physical processes responsible for positional fix errors obtained from the Omega navigation system at high southern latitudes (70-75 deg S). Optimal strategies are suggested for station selection and rejection which should improve significantly the accuracy of the Omega navigation system, bringing it to levels accepted for low-latitude navigation. V.L.

A89-43894
EVALUATING ILS AND MLS SITES WITHOUT FLIGHT TESTS
P. R. MAHAPATRA (Indian Institute of Science, Bangalore, India) and M. M. POULOSE (National Airports Authority of India, Bangalore, India) Journal of Navigation (ISSN 0373-4633), vol. 42, May 1989, p. 278-290. refs

Instrument landing systems (ILS) and the upcoming microwave landing systems (MLS) are (or are planned to be) very important navigational aids at most major airports of the world. However, their performance is directly affected by the features of the site in which they are located. Currently, validation of the ILS performance is through costly and time-consuming experimental methods. This paper outlines a powerful and versatile analytical approach for performing the site evaluation, as an alternative to the experimental methods. The approach combines a multi-plate model for the terrain with a powerful and exhaustive ray-tracing technique and a versatile and accurate formulation for estimating the electromagnetic fields due to the array antenna in the presence of the terrain. It can model the effects of the undulation, the roughness and the impedance (depending on the soil type) of the terrain at the site. The results computed from the analytical method are compared with the actual measurements and good agreement is shown. Considerations for site effects on MLS are also outlined. Author

A89-45065
A KNOWLEDGE-BASED EN ROUTE MONITOR FOR AIR TRAFFIC CONTROL
CHIN E. LIN and M. C. HONG (National Cheng Kung University, Tainan, Republic of China) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 25, May 1989, p. 392-400. refs

The en route monitor system (ERMS), which is a software system designed to assist human controllers, was developed as a tool for the control center. A domain-specific knowledge-based design approach was used. The system is implemented in Turbo Prolog. The problem and solution techniques are discussed in detail, and examples and simulations are demonstrated to show the potential application of the ERMS in air traffic control. I.E.

A89-45134
THE SYSTEM 500, A REAL-TIME FLIGHT TEST TELEMETRY SYSTEM
PAUL J. FRIEDMAN and GALE L. WILLIAMSON (Loral Instrumentation, San Diego, CA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. III-4.1 to III-4.7.

The System 500 is a distributed architecture, real-time telemetry data acquisition, processing, and graphics display system developed specifically for flight test applications. It was designed for flight test engineers to make real-time decisions on quality and safety of maneuver and to evaluate vehicle and system performance. Traditional system solutions make extensive use of large, powerful, and expensive computers for processing, data storage, and distribution. Instead, the System 500 brings functions to the source in a distributed architecture. Data is captured, decommutated, processed in real time by traditional or user-created algorithms, displayed on color graphics workstations, and stored on very high performance media or transferred to a central computer for use in traditional analysis and distribution. Author

A89-45138
A SIMPLE LOW-COST TELEMETRY SYSTEM FOR THOSE OF MODEST MEANS
DAVID B. BUSHNELL, WILLIAM C. SCHINSTOCK, and WILLIAM G. SCHWEIKHARD (Kohlman Systems Research, Lawrence, KS) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. IV-3.1 to IV-3.10.

A simple low-cost low-data-rate telemetry system has been developed and flight tested. The telemetry system consists of an airborn modem and transmitter, and a ground-based receiver, modem, and computer. Data to be telemetered is entered in RS-232 format and is used to frequency modulate an RF transmiter. It is shown that the 10-W S-band transmitter can provide a telemetry range in excess of 100 nautical miles and that the system can record 87 parameters at one sample per second. The ground-based system stores, processes, and displays the telemetered data in engineering units. R.R.

A89-45221
SOME ASPECTS OF INTERFERENCE ON LORAN-C
L. P. REMMERSWAAL (Philips Telecommunications and Data Systems, Netherlands) and D. VAN WILLIGEN (Delft, Technische Universiteit, Netherlands) IEE Proceedings, Part F: Radar and Signal Processing (ISSN 0956-375X), vol. 136, pt. F, no. 3, June 1989, p. 109-117. Research supported by Stichting voor de Technische Wetenschappen. refs

The expansion of Loran-C in Europe with its already heavily loaded LF frequency spectrum is a challenge to the receiver designer. The number of continuous wave (CW) interferences often exceeds the number of notch filters available in Loran-C receivers. Thus, decisions have to be made about which interfering signals are to be suppressed. However, the complex nature of the disturbance of phase and envelope of Loran-C signals by CW interference makes understanding of the process difficult. Therefore, a practical vector-analysis method is outlined which helps to explain the effects of asynchronous and various types of synchronous interferences and noise. The net result on the phase and envelope tracking process is demonstrated with the LOran Simulation Program LOSP which runs on a personal computer. Finally, some general ideas on interference-reduction techniques are discussed. Author

A89-45875
RADIO TECHNICAL COMMISSION FOR AERONAUTICS, ANNUAL ASSEMBLY MEETING AND TECHNICAL SYMPOSIUM, WASHINGTON, DC, NOV. 28-30, 1988, PROCEEDINGS
JOANN C. JAGO, ED. (Radio Technical Commission for Aeronautics, Washington, DC) Meeting and Symposium sponsored by the Radio Technical Commission for Aeronautics. Washington, DC, Radio Technical Commission for Aeronautics, 1988, 288 p. No individual items are abstracted in this volume.

Technological and standardization problems in the development of communication avionics are examined in reviews and reports. Particular attention is given to ICAO planning for future aeronautical communication standards, digital voice communication techniques, communication systems for next-generation commercial aircraft, extending data communication to oceanic routes, RTCA mode-S data-link standardization, AEEC satellite-systems standardization, air communication using Inmarsat, and FAA support for future air-ground digital communication. Also included is a panel discussion presenting user perspectives on aeronautical telecommunication. Diagrams, drawings, and tables of numerical data are provided. T.K.

A89-47335
AIR TRAFFIC CONTROL - NO EASY SOLUTIONS IN A COMPLEX TERMINAL ENVIRONMENT
JOHN BENNETT (Luton International Airport, Ltd., London, England) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 79-85.
(SAE PAPER 881469)

Traffic control problems in a busy terminal area are discussed, with particular consideration given to control problems specific for the Luton International Airport, which lies 30 miles north of London. Factors which affect the air traffic (such as noise preferential routes, night restrictions, and flight-coordination schedules) are discussed along with the present equipment and procedures used in the traffic control and the effect of automatic data processing. It is concluded that the sectorization of airspace according to route, together with the introduction of free-flow systems separate from other outbound and inbound routes, would allow more capacity for air traffic; however, these measures will lead to diminished flexibility, making the air traffic structure very rigid in 'slot time', route, and level terms. I.S.

A89-47336
RESEARCH IN AUTOMATION FOR AIR TRAFFIC CONTROL - UNITED KINGDOM WORK AND ASSOCIATED EUROPEAN PROJECTS
ARTHUR G. THORNING (Civil Aviation Authority, London, England) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 87-94.
(SAE PAPER 881470)

Research work in the United Kingdom aimed at developing the benefits of automation in Air Traffic Management is described. To emphasize the systematic and international nature of such work, related projects are also outlined. The paper gives a broad overview of projects in UK and Europe rather than much detail and as such is aimed at stimulating interest in and understanding of the ATC aspects of automation. Author

A89-47340
MICROWAVE LANDING SYSTEM INSTRUMENTATION - A PILOT'S VIEWPOINT
N. J. DUNSFORD (International Federation of Air Line Pilots's Associations, Egham, England) IN: Aerospace Behavioral Technology Conference and Exposition, 7th, Anaheim, CA, Oct. 3-6, 1988, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1989, p. 121-130.
(SAE PAPER 881461)

This paper presents a pilot's viewpoint of the Microwave Landing System (MLS), which is being developed as a replacement for the Instrument Landing System (ILS) as the ICAO standard approach landing aid. The basic and advanced MLS procedures are outlined, and all the steps to be followed in an MLS approach procedure are described in detail, with special consideration given to the role of the aircraft crew during the approach. It is shown that the MLS has a degree of flexibility not allowed by the ILS. I.S.

N89-25984# Federal Aviation Administration, Atlantic City, NJ.
HELIPORT IDENTIFICATION BEACON
PAUL H. JONES Apr. 1989 14 p
(DOT/FAA/CT-TN89/31) Avail: NTIS HC A03/MF A01

The International Civil Aviation Organization (ICAO) has proposed the adoption of a standard international heliport beacon. This beacon consists of a white strobe light coded to display a sequence of four flashes that signify the Morse code letter H. For evaluation purposes, the proposed strobe beacon was compared to the United States standard three-color rotating beacon. Pilots completed post-flight questionnaires after viewing both beacons. Without any clear-cut choice as to which beacon was the best, pilot responses indicated that both beacons provide adequate guidance in locating a heliport. From these results, there does not appear to be reasonable cause for opposing adoption of the proposed strobe beacon as an ICAO standard. Furthermore, there does not appear to be any compelling reason to change the present United States standard for heliport identification beacons at this time. Author

N89-25985# Federal Aviation Administration, Atlantic City, NJ.
EVALUATION OF A PROJECTION ALGORITHM FOR THE STEREOGRAPHIC REPRESENTATION OF AIRCRAFT IN AN AIR TRAFFIC CONTROL SYSTEM
ROBERT G. MULHOLLAND Apr. 1989 27 p
(DOT/FAA/CT-TN89/20) Avail: NTIS HC A03/MF A01

In an air traffic control system such as the National Airspace System (NAS) horizontal control is effected from a ground facility through the separation of aircraft in at least one of the dimensions of latitude and longitude. Ideally, these dimensions are obtained indirectly in real time by means of a projection algorithm that maps raw surveillance information into the stereographic representation of aircraft latitude and longitude on a plane surface. In practice, there is always some processing delay and some difference between the algorithm output and the actual stereographic representation of aircraft position. In addition, the accuracy is affected by the orientation of the plane relative to the control jurisdiction of the facility. While the projection algorithm currently employed in NAS is capable of timely delivery of output due to its structural simplicity, it cannot meet the accuracy requirement of the Advanced Automation System. The accuracy of a simple modification of the NAS algorithm that does meet this requirement is evaluated by means of a technique that avoids determination of the geometric relationship of the plane and the control jurisdiction. Author

N89-25986# Federal Aviation Administration, Atlantic City, NJ. Technical Center.
CONTROLLER EVALUATION OF INITIAL DATA LINK AIR TRAFFIC CONTROL SERVICES. VOLUME 2: MINI STUDY 2 Final Report
NICHOLAS J. TALOTTA, CLARK SHINGLEDECKER, THOMAS ZURINSKAS, KAROL KERNS, PRESTON CRATCH (Mitre Corp., Atlantic City, NJ.), and HENRY R. MAREK Mar. 1989 73 p
(DOT/FAA/CT-89/14-VOL-2) Avail: NTIS HC A04/MF A01

The results of Mini Study 2 are given. This Mini Study was conducted at the Federal Aviation Administration (FAA) Technical Center utilizing the Data Link test bed. Initial Data Link air traffic control services were evaluated under part task simulation conditions in order to identify service delivery methods which optimize controller acceptance, performance, and workload. Author

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A89-43884
DAMAGE TOLERANCE ANALYSIS AND STRUCTURAL INTEGRITY IN AIR FORCE AIRCRAFT
ALFRED G. HANSEN Aerospace Engineering (ISSN 0736-2536), vol. 9, June 1989, p. 19-21.

Damage tolerance analysis (DTA) of high-performance aircraft structures proceeds on the assumption that flaws exist which cannot always be detected. The flaws are initially due to the manufacturing process, which through subsequent service trauma grow into cracks that degrade structural strength. By analyzing the growth pattern for a given load history, DTA allows engineers to predict how large the crack can become before safety is jeopardized, as well as the time remaining before that point is

reached. In the course of DTA testing, full-scale aircraft are subjected to millions of load applications to discover unanticipated problem areas and define their solution. O.C.

A89-43887
TUPOLEV'S NEW TWIN
ALAN POSTLETHWAITE Flight International (ISSN 0015-3710), vol. 135, May 20, 1989, p. 44-46.

The Tu-204 is the first Soviet airliner to incorporate a fly-by-wire control system without mechanical backup; it also employs such B757-equivalent technologies as all-graphics-display cockpit instrumentation, a supercritical-airfoil geometry wing, winglets, and Al-Li alloy primary structures. Derivatives of the Tu-204 currently planned involve the use of ultrahigh-bypass turbofans, and even the accommodation of cryotankage for the use of liquefied natural gas as fuel. A primary design task has been the reduction of direct operating costs; with this in view, routine overhauls have been eliminated, and units will be changed only upon failure. Service life is projected to be 20 years of use at an annual utilization of up to 3000 hours. O.C.

A89-43888
ILYUSHIN GOES THE DISTANCE
ALAN POSTLETHWAITE Flight International (ISSN 0015-3710), vol. 135, May 20, 1989, p. 49-51.

The USSR's Il-96-300, which is a 300-seat wide-body airliner optimized for long-range flights of 9000 km with full passenger load, is that nation's first fly-by-wire commercial aircraft and appears to be intended for a production run of at least 100 units. Like the A340-300 aircraft to which it is approximately comparable, the Il-96-300 is a four-turbofan aircraft with winglets and six color-coded graphics CRTs that serve as cockpit instrument displays. A stretch-version capable of accommodating 400 passengers is being contemplated. The excellent range characteristics are substantially due to the use of advanced aluminum alloy and composite airframe components. The fly-by-wire system used is claimed to offer performance comparable to that of the A320 airliner. O.C.

A89-44375
ILYUSHIN'S NEW WORKHORSE
ALAN POSTLETHWAITE Flight International (ISSN 0015-3710), vol. 135, May 13, 1989, p. 29-31.

The Il-114 60-seat regional airliner, which will have its first flight some time in 1989, is expected to offer half the fuel consumption/passenger-km of the 52-seat An-24 transport that it will be replacing on routes of about 1000-km range. The two Isotov TV7-117 turboprop engines employed drive six-bladed synchronized propellers. Although the primary structure is entirely of conventional aluminum alloys, extensive use is made of composites in secondary structures. The planned production run is intensive, with 500 aircraft being manufactured in the first 5 years in two factories in the USSR; components are expected to be supplied by East European subcontractors. O.C.

A89-44975#
A SIMPLE THEORY OF AEROSPACEPLANE
RYOJIRO AKIBA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 423, 1989, p. 202-204. In Japanese, with abstract in English.

Simplified equations of energy and momentum conservation lead to a closed form expression of effective exhaust velocity of an air-breathing engine which characterizes an aerospace plane. Following features of hypervelocity propulsion are disclosed. First, the intake air is effective as an oxygen carrier, a momentum carrier, and an energy carrier, depending on the flight velocity. Second, actual thermochemical values allow only hydrogen to be the fuel of an aerospace plane. Third, the efficiency of energy utilization for intake air must exceed 90 percent in order to reach near an orbital speed. Author

A89-45030
RAFALE - DASSAULT'S NEW DAWN
MIKE GAINES Flight International (ISSN 0015-3710), vol. 135, June 10, 1989, p. 80, 81, 84 (3 ff.).

An account is given of the design features, variants, economic viability, performance capabilities and weapons suites of the French next-generation fighter aircraft, Rafale. Air-to-air, air-to-ground, and air-to-sea missions are envisioned. The last of these will be the preserve of a carrier-based naval variant, the Rafale M or 'maritime'; the other variant, Rafale D, or 'discrete', will be operated by the French Air Force and is optimized for stealthyness. Although the current, Rafale A technology-demonstrator is powered by two U.S.-built F404-GE-400 engine, Rafales M and D will be powered by M-88-2 augmented turbofans ultimately capable of producing 23,600 lbs of thrust on afterburner. SPF/DB Ti and Al-Li alloys are employed in the airframe primary structure. O.C.

A89-45041
THE ACE/RAFALE [L'ACE/RAFALE]
BRUNO REVELLIN-FALCOZ (Avions Marcel Dassault Breguet Aviation, S. A., Vaucresson, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 72-78. In French.

The characteristics and flight results of the Rafale A technology demonstrator are discussed. The ACE/Rafale employs large-aspect-ratio delta wings, a large all-flying canard surface, and semiventral air intakes. The flight control system includes a new control approach mode (drag-thrust control), large-incidence control, and a velocity-vector holding mode. Composite materials and other advanced materials make up 35 percent of the aircraft mass. Also considered are the M88 engine and man-machine interfaces of the aircraft. R.R.

A89-45043
AIRBUS - THE NEW FAMILIES [AIRBUS - LES NOUVELLES FAMILLES]
JACQUES MORISSET L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 89-98. In French.

The characteristics of the A320, A320 Stretch, A330, and A340 aircraft are described. The A320, with a seating capacity of 150-170, has a wider diameter than the B727, B737, and B757 and employs an electronic flight control system. The A320 stretch, with a seating capacity of 186-200, is proposed as an alternative to the B757. The A320 stretch uses double-slotted high-lift flaps, and it employs more powerful engines (13.15 tons of thrust for the CFM56-5B and 12.7 tons of thrust for the V2500-A5) than the A320. The A330 and A340 aircraft, variants of the A320, will have seating capacities of 295-335, and will employ optimized aerodynamic wing profiles, Al-Li alloys and composite materials, and an optimized cockpit design. R.R.

A89-45044
THE SYSTEMS OF THE FUTURE AIRBUS A330 AND A340 AIRCRAFT [LES SYSTEMES DES FUTURS AVIONS AIRBUS A.330 ET A.340]
JEAN-PIERRE LABORIE (Aerospatiale, Division Avions, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 99-108. In French.

The A330 and A340 aircraft, using the power generation technology and avionics of the A320, are described in detail. The CFM 56-5C2 engine has been selected for the A340 (providing 31,200 lbs of take-off thrust), while three engines are considered for the A330: (1) the CF6 80-E1 (providing 65,500 lbs of take-off thrust); (2) the PW4164 (providing 64,000 lbs of take-off thrust); and (3) the RB 211-524L (providing 65,000 lbs of take-off thrust). Other features of the A330 and A340 aircraft include a rocking bogie design for the landing gear system and optimized aerodynamic surfaces. R.R.

A89-45126
SOCIETY OF FLIGHT TEST ENGINEERS, ANNUAL SYMPOSIUM, 19TH, ARLINGTON, TX, AUG. 14-18, 1988, PROCEEDINGS
Symposium sponsored by the Society of Flight Test Engineers.

Lancaster, CA, Society of Flight Test Engineers, 1988, 220 p. For individual items see A89-45127 to A89-45146.

The present symposium includes such topics as powered lift aircraft takeoff, air-to-air combat helicopter development, the flight testing of a multimegawatt wind turbine, and outer wing residual strength testing of the C-130 Hercules. Papers are also presented on a real-time flight test telemetry system, the establishment of AI technology in a flight test environment, a video-based noncontact system for motion measurement, and low-cost equipment for flight test film and video evaluation. Also considered are a new flight flutter excitation system, the measurement of linear and angular displacement in prototype aircraft, and aircraft development test and evaluation. R.R.

A89-45127
POWERED LIFT AIRCRAFT TAKE OFF CLIMB PERFORMANCE WITH ONE ENGINE INOPERATIVE
JAMES R. ARNOLD and MICHELLE M. CORNING (FAA, Washington, DC) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. I-2.1 to I-2.5.

An analytical method for predicting the one engine inoperative takeoff climb performance of a powered lift aircraft is presented. The analysis is intended to include the possibility of a major aircraft configuration conversion and to highlight potential safety critical takeoff flight envelopes. The level flight data of the Bell XV-15 Tilt Rotor is used to illustrate the method, and the results of this analysis is compared to the FAA Proposed Powered Lift Criteria. Author

A89-45128
COST-EFFECTIVE APPROACH TO FLIGHT TESTING THE 'CASMU SKYSHARK' A STAND-OFF WEAPON DISPENSER
G. FERRETTI and P. DURANTI (Aeritalia S.p.A., Turin, Italy) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. I-3.1 to I-3.13.

The planning, designing, and carrying-out of the preliminary flight test program of the stand-off weapon dispenser Skyshark are discussed. The goals of the demonstration phase include proof-of-concept testing, the definition of the final aerodynamic configuration, and the assessement of the effectiveness of the flight control and armament systems. The most cost-effective mission sequence is found to be: (1) release from the parent aircraft; (2) separation; (3) controlled flight and deceleration; (4) firing of submunitions; (5) climb; (6) parachute deployment; (7) sinking and alighting on water; and (8) retrieval via helicopter. R.R.

A89-45132#
C-130 HERCULES OUTER WING RESIDUAL STRENGTH TESTS
ANDREW T. ZIMMERMAN (Lockheed Aeronautical Systems Co., Marietta, GA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. II-4.1 to II-4.12.

Static test were performed to calculate the residual strength of used outer wings removed from four operational C-130E and one C-130A aircraft. The results showed one of the three C-130E test specimens with in-service repairs to the wing structure to fail at slightly less than the limit load and the other two to fail at less than 150 percent. The C-130E test specimen with no repairs failed at 171 percent of the limit load. Existing USAF NDI procedures could not detect fatigue cracks which were the cause of test specimen failures at less than 150 percent of the design limit load, and new NDI methods were developed to improve detection of critical fatigue damage in the wing structure. R.R.

A89-45135
ESTABLISHING ARTIFICIAL INTELLIGENCE TECHNOLOGY IN A FLIGHT TEST ENVIRONMENT
JOSEPH N. BEASLEY and RICHARD T. BLACK (USAF, Flight Test Center, Edwards AFB, CA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. III-5.1 to III-5.7.

The application of AI technology to flight testing has been motivated by such problems as the recent data explosion, increased flying schedules, inexperienced engineers, and engineer attrition. Special attention is given to the development of an expert system that identifies flight maneuvers (such as sidelip, 1-g roll, windup turning, maximum g roll, slowdown turning, and 1-g deceleration) from flight data. It is pointed out that the knowledge base for the event identifier is simple, readable, and easily modified. Limitations of the system are addressed. R.R.

A89-45139
NUMERICAL MODELLING OF FLIGHT DYNAMICS AND FLIGHT TEST DATA IDENTIFICATION OF A JET TRAINER AIRPLANE
ZBIGNIEW DZYGADLO (Instytut Lotnictwa, Warsaw, Poland) and JERZY MARYNIAK (Warszawa, Politechnika, Warsaw, Poland) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. IV-4.1 to IV-4.11. refs

Flight test data identification methods and digital simulation techniques are used to model the flight dynamics and identify the aerodynamic performance and handling qualities of a jet trainer airplane. Wind tunnel test data, theoretical analysis results, and flight test results are used as input to nonlinear mathematical models. The method has been successfully demonstrated using the example of the TS-11 Iskra jet trainer airplane. R.R.

A89-45140
A NEW FLIGHT FLUTTER EXCITATION SYSTEM
WILMER H. REED, III (Dynamic Engineering, Inc., Newport News, VA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. V-1.1 to V-1.7. refs

An aerodynamic vane-type excitation system is described which can be powered by a small dc motor and readily installed on a test aircraft. The system consists of a fixed vane with a rotating slotted cylinder installed at the trailing edge. In the system, the sinusoidal excitation frequency is determined by the cylinder's rotation frequency, and the dynamic force amplitude by the degree of slot opening. Results obtained from wind tunnmel exciter model tests performed as low subsonic and transonic speeds show that the present system is capable, with very little electrical power, of producing dynamic forces comparable to those produced by conventional oscillating-vane systems. R.R.

A89-45141* National Aeronautics and Space Administration. Flight Research Center, Edwards, CA.
CURRENT FLIGHT TEST EXPERIENCE RELATED TO STRUCTURAL DIVERGENCE OF FORWARD-SWEPT WINGS
LAWRENCE S. SCHUSTER and WILLIAM A. LOKOS (NASA, Flight Research Center, Edwards, CA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. V-2.1 to V-2.10. Previously announced in STAR as N88-24633.

Flight testing the X-29A forward-swept wing aircraft has required development of new flight test techniques to accomplish subcritical extrapolations to the actual structural divergence dynamic pressure of the aircraft. This paper provides current experience related to applying these techniques to analysis of flight data from the forward-swept wing in order to assess the applicability of these techniques to flight test data. The measurements required, manuevers flown, and flight test conditions are described. Supporting analytical predictions for the techniques are described and the results using flight data are compared to these predictions. Use of the results during envelope expansion and the resulting modifications to the techniques are discussed. Some of the analysis

challenges that occurred are addressed and some preliminary conclusions and recommendations are made relative to the usefulness of these techniques in the flight test environment.
Author

A89-45145
THE MILITARY DASH 8 FLIGHT TEST PROGRAM
PAUL F. W. ADAMS and J. D. COLE (De Havilland Aircraft Company of Canada, Ltd., Downsview) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. VI-3.1 to VI-3.5.

Differences between the civil and military versions of the Dash 8 aircraft are pointed out, and results of the military Dash 8 flight test program are discussed. The stability and control tests included sidelip, stall, longitudinal stability, and response to sudden engine failure. The avionics system tests included bearing operation, beam tilting, antenna stabilization, and power density measurement. The navigation training system instruments include a ground mapping system, an inertial navigation system, and a dead reckoning computer. Test results have confirmed the effectiveness of the C 142 Transport and the CT 142 Navigation Trainer. R.R.

A89-45146
SERVICE SUITABILITY TESTING OF THE F/A-18A FOR USE BY THE BLUE ANGELS NAVY FLIGHT DEMONSTRATION TEAM
EUGENE J. FRASER and BRUCE A. KAPLAN (U.S. Navy, Naval Air Test Center, Patuxent River, MD) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. VI-4.1 to VI-4.16.

The results of continuous horizontal and vertical roll tests, along with flying quality and fuel system studies, for the F/A-18A aircraft (selected for the Blue Angels Flight Demonstration Team) are reported. The longitudinal trim system, the mechanical characteristics of the FCS, the static longitudinal stability, the maneuvering longitudinal stability, and the formation flight behavior of the F/A-18A were investigated for the case of aircraft employing an artificial force system for position control. The results show that the small pitch and heading oscillations and small lateral displacements produced by the near body axis roll improved the aesthetic qualities of the continuous horizontal roll maneuver.
R.R.

A89-45156
THE ATF IS ON ITS WAY
JAY JABOUR and DON NEWMAN (USAF, Advanced Tactical Fighter System Program Office, Edwards AFB, CA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 90-108.

This paper presents an overview of the development of the USAF's next air superiority fighter - the Advanced Tactical Fighter (ATF). The management of the Demonstration/Validation phase of the ATF is discussed, and the avionics approach of the ATF is examined. The testing that will be done in the Demonstration/Validation phase is described. C.D.

A89-45160
DIGITAL FLIGHT AND INLET CONTROL IN THE SR-71
THOMAS V. TILDEN (USAF, Logistics Command, Wright-Patterson AFB, OH) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 167-181. refs

The original analog controls in SR-71 for stability augmentation, autopilot, inlet control, air data computation, and pitch warning functions were replaced by a single three-computer digital control system. The Digital Automatic Flight and Inlet Control System (DAFICS) is described in this paper. Computer self-testing in the DAFICS system is discussed, and operational experience using DAFICS is described. C.D.

A89-45163
A LOOK AT THE MODEL 360 DEVELOPMENT
RON MECKLIN (Boeing Helicopters, Philadelphia, PA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 207-222.

The Model 360 helicopter is a new technology flight demonstrator used to investigate the extensive use of composite materials. This paper presents a description of the aircraft along with unique tooling and fabrication methods used to assemble the composite airframe and components. Simulation activities conducted prior to flying this new aircraft and the flight test results obtained to date are described. C.D.

A89-45167
A SUPERSONIC CRUISE FIGHTER DESIGN
EVEREST E. RICCIONI (Northrop Corp., Aircraft Div., Hawthorne, CA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 321-333.

A design is presented for an affordable, reasonably small fighter which has supersonic mobility, defined as the ability quickly to generate high supersonic speeds and to persist in flying at those speeds. The performance, supersonic persistence, and supersonic range of this supersonic cruise fighter (SCF) are examined. The value of supersonic mobility in battle and the SCF's remarkable potential for intercept are briefly addressed. C.D.

A89-45168
X-15 PILOT-IN-THE-LOOP AND REDUNDANT/EMERGENCY SYSTEMS EVALUATION
RICHARD E. SMITH (Honeywell, Inc., Defense Avionics Systems Div., Albuquerque, NM) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 334-357.

The results are reported of a study of the first 47 free flights of the X-15 Research Airplane through Jaunuary 15, 1962 are reviewed. It is concluded that a pilot in the control loop and redundant/emergency systems in the X-15 provided dramatic net benefits in terms of mission success and safe aircraft recovery. There were also some detrimental effects, but these were overshadowed by the pilot nad redundancy benefits. C.D.

A89-45207
FULL SCALE FATIGUE CRACK GROWTH TEST OF ADVANCED JET TRAINER AT-3
S. S. WANG and R. C. CHU (Aeronautical Industry Development Center, Taichung, Republic of China) Theoretical and Applied Fracture Mechanics (ISSN 0167-8442), vol. 11, May 1989, p. 71-91. refs

The test equipment, procedures, and results of full-scale fatigue tests on the AT-3 jet trainer aircraft are described in detail and illustrated with extensive diagrams, drawings, graphs, photographs, and tables of numerical data. The tests included 30,000 h of a training-mission spectrum, 7500 h of special-service load spectra, and 6170 cycles of 6-G symmetrical pull-up to full-scale fatigue load. Particular attention is given to the design of the test program, the NDE and fatigue-life analysis methods applied, and the damage-tolerant crack-control strategy. The service life of the AT-3 is estimated as more than 7500 h. T.K.

A89-46278#
OPTIMIZATION DESIGN FOR SUPPRESSING 'GROUND RESONANCE' OF HELICOPTERS
ZHONGQUAN GU (Nanjing Aeronautical Institute, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN

1000-6893), vol. 10, March 1989, p. A113-A118. In Chinese, with abstract in English.

The design problem for suppressing 'ground resonance' of helicopters is studied. A method for optimally designing the stiffness and damping parameters of the system with specified requirements based on pole region placement in control theory and optimization is presented. Effective design criteria and procedures are presented according to the 'ground resonance' principle. Three typical calculation models are examined as examples. C.D.

A89-46470
PROBABILISTIC ANALYSIS OF AIRCRAFT STRUCTURE
PAUL A. ZIELINSKI (Boeing Military Airplane Co., Wichita, KS) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 140-145. refs

Probabilistic structural mechanics (PSM) has been promoted for use in the design of products. The author presents the practical methods for applying PSM to critical aircraft component fault-tree analysis. The B-1B Common Strategic Rotary Launcher (CSRL) fault-tree analysis is used as a demonstative example of mechanical component failure probabilities calculated using PSM. The CSRL components demonstrate how this methodology accounts for aircraft limit loads, limit load exceedances per flight hour, material properties, and stress analysis or structural test results. I.E.

A89-46705#
EASY METHOD OF MATCHING FIGHTER ENGINE TO AIRFRAME FOR USE IN AIRCRAFT ENGINE DESIGN COURSES
JACK D. MATTINGLY (USAF, Aero-Propulsion and Power Laboratory and Institute of Technology, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. refs
(AIAA PAPER 89-2260)

The proper match of the engine(s) to the airframe affects both aircraft size and life cycle cost. A fast and straightforward method is developed and used for the matching of fighter engine(s) to airframes during conceptual design. A thrust-lapse equation is developed for the dual-spool, mixed-flow, afterburning turbofan type of engine based on the installation losses of 'Aircraft Engine Design' and the performance predictions of the cycle analysis programs ONX and OFFX. Using system performance requirements, the effects of aircraft thrust-to-weight, wing loading, and engine cycle on takeoff weight are analyzed and example design course results presented. Author

A89-46773*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NOISE CONSIDERATIONS FOR TILTROTOR
ROBERT J. HUSTON, ROBERT A. GOLUB, and JAMES C. YU (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. refs
(AIAA PAPER 89-2359)

A projection is made of the technology-development requirements faced by aircraft designers contemplating the evolution of V-22-type tilt-rotor aircraft technology into a civilian tilt-rotor commuter aircraft of the requisite scale and payload. These research challenges are noted to often involve the reduction of noise level to values tolerated by passengers within the cabin and communities in the vicinity of airports, especially during hover and in the course of transition from vertical to horizontal flight (and vice-versa). Noise-generation and noise-radiation characteristics research has been undertaken using the XV-15 tilt-rotor proof-of-concept aircraft. O.C.

A89-46852#
F-16 INLET STABILITY INVESTIGATION
B. N. MCCALLUM (General Dynamics Corp., Fort Worth, TX) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2465)

An investigation of the stability characteristics of the F-16 MCID-771 inlet was conducted as a result of an inlet shock instability which occurred during flight test. Wind tunnel test data for the production F-16 vehicle configuration indicated that the inlet operation should be stable for conditions corresponding to those of the flight test incident. However, a flight test air data probe (ADP), which is larger than the ADP used on production aircraft, was found to create a disturbance in the forebody flow field which can adversely interact with the inlet shock. This interaction between the shock and the disturbance created by the ADP causes shock instabilities to occur at higher inlet corrected airflow than with the production ADP. The effect of the ADP was predominant at negative and low positive values of angle-of-attack. As a result of the investigation, new inlet operational airflow limits were developed for the aircraft configuration with the flight test ADP installed. Author

A89-46853#
T-4 INLET/ENGINE COMPATIBILITY FLIGHT TEST RESULTS
TADAYUKI HAMADA, MASAHIRO AKAGI (Japan Defense Agency, Technical Research and Development Institute, Gifu), DAISUKE TODA (Air Self-Defense Force, Tokyo, Japan), HIROSHI SHIMAZAKI (Kawasaki Heavy Industries Co., Ltd, Japan), and MITSUHARU OHMOMO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2466)

Results are presented on the flight tests conducted to evaluate the engine/inlet compatibility for the F3-30 engine developed for the T-4 intermediate trainer. The test program included all the critical maneuvering conditions (including spin flight) involved in the T-4 training missions. Measurements of the pressure distortion level and the pressure recovery factor were performed by an inlet rake which had 30 pressure probes (six-leg five-ring configuration) installed at the engine face. The results of T-4/F3-30 flight tests showed no engine stalls or flame-outs beyond the design goal envelopes; the engine operation was satisfactory to 60-deg of the angle-of-attack and 40-deg sideslip at idle rating. I.S.

A89-46864*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NACELLE/PYLON INTERFERENCE STUDY ON A 1/17TH-SCALE, TWIN-ENGINE, LOW-WING TRANSPORT MODEL
ODIS C. PENDERGRAFT, JR., ANTHONY M. INGRALDI, RICHARD J. RE (NASA, Langley Research Center, Hampton, VA), and TIMMY T. KARIYA (Vigyan Research Associates, Inc., Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2480)

NASA-Langley has conducted wind tunnel tests of a twin-engine, low-wing transport aircraft configuration with 10.8-aspect ratio supercritical wing, in order to ascertain and compare the wing/nacelle interference effects of through-flow nacelled simulating 'superfan' very high bypass ratio (BPR=20) turbofans and current-technology (BPR=6) turbofans. Measurements of model forces and moments have been obtained, together with extensive external static pressure measurement on the model's wings, nacelles, and pylons in the Mach 0.5-0.8 range, at angles of attack in the -4 to +8 deg range. The superfan nacelles exhibit a significant advantage over current-technology turbofan nacelles, when the superfan's SFC gains are taken into account. O.C.

A89-46866#
AERODYNAMIC DESIGN AND TESTING OF FOKKER 50 NACELLE AND INTAKE DUCTS
J. VAN HENGST, N. VOOGT, and G. J. SCHIPHOLT (Fokker Aircraft, Amsterdam, Netherlands) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2483)

The paper describes the aerodynamic design process of the

Fokker 50 nacelle and its intake ducts for engine and oil cooler. Much emphasis has been given to the prediction and prevention of ice accretion inside and around the duct. CFD is shown to play an important role complementary to wind tunnel and flight testing. Author

A89-46867#
DESIGN AND TESTING OF A COMMON ENGINE AND NACELLE FOR THE FOKKER 100 AND GULFSTREAM GIV AIRPLANES
H. NAWROCKI (Gulfstream Aerospace Corp., Savannah, GA), J. VAN HENGST, and L. DE HAIJ (Fokker Aircraft, Amsterdam, Netherlands) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p.
(AIAA PAPER 89-2486)

The design of an engine-nacelle configuration suitable for use in two aircraft (a commercial airline jet and a business jet) that differ in both the configuration and flight envelope is described. The configuration, the flight and inlet flow angle envelopes, and the engine selected for both aircraft are examined, and, on the basis of these characteristics, the design requirements for a common nacelle (i.e., those of the intake, nacelle, exhaust, mass flow, and intake flow) are established. Based on these requirements, the preliminary nacelle dimensions were selected and wind-tunnel tested. The final configuration of the common engine nacelle selected on the basis of the results of flight testing is presented. I.S.

A89-46937#
CONFIGURATION STUDIES FOR A REGIONAL AIRLINER USING OPEN-ROTOR ULTRA-HIGH-BYPASS-RATIO ENGINES
B. FISCHER and H. G. KLUG (Messerschmitt-Boelkow-Blohm GmbH, Hamburg, Federal Republic of Germany) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2580)

This paper reviews aspects of using open-rotor ultrahigh bypass engines in regional aircraft. Favorable and less favorable characteristics are discussed. Typical problems caused by open-rotor engines as to configuration, structure, and systems are presented. To assess the overall effect upon economics, two aircraft defined to perform the same mission, but using open-rotor engines and turbofan engines respectively, are compared. Direct operating cost differences are found to be relatively small, depending upon operational and economic conditions (e.g., aircraft utilization, fuel price). Under fuel prices higher than current ones, there is a clear case for the regional airliner powered by open-rotor ultrahigh bypass engines. Author

A89-47012#
RAPID METHODOLOGY FOR DESIGN AND PERFORMANCE PREDICTION OF INTEGRATED SCRAMJET/HYPERSONIC VEHICLE
HIDEO IKAWA (Northrop Corp., Aircraft Div., Hawthorne, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. Research supported by Northrop Corp.
(Contract F33615-87-C-3606)
(AIAA PAPER 89-2682)

The design integration of a supersonic combustion ramjet with the airframe dictates the mission success of transatmospheric boost or hypersonic cruise vehicle. The special interest must be given for the hypersonic atmospheric boost phase of the mission where most of the energy is expanded. For this purpose, the effective specific impulse and the thrust to weight ratio of accelerating vehicle play the key role in establishing the operational efficiency. A methodology that permits a quick performance evaluation of an idealized, integrated scramjet/hypersonic vehicle for preliminary design analysis is discussed. The methodology capability includes: (1) designing an integrated vehicle consisting of the forebody inlet, supersonic flow combustor, and afterbody expansion nozzle; (2) generating the design and off-design performance data; and (3) performing many design iterations for trade-off study. The methodology is coded on IBM PC in BASIC language. Samples of the design and off-design performance analysis of generic hypersonic vehicles are presented. Author

A89-47101#
FIGHTER AIRCRAFT AFFORDABILITY, SURVIVABILITY, AND EFFECTIVENESS THROUGH MULTI-FUNCTION NOZZLES
PAUL W. HERRICK (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2815)

Next-generation fighters will be able to maneuver at higher angles of attack, higher angular rotation rates and accelerations, and quicker flight path turn and deceleration rates, through the incorporation of multifunction nozzles (MFNs) that allow pitch and yaw thrust vectoring, thrust reversing, and the ability to optimize nozzle area ratios. These performance enhancements call for a fundamental change in fighter aircraft design philosophy, involving the supplementing or entire obviation of empennage surfaces by the use of MFNs. Fighter affordability is expected to be enhanced through reductions in airframe size and cost, greater fuel efficiency, less stringent basing requirements, lower peacetime attrition, and reduced pilot training requirements; survivability will also be enhanced through reductions in detectability and vulnerability. O.C.

A89-47165*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LARGE-SCALE WIND TUNNEL TESTS OF AN EJECTOR-LIFT STOVL AIRCRAFT MODEL
VICTOR CORSIGLIA, MICHAEL DUDLEY, BRIAN SMITH (NASA, Ames Research Center, Moffett Field, CA), and JOSEPH FARBRIDGE (Boeing Canada, de Havilland Aircraft Div., Toronto) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs
(AIAA PAPER 89-2905)

The initial results of a test program conducted on an ejector-augmented-lift STOVL aircraft design in the NASA-Ames 40-by-80-Foot Wind Tunnel has established the efficient performance of this full-scale aircraft realization of the propulsion-system configuration. It has also been noted that the generation of larger lift-augmentation ratios in this form than in component tests. In addition, it is found that configurations possessing thrust/weight ratios and wing loadings representative of current practice could, when outfitted with the present propulsion scheme, produce adequate level-flight acceleration through transition from VTOL hover to wingborne flight. O.C.

N89-25146*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT ADVANCES IN MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, PART 1
JEAN-FRANCOIS M. BARTHELEMY, ed. Washington Apr. 1989 527 p Symposium held in Hampton, VA, 28-30 Sep. 1988; sponsored by NASA, Langley Research Center, NASA, Lewis Research Center, and Wright Research Development Center
(NASA-CP-3031-PT-1; L-16568-PT-1; NAS 1.55:3031-PT-1)
Avail: NTIS HC A23/MF A01 CSCL 01/3

This three-part document contains a collection of technical papers presented at the Second NASA/Air Force Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, held September 28-30, 1988 in Hampton, Virginia. The topics covered include: helicopter design, aeroelastic tailoring, control of aeroelastic structures, dynamics and control of flexible structures, structural design, design of large engineering systems, application of artificial intelligence, shape optimization, software development and implementation, and sensitivity analysis.

N89-25147*# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.
APPLICATIONS OF INTEGRATED DESIGN/ANALYSIS SYSTEMS IN AEROSPACE STRUCTURAL DESIGN

PHILIP MASON, EDWIN LERNER, and LAWRENCE SOBEL *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 3-37 Apr. 1989

Avail: NTIS HC A23/MF A01 CSCL 01/3

Integrated structural analysis and design systems and structural optimization procedures are being used in a production environment. Successful use of these systems requires experienced personnel. Interactive computer graphics can and will play a significant role in the analysis, optimization, design and manufacturing areas. Practical structural optimization procedures are tools that must be made available to the team. Much work still needs to be done to tie finite-element modeling to actual design details which are being tracked on systems such as CADAM or CATIA. More work needs to be done to automate the detailed design and analysis process. More emphasis should be placed on the real design problems. Author

N89-25150*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

OVERVIEW OF DYNAMICS INTEGRATION RESEARCH (DIR) PROGRAM AT LANGLEY RESEARCH CENTER

STEVEN M. SLIWA and IRVING ABEL *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 79-105 Apr. 1989

Avail: NTIS HC A23/MF A01 CSCL 01/3

Research goals and objectives for an ongoing activity at Langley Research Center (LaRC) are described. The activity is aimed principally at dynamics optimization for aircraft. The effort involves active participation by the Flight Systems, Structures, and Electronics directorates at LaRC. The Functional Integration Technology (FIT) team has been pursuing related goals since 1985. A prime goal has been the integration and optimization of vehicle dynamics through collaboration at the basic principles or equation level. Some significant technical progress has been accomplished since then and is reflected here. An augmentation for this activity, Dynamics Integration Research (DIR), has been proposed to NASA Headquarters and is being considered for funding in FY 1990 or FY 1991. Author

N89-25151*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AN INITIATIVE IN MULTIDISCIPLINARY OPTIMIZATION OF ROTORCRAFT

HOWARD M. ADELMAN and WAYNE R. MANTAY (Army Aerostructures Directorate, Hampton, VA.) *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 109-144 Apr. 1989 Previously announced as N89-15108

Avail: NTIS HC A23/MF A01 CSCL 01/3

Described is a joint NASA/Army initiative at the Langley Research Center to develop optimization procedures aimed at improving the rotor blade design process by integrating appropriate disciplines and accounting for important interactions among the disciplines. The activity is being guided by a Steering Committee made up of key NASA and Army researchers and managers. The committee, which has been named IRASC (Integrated Rotorcraft Analysis Steering Committee), has defined two principal foci for the activity: a white paper which sets forth the goals and plans of the effort; and a rotor design project which will validate the basic constituents, as well as the overall design methodology for multidisciplinary optimization. The optimization formulation is described in terms of the objective function, design variables, and constraints. Additionally, some of the analysis aspects are discussed and an initial attempt at defining the interdisciplinary couplings is summarized. At this writing, some significant progress has been made, principally in the areas of single discipline optimization. Results are given which represent accomplishments in rotor aerodynamic performance optimization for minimum hover horsepower, rotor dynamic optimization for vibration reduction, and rotor structural optimization for minimum weight. Author

N89-25152*# California Univ., Los Angeles. Dept. of Mechanical, Aerospace and Nuclear Engineering.

STRUCTURAL OPTIMIZATION OF ROTOR BLADES WITH STRAIGHT AND SWEPT TIPS SUBJECT TO AEROELASTIC CONSTRAINTS

PERETZ P. FRIEDMANN and ROBERTO CELI (Maryland Univ., College Park.) *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 145-162 Apr. 1989

Avail: NTIS HC A23/MF A01 CSCL 01/3

The main conclusions obtained in the present study are summarized. Their application to the structural optimization of a helicopter blade should be limited by the assumptions used in obtaining the numerical results presented here. The optimum design procedure described here is very efficient, and can produce improved designs with a very limited number of precise analyses. The method of constructing the approximate problem is such that previously conducted aeroelastic analyses can be reused in a new optimization problem. For example, if an optimization study is preceded by a parametric study in which the effect of various combinations of blade design parameters is examined, all the aeroelastic analyses performed for the parametric study can be reutilized in the optimization study. This is not possible when the approximate problem is built from Taylor series expansions. The results of the optimization are quite sensitive to the aeroelastic stability margins required of the blade. In the optimization of case 2, changing the aeroelastic stability constraints from simply requiring that the blade be stable in hover, to requiring that the stability margins be maintained during the course of the optimization, reduced the gains in n/rev vibration levels by more than 50 percent. The introduction of tip sweep can reduce the n/rev vertical hub shears beyond the level that can be obtained by just modifying the mass and stiffness distributions of the blade. Author

N89-25153*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

OPTIMIZATION OF ROTOR BLADES FOR COMBINED STRUCTURAL, PERFORMANCE, AND AEROELASTIC CHARACTERISTICS

DAVID A. PETERS and Y. P. CHENG *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 163-180 Apr. 1989

Avail: NTIS HC A23/MF A01 CSCL 01/3

The strategies whereby helicopter rotor blades can be optimized for combined structural, inertial, dynamic, aeroelastic, and aerodynamic performance characteristics are outlined. There are three key ingredients in the successful execution of such an interdisciplinary optimization. The first is the definition of a satisfactory performance index that combines all aspects of the problem without too many constraints. The second element is the judicious choice of computationally efficient analysis tools for the various quantitative components in both the cost functional and constraints. The third element is an effective strategy for combining the various disciplines either in parallel or sequential optimizations. Author

N89-25154*# McDonnell-Douglas Helicopter Co., Mesa, AZ.

TRANSONIC AIRFOIL DESIGN FOR HELICOPTER ROTOR APPLICATIONS

AHMED A. HASSAN and B. JACKSON *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 181-193 Apr. 1989

Avail: NTIS HC A23/MF A01 CSCL 01/3

Despite the fact that the flow over a rotor blade is strongly influenced by locally three-dimensional and unsteady effects, practical experience has always demonstrated that substantial improvements in the aerodynamic performance can be gained by improving the steady two-dimensional charateristics of the airfoil(s) employed. The two phenomena known to have great impact on the overall rotor performance are: (1) retreating blade stall with the associated large pressure drag, and (2) compressibility effects on the advancing blade leading to shock formation and the associated wave drag and boundary-layer separation losses. It

was concluded that: optimization routines are a powerful tool for finding solutions to multiple design point problems; the optimization process must be guided by the judicious choice of geometric and aerodynamic constraints; optimization routines should be appropriately coupled to viscous, not inviscid, transonic flow solvers; hybrid design procedures in conjunction with optimization routines represent the most efficient approach for rotor airfoil design; unsteady effects resulting in the delay of lift and moment stall should be modeled using simple empirical relations; and inflight optimization of aerodynamic loads (e.g., use of variable rate blowing, flaps, etc.) can satisfy any number of requirements at design and off-design conditions. Author

N89-25155*# Maryland Univ., College Park. Dept. of Aerospace Engineering.
EFFICIENT SENSITIVITY ANALYSIS AND OPTIMIZATION OF A HELICOPTER ROTOR
JOON W. LIM and INDERJIT CHOPRA *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 195-208 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

Aeroelastic optimization of a system essentially consists of the determination of the optimum values of design variables which minimize the objective function and satisfy certain aeroelastic and geometric constraints. The process of aeroelastic optimization analysis is illustrated. To carry out aeroelastic optimization effectively, one needs a reliable analysis procedure to determine steady response and stability of a rotor system in forward flight. The rotor dynamic analysis used in the present study developed inhouse at the University of Maryland is based on finite elements in space and time. The analysis consists of two major phases: vehicle trim and rotor steady response (coupled trim analysis), and aeroelastic stability of the blade. For a reduction of helicopter vibration, the optimization process requires the sensitivity derivatives of the objective function and aeroelastic stability constraints. For this, the derivatives of steady response, hub loads and blade stability roots are calculated using a direct analytical approach. An automated optimization procedure is developed by coupling the rotor dynamic analysis, design sensitivity analysis and constrained optimization code CONMIN. Author

N89-25156*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL OPTIMIZATION OF ROTOR BLADES WITH INTEGRATED DYNAMICS AND AERODYNAMICS
ADITI CHATTOPADHYAY (Analytical Services and Materials, Inc., Hampton, VA.) and JOANNE L. WALSH *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 209-233 Apr. 1989 Previously announced as N89-15110
Avail: NTIS HC A23/MF A01 CSCL 01/3

The problem of structural optimization of helicopter rotor blades with integrated dynamic and aerodynamic design considerations is addressed. Results of recent optimization work on rotor blades for minimum weight with constraints on multiple coupled natural flap-lag frequencies, blade autorotational inertia and centrifugal stress has been reviewed. A strategy has been defined for the ongoing activities in the integrated dynamic/aerodynamic optimization of rotor blades. As a first step, the integrated dynamic/airload optimization problem has been formulated. To calculate system sensitivity derivatives necessary for the optimization recently developed, Global Sensitivity Equations (GSE) are being investigated. A need for multiple objective functions for the integrated optimization problem has been demonstrated and various techniques for solving the multiple objective function optimization are being investigated. The method called the Global Criteria Approach has been applied to a test problem with the blade in vacuum and the blade weight and the centrifugal stress as the multiple objectives. The results indicate that the method is quite effective in solving optimization problems with conflicting objective functions. Author

N89-25157*# McDonnell-Douglas Helicopter Co., Mesa, AZ.
MULTI-OBJECTIVE/LOADING OPTIMIZATION FOR ROTATING COMPOSITE FLEXBEAMS
BRIAN K. HAMILTON and JAMES R. PETERS *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 235-256 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

With the evolution of advanced composites, the feasibility of designing bearingless rotor systems for high speed, demanding maneuver envelopes, and high aircraft gross weights has become a reality. These systems eliminate the need for hinges and heavily loaded bearings by incorporating a composite flexbeam structure which accommodates flapping, lead-lag, and feathering motions by bending and twisting while reacting full blade centrifugal force. The flight characteristics of a bearingless rotor system are largely dependent on hub design, and the principal element in this type of system is the composite flexbeam. As in any hub design, trade off studies must be performed in order to optimize performance, dynamics (stability), handling qualities, and stresses. However, since the flexbeam structure is the primary component which will determine the balance of these characteristics, its design and fabrication are not straightforward. It was concluded that: pitchcase and snubber damper representations are required in the flexbeam model for proper sizing resulting from dynamic requirements; optimization is necessary for flexbeam design, since it reduces the design iteration time and results in an improved design; and inclusion of multiple flight conditions and their corresponding fatigue allowables is necessary for the optimization procedure. Author

N89-25159*# Hall (David) Consulting, Sunnyvale, CA.
DEVELOPMENT OF A MICROCOMPUTER BASED INTEGRATED DESIGN SYSTEM FOR HIGH ALTITUDE LONG ENDURANCE AIRCRAFT
DAVID W. HALL and J. EDWARD ROGAN *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 275-296 Apr. 1989 Previously announced in IAA as A88-53734
Avail: NTIS HC A23/MF A01 CSCL 01/3

A microcomputer-based integration of aircraft design disciplines has been applied theoretically to sailplane, microwave-powered aircraft, and High Altitude Long-Endurance (HALE) aircraft configurational definition efforts. Attention is presently given to the further development of such integrated-discipline approaches through the incorporation of AI techniques; these are then applied to the aforementioned case of the HALE. The windFrame language used, which is based on HyperTalk, will allow designers to write programs using a highly graphical, user interface-oriented environment. Author

N89-25167*# General Dynamics Corp., Fort Worth, TX.
AEROLASTIC TAILORING AND INTEGRATED WING DESIGN
MIKE H. LOVE and JON BOHLMANN *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 431-444 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

Much has been learned from the TSO optimization code over the years in determining aeroelastic tailoring's place in the integrated design process. Indeed, it has become apparent that aeroelastic tailoring is and should be deeply embedded in design. Aeroelastic tailoring can have tremendous effects on the design loads, and design loads affect every aspect of the design process. While optimization enables the evaluation of design sensitivities, valid computational simulations are required to make these sensitivities valid. Aircraft maneuvers simulated must adequately cover the plane's intended flight envelope, realistic design criteria must be included, and models among the various disciplines must be calibrated among themselves and with any hard-core (e.g., wind tunnel) data available. The information gained and benefits derived from aeroelastic tailoring provide a focal point for the various disciplines to become involved and communicate with one another to reach the best design possible. Author

N89-25168*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED AERODYNAMIC-STRUCTURAL DESIGN OF A FORWARD-SWEPT TRANSPORT WING
RAPHAEL T. HAFTKA, BERNARD GROSSMAN, PI-JEN KAO, DAVID M. POLEN (Virginia Polytechnic Inst. and State Univ., Blacksburg.), and JAROSLAW SOBIESZCZANSKI-SOBIESKI *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 445-463 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

The introduction of composite materials is having a profound effect on aircraft design. Since these materials permit the designer to tailor material properties to improve structural, aerodynamic and acoustic performance, they require an integrated multidisciplinary design process. Futhermore, because of the complexity of the design process, numerical optimization methods are required. The utilization of integrated multidisciplinary design procedures for improving aircraft design is not currently feasible because of software coordination problems and the enormous computational burden. Even with the expected rapid growth of supercomputers and parallel architectures, these tasks will not be practical without the development of efficient methods for cross-disciplinary sensitivities and efficient optimization procedures. The present research is part of an on-going effort which is focused on the processes of simultaneous aerodynamic and structural wing design as a prototype for design integration. A sequence of integrated wing design procedures has been developed in order to investigate various aspects of the design process. Author

N89-25170*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECTS OF NONLINEAR AERODYNAMICS AND STATIC AEROELASTICITY ON MISSION PERFORMANCE CALCULATIONS FOR A FIGHTER AIRCRAFT
GARY L. GILES, KENNETH E. TATUM (Planning Research Corp., Hampton, VA.), and WILLARD E. FOSS, JR. *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 477-496 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

During conceptual design studies of advanced aircraft, the usual practice is to use linear theory to calculate the aerodynamic characteristics of candidate rigid (nonflexible) geometric external shapes. Recent developments and improvements in computational methods, especially computational fluid dynamics (CFD), provide significantly improved capability to generate detailed analysis data for the use of all disciplines involved in the evaluation of a proposed aircraft design. A multidisciplinary application of such analysis methods to calculate the effects of nonlinear aerodynamics and static aeroelasticity on the mission performance of a fighter aircraft concept is described. The aircraft configuration selected for study was defined in a previous study using linear aerodynamics and rigid geometry. The results from the previous study are used as a basis of comparison for the data generated herein. Aerodynamic characteristics are calculated using two different nonlinear theories, potential flow and rotational (Euler) flow. The aerodynamic calculations are performed in an iterative procedure with an equivalent plate structural analysis method to obtain lift and drag data for a flexible (nonrigid) aircraft. These static aeroelastic data are then used in calculating the combat and mission performance characteristics of the aircraft. Author

N89-25171*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
OPTIMUM STRUCTURAL DESIGN WITH STATIC AEROELASTIC CONSTRAINTS
KEITH B BOWMAN, RAMANA V. GRANDHI, and F. E. EASTEP (Dayton Univ., OH.) *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 497-508 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

The static aeroelastic performance characteristics, divergence velocity, control effectiveness and lift effectiveness are considered in obtaining an optimum weight structure. A typical swept wing structure is used with upper and lower skins, spar and rib thicknesses, and spar cap and vertical post cross-sectional areas as the design parameters. Incompressible aerodynamic strip theory is used to derive the constraint formulations, and aerodynamic load matrices. A Sequential Unconstrained Minimization Technique (SUMT) algorithm is used to optimize the wing structure to meet the desired performance constraints. Author

N89-25172*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPTIMUM DESIGN OF SWEPT-FORWARD HIGH-ASPECT-RATION GRAPHITE-EPOXY WINGS
MARK J. SHUART, RAPHAEL T. HAFTKA, and R. L. CAMPBELL *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 509-525 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 01/3

An analytical investigation of a swept-forward high-aspect-ratio graphite-epoxy transport wing is described. The objectives of this investigation are to illustrate an effective usage of the unique properties of composite materials by exploiting material tailoring and to demonstrate an integrated multidisciplinary approach for conducting this investigation. Author

N89-25173*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT ADVANCES IN MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, PART 2
JEAN-FRANCOIS M. BARTHELEMY, ed. Washington Apr. 1989 501 p Symposium held in Hampton, VA, 28-30 Sep. 1988; sponsored by NASA, Langley Research Center, NASA, Lewis Research Center, and Wright Research Development Center
(NASA-CP-3031-PT-2; L-16568-PT-2; NAS 1.55:3031-PT-2)
Avail: NTIS HC A22/MF A01 CSCL 01/3

This three-part document contains a collection of technical papers presented at the Second NASA/Air Force Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, held September 28-30, 1988 in Hampton, Virginia. The topics covered include: helicopter design, aeroelastic tailoring, control of aeroelastic structures, dynamics and control of flexible structures, structural design, design of large engineering systems, application of artificial intelligence, shape optimization, software development and implementation, and sensitivity analysis.

N89-25190*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RESULTS OF INCLUDING GEOMETRIC NONLINEARITIES IN AN AEROELASTIC MODEL OF AN F/A-18
CAREY S. BUTTRILL *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 815-836 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

An integrated, nonlinear simulation model suitable for aeroelastic modeling of fixed-wing aircraft has been developed. While the author realizes that the subject of modeling rotating, elastic structures is not closed, it is believed that the equations of motion developed and applied herein are correct to second order and are suitable for use with typical aircraft structures. The equations are not suitable for large elastic deformation. In addition, the modeling framework generalizes both the methods and terminology of non-linear rigid-body airplane simulation and traditional linear aeroelastic modeling. Concerning the importance of angular/elastic inertial coupling in the dynamic analysis of fixed-wing aircraft, the following may be said. The rigorous inclusion of said coupling is not without peril and must be approached with care. In keeping with the same engineering judgment that guided the development of the traditional aeroelastic equations, the effect of non-linear inertial effects for most airplane applications is expected to be small. A parameter does not tell the whole story, however, and modes flagged by the parameter as significant also need to be checked to see if the coupling is not a one-way path, i.e., the inertially affected modes can influence other modes. Author

N89-25192*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AEROELASTIC MODELING FOR THE FIT (FUNCTIONAL INTEGRATION TECHNOLOGY) TEAM F/A-18 SIMULATION
THOMAS A. ZEILER (Planning Research Corp., Hampton, VA.) and CAROL D. WIESEMAN *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 861-877 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

As part of Langley Research Center's commitment to developing multidisciplinary integration methods to improve aerospace systems, the Functional Integration Technology (FIT) team was established to perform dynamics integration research using an existing aircraft configuration, the F/A-18. An essential part of this effort has been the development of a comprehensive simulation modeling capability that includes structural, control, and propulsion dynamics as well as steady and unsteady aerodynamics. The structural and unsteady aerodynamics contributions come from an aeroelastic mode. Some details of the aeroelastic modeling done for the Functional Integration Technology (FIT) team research are presented. Particular attention is given to work done in the area of correction factors to unsteady aerodynamics data. Author

N89-25194*# California Univ., Los Angeles. Dept. of Mechanical, Aerospace and Nuclear Engineering.
AN INTEGRATED APPROACH TO THE OPTIMUM DESIGN OF ACTIVELY CONTROLLED COMPOSITE WINGS
E. LIVNE *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 897-918 Apr. 1989
(Contract F49620-87-K-0003)
Avail: NTIS HC A22/MF A01 CSCL 01/3

The importance of interactions among the various disciplines in airplane wing design has been recognized for quite some time. With the introduction of high gain, high authority control systems and the design of thin, flexible, lightweight composite wings, the integrated treatment of control systems, flight mechanics and dynamic aeroelasticity became a necessity. A research program is underway now aimed at extending structural synthesis concepts and methods to the integrated synthesis of lifting surfaces, spanning the disciplines of structures, aerodynamics and control for both analysis and design. Mathematical modeling techniques are carefully selected to be accurate enough for preliminary design purposes of the complicated, built-up lifting surfaces of real aircraft with their multiple design criteria and tight constraints. The presentation opens with some observations on the multidisciplinary nature of wing design. A brief review of some available state of the art practical wing optimization programs and a brief review of current research effort in the field serve to illuminate the motivation and support the direction taken in our research. The goals of this research effort are presented, followed by a description of the analysis and behavior sensitivity techniques used. The presentation concludes with a status report and some forecast of upcoming progress. Author

N89-25201*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT ADVANCES IN MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, PART 3
JEAN-FRANCOIS M. BARTHELEMY, ed. Washington Apr. 1989 513 p Symposium held in Hampton, VA, 28-30 Sep. 1988; sponsored by NASA, Langley Research Center, NASA, Lewis Research Center, and Wright Research Development Center
(NASA-CP-3031-PT-3; L-16568-PT-3; NAS 1.55:3031-PT-3)
Avail: NTIS HC A22/MF A01 CSCL 01/3

This three-part document contains a collection of technical papers presented at the Second NASA/Air Force Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, held September 28-30, 1988 in Hampton, Virginia. The topics covered include: aircraft design, aeroelastic tailoring, control of aeroelastic structures, dynamics and control of flexible structures, structural design, design of large engineering systems, application of artificial intelligence, shape optimization, software development and implementation, and sensitivity analysis.

N89-25205*# Missouri Univ., Columbia. Design Productivity Center.
MULTILEVEL DECOMPOSITION OF COMPLETE VEHICLE CONFIGURATION IN A PARALLEL COMPUTING ENVIRONMENT
VINAY BHATT and K. M. RAGSDELL *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1069-1082 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

This research summarizes various approaches to multilevel decomposition to solve large structural problems. A linear decomposition scheme based on the Sobieski algorithm is selected as a vehicle for automated synthesis of a complete vehicle configuration in a parallel processing environment. The research is in a developmental state. Preliminary numerical results are presented for several example problems. Author

N89-25206*# Kansas Univ., Lawrence. Dept. of Aerospace Engineering.
DESIGN OPTIMIZATION OF AXISYMMETRIC BODIES IN NONUNIFORM TRANSONIC FLOW
C. EDWARD LAN *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1085-1095 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

An inviscid transonic code capable of designing an axisymmetric body in a uniform or nonuniform flow was developed. The design was achieved by direct optimiation by coupling an analysis code with an optimizer. Design examples were provided for axisymmetric bodies with fineness ratios of 8.33 and 5 at different Mach numbers. It was shown that by reducing the nose radius and increasing the afterbody thickness of initial shapes obtained from symmetric NACA four-digit airfoil contours, wave drag could be reduced by 29 percent for a body of fineness ratio 8.33 in a nonuniform transonic flow of $M = 0.98$ to 0.995. The reduction was 41 percent for a body of fineness ratio 5 in a uniform transonic flow of $M = 0.925$ and 65 percent for the same body but in a nonuniform transonic flow of $M = 0.90$ to 0.95. Author

N89-25210*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC AIRBREATHING VEHICLE CONCEPTUAL DESIGN (FOCUS ON AERO-SPACE PLANE)
JAMES L. HUNT and JOHN G. MARTIN (Planning Research Corp., Hampton, VA.) *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1157-1194 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

The airbreathing single stage to orbit (SSTO) vehicle design environment is variable-rich, intricately networked and sensitivity intensive. As such, it represents a tremondous technology challenge. Creating a viable design will require sophisticated configuration/synthesis and the synergistic integration of advanced technologies across the discipline spectrum. In design exercises, reductions in the fuel weight-fraction requirements projected for an orbital vehicle concept can result from improvements in aerodynamics/controls, propulsion efficiencies and trajectory optimization; also, gains in the fuel weight-fraction achievable for such a concept can result from improvements in structural design, heat management techniques, and material properties. As these technology advances take place, closure on a viable vehicle design will be realizable. Author

N89-25211*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPTIMIZING CONCEPTUAL AIRCRAFT DESIGNS FOR MINIMUM LIFE CYCLE COST
VICKI S. JOHNSON *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1195-1217 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

A life cycle cost (LCC) module has been added to the FLight

Optimization System (FLOPS), allowing the additional optimization variables of life cycle cost, direct operating cost, and acquisition cost. Extensive use of the methodology on short-, medium-, and medium-to-long range aircraft has demonstrated that the system works well. Results from the study show that optimization parameter has a definite effect on the aircraft, and that optimizing an aircraft for minimum LCC results in a different airplane than when optimizing for minimum take-off gross weight (TOGW), fuel burned, direct operation cost (DOC), or acquisition cost. Additionally, the economic assumptions can have a strong impact on the configurations optimized for minimum LCC or DOC. Also, results show that advanced technology can be worthwhile, even if it results in higher manufacturing and operating costs. Examining the number of engines a configuration should have demonstrated a real payoff of including life cycle cost in the conceptual design process: the minimum TOGW of fuel aircraft did not always have the lowest life cycle cost when considering the number of engines. Author

N89-25212*# Stanford Univ., CA. Dept. of Aeronautics and Astronautics.
AIRCRAFT DESIGN OPTIMIZATION WITH MULTIDISCIPLINARY PERFORMANCE CRITERIA
STEPHEN MORRIS and ILAN KROO *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1219-1235 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

The method described here for aircraft design optimization with dynamic response considerations provides an inexpensive means of integrating dynamics into aircraft preliminary design. By defining a dynamic performance index that can be added to a conventional objective function, a designer can investigate the trade-off between performance and handling (as measured by the vehicle's unforced response). The procedure is formulated to permit the use of control system gains as design variables, but does not require full-state feedback. The examples discussed here show how such an approach can lead to significant improvements in the design as compared with the more common sequential design of system and control law. Author

N89-25221*# McDonnell-Douglas Corp., Long Beach, CA.
AN OVERVIEW OF THE DOUGLAS AIRCRAFT COMPANY AEROELASTIC DESIGN OPTIMIZATION PROGRAM (ADOP)
ALAN J. DODD *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1359-1369 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

From a program manager's viewpoint, the history, scope and architecture of a major structural design program at Douglas Aircraft Company called Aeroelastic Design Optimization Program (ADOP) are described. ADOP was originally intended for the rapid, accurate, cost-effective evaluation of relatively small structural models at the advanced design level, resulting in improved proposal competitiveness and avoiding many costly changes later in the design cycle. Before release of the initial version in November 1987, however, the program was expanded to handle very large production-type analyses. Author

N89-25222*# McDonnell-Douglas Corp., Long Beach, CA.
MEETING THE CHALLENGES WITH THE DOUGLAS AIRCRAFT COMPANY AEROELASTIC DESIGN OPTIMIZATION PROGRAM (ADOP)
BRUCE A. ROMMEL *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1369-1378 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

An overview of the Aeroelastic Design Optimization Program (ADOP) at the Douglas Aircraft Company is given. A pilot test program involving the animation of mode shapes with solid rendering as well as wire frame displays, a complete aircraft model of a high-altitude hypersonic aircraft to test ADOP procedures, a flap model, and an aero-mesh modeler for doublet lattice aerodynamics are discussed. R.J.F.

N89-25232*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TIME-CORRELATED GUST LOADS USING MATCHED-FILTER THEORY AND RANDOM-PROCESS THEORY: A NEW WAY OF LOOKING AT THINGS
ANTHONY S. POTOTZKY, THOMAS A. ZEILER, and BOYD PERRY, III (Planning Research Corp., Hampton, VA.) Apr. 1989 11 p Presented at the AIAA 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-5 Apr. 1989 Previously announced in IAA as A89-30849
(NASA-TM-101573; NAS 1.15:101573) Avail: NTIS HC A03/MF A01 CSCL 01/3

Two ways of performing time-correlated gust-load calculations are described and illustrated. The first is based on Matched Filter Theory; the second on Random Process Theory. Both approaches yield theoretically identical results and represent novel applications of the theories, are computationally fast, and may be applied to other dynamic-response problems. A theoretical development and example calculations using both Matched Filter Theory and Random Process Theory approaches are presented. Author

N89-25233*# California Univ., Berkeley.
THE CONCEPTUAL DESIGN OF A MACH 2 OBLIQUE FLYING WING SUPERSONIC TRANSPORT
ALEXANDER J. M. VANDERVELDEN May 1989 39 p
(Contract NAG2-471)
(NASA-CR-177529; NAS 1.26:177529) Avail: NTIS HC A03/MF A01 CSCL 01/3

This paper is based on a performance and economics study of a Mach two oblique flying wing transport aircraft that is to replace the B747B. In order to fairly compare our configuration with the B747B an equal structural technology level is assumed. It will be shown that the oblique flying wing configuration will equal or outperform the B747 in speed, economy and comfort while a modern stability and control system will balance the aircraft and smooth out gusts. The aircraft is designed to comply with the FAR25 airworthiness requirements and FAR36 stage 3 noise regulations. Geometry, aerodynamics, stability and control parameters of the oblique flying wing transport are discussed. Author

N89-25234 Department of the Air Force, Washington, DC.
FLAP SYSTEM FOR SHORT TAKEOFF AND LANDING AIRCRAFT Patent
GERALD T. BRINE, inventor (to AF) 15 Nov. 1988 9 p Filed 10 Nov. 1986
(AD-D013981; US-PATENT-4,784,355;
US-PATENT-APPL-SN-928350) Avail: US Patent and Trademark Office CSCL 01/3

A flap system for deploying high lift flaps on short takeoff and landing aircraft is presented. The flap system utilizes an activating mechanism that is used to extend a flap, a vane and a spoiler for maximum lift. The mechanism utilizes relatively few linkage pieces which are attached to the flap at single pivot points. The flap is supported by an actuator and a flap hinge support bracket. Increased mechanism rigidity and single pivot mountings allow use of roller and track guides at flap ends to smoothly guide flap movement and provide a fail-safe system in case of pivot mounting failure. Spherical bearings are utilized for mounting of rollers and actuators in order to compensate for misalignment of the flap and the flap mechanism when used with tapered flaps on swept wing aircraft. The spoiler is joined by a guide link that adjusts spoiler position with flap movement in order to maximize lift. The spoiler can also be used conventionally by activation of the actuator. GRA

N89-25235*# California Univ., Berkeley.
AN ECONOMIC MODEL FOR EVALUATING HIGH-SPEED AIRCRAFT DESIGNS
ALEXANDER J. M. VANDERVELDEN May 1989 38 p
(Contract NAG2-471)
(NASA-CR-177530; NAS 1.26:177530) Avail: NTIS HC A03/MF A01 CSCL 01/3

A Class 1 method for determining whether further development of a new aircraft design is desirable from all viewpoints is presented. For the manufacturer the model gives an estimate of the total cost of research and development from the preliminary design to the first production aircraft. Using Wright's law of production, one can derive the average cost per aircraft produced for a given break-even number. The model will also provide the airline with a good estimate of the direct and indirect operating costs. From the viewpoint of the passenger, the model proposes a tradeoff between ticket price and cruise speed. Finally all of these viewpoints are combined in a Comparative Aircraft Seat-kilometer Economic Index. Author

N89-25237 George Washington Univ., Washington, DC.
PROBABILISTIC DAMAGE TOLERANCE METHODS FOR METALLIC AEROSPACE STRUCTURES Ph.D. Thesis
MARGERY E. ARTLEY 1989 132 p
Avail: Univ. Microfilms Order No. DA8906814

Damage tolerance analysis, based on fracture mechanics, is an important tool for ensuring the safety of flight of airframes. Traditionally, these analyses are deterministic in nature, but probabilistic methods have been applied to damage tolerance analysis in limited cases. The purpose of this dissertation is to formulate probabilistic damage tolerance analyses for metallic structural components, based on U.S. Air Force damage tolerance philosophy for slow crack growth and fail safe components. A survey of the literature was conducted on probabilistic durability and damage tolerance methods. The important elements of the methods are covered; including the initial fatigue quality, the variability in crack growth rate, and the probability of crack detection. A probabilistic damage tolerance analysis was performed with a deterministic crack growth rate and then a stochastic crack growth rate, based on a probabilistic durability method. Examples of slow crack growth and fail safe structures are presented. As an example of a slow crack growth component, a lug from an aircraft subjected to an 80-flight fighter/trainer wing lower surface spectrum was selected. A stiffened panel from a lower wing skin of a tanker was selected as an example of a fail-safe component. Crack arrest in the panel, followed by catastrophic failure of the stiffener was considered as the failure mechanism. The model formulated here can be used to decide on the frequency and quality of the inspection of a component needed to keep the probability of failure at acceptable levels. Results of this study can serve as bases for decision making for inspection maintenance and fleet management. Dissert. Abstr.

N89-25990# National Aerospace Lab., Tokyo (Japan).
LONGITUDINAL NONLINEAR AERODYNAMIC MODEL FORM FOR USB-STOL AIRCRAFT
Sep. 1988 52 p In JAPANESE; ENGLISH summary
(NAL-TR-995; ISSN-0389-4010) Avail: NTIS HC A04/MF A01

A longitudinal nonlinear aerodynamic model form for USB-STOL aircraft was prepared. The static and dynamic parts of the model form were drawn separately. The static model form was then verified by fitting it to wind tunnel test data of the NAL-STOL experimental airplane ASUKA. For the dynamic form, three types of model form were proposed as candidates. The candidates differ from each other in the method of modeling the lag of downwash: In the first model the lag is simulated precisely, in the second model it is approximated from the first lag, and in the third model, the lag is neglected. A comparison of the results of dynamic flight simulation with these three models comes to the conclusion that the second model is the most appropriate for parameter identification from flight test data. Author

N89-25991 Department of the Air Force, Washington, DC.
AIRCRAFT ENGINE OUTER DUCT MOUNTING DEVICE Patent
RONALD E. QUINN, inventor (to Air Force) 13 Dec. 1988 4 p
Filed 17 Jul. 1987
(AD-D013988; US-PATENT-4,790,137;
US-PATENT-APPL-SN-074802) Avail: US Patent and Trademark Office CSCL 21/5

The invention comprises a mounting assembly for supporting the turbine outer casing duct adjacent to the turbine frame. Multiple support posts are mounted to the turbine frame and roller means are rotatably attached to each support post. The roller means are aligned to rotate on a contact surface of the outer casing duct. Movement of the rollers on the contact surface is caused by the relative movement of the turbine frame and outer casing duct. GRA

N89-25994# Federal Aviation Administration, Atlantic City, NJ.
FUEL CONTAINMENT SYSTEM CONCEPT TO REDUCE SPILLAGE
ROBERT F. SALMON Jun. 1989 28 p
(DOT/FAA/CT-TN89/22) Avail: NTIS HC A03/MF A01

The purpose is to describe a new concept in aircraft fuel tank design to reduce the spillage from an aircraft fuel tank which has been ruptured during what could be considered a survivable crash. The time element is very critical for survival after a crash. By reducing the amount of fuel spilled during the first minute after the aircraft comes to rest, the probability of passenger survival can be greatly enhanced. Author

N89-25995# Nondestructive Testing Information Analysis Center, San Antonio, TX. Dept. of Mechanical Sciences.
NONDESTRUCTIVE QUALIFICATION OF UH-1 REPLACEMENT PARTS: COMPLETION ENHANCEMENT Final Report, Sep. 1986 - Dec. 1987
ROGER L. BESSEY 7 Nov. 1988 5 p
(Contract DLA900-84-C-0910; SWRI PROJ. 17-7958-832)
(AD-A206674) Avail: NTIS HC A02/MF A01 CSCL 01/3

A listing of data packages completed on this program and breakout/feasibility studies which were performed, are presented. GRA

N89-25996# Virginia Polytechnic Inst. and State Univ., Blacksburg.
RELAXATION OSCILLATIONS IN AIRCRAFT CRUISE-DASH OPTIMIZATION Technical Paper Aug. 1986 - Mar. 1988
U. J. SHANKAR, H. J. KELLEY (RCA Astro-Electronics Div., Princeton, NJ.), and E. M. CLIFF 15 Aug. 1988 35 p
(Contract F08635-86-K-0390)
(AD-A206722; AFATL-TP-89-03) Avail: NTIS HC A03/MF A01 CSCL 01/1

Periodic solutions in energy approximation are sought for aircraft optimal cruise-dash problems. The cost functional is the weighted sum of the time taken and the fuel used average over the cycle. It is known from previous work that in energy-state approximation, relaxed-steady-state control gives lower costs than the steady-state solution. However, this control is not implementable. Higher approximations to this are sought via averaging oscillations. The fast dynamics (path angle/attitude/throttle/lift coefficient) is modeled in terms of periodic solutions in a boundary-layer-like motion which does not die out but moves along with the progression of the slow state energy. This is shown not to help the situation. A better approximation in terms of relaxation oscillations is proposed. Unlike earlier models, the energy is allowed to vary. However, the net change in energy per cycle is zero. Fast, constant-energy climbs and descents and slow energy transitions are spliced together in zeroth order approximation to obtain the periodic solutions. The energies in question are determined as part of the problem. This technique is shown to produce a more practical solution, but still needs improvement for practical application. GRA

N89-25997# Naval Ship Research and Development Center, Bethesda, MD. Aviation Dept.
TIPJET VTOL UAV (VERTICAL TAKEOFF AND LANDING/UNMANNED AERIAL VEHICLE) SUMMARY. VOLUME 1: A 1200 POUND TIPJET VTOL UNMANNED AERIAL VEHICLE. PART 1: CONCEPTUAL DESIGN STUDY OF A 1200-POUND VEHICLE Interim Report, Apr. - Dec. 1988
KENNETH R. READER, JANE S. ABRAMSON, ALAN W. SCHWARTZ, and JAMES C. BIGGERS Jan. 1989 80 p

(AD-A206738; DTRC/AD-89/01) Avail: NTIS HC A05/MF A01 CSCL 01/3

A new concept is developed for an Unmanned Aerial Vehicle (UAV) configured with a tip-jet driven, two-bladed, stoppable rotor and circulation control airfoils. The conceptual design of the Tipjet Vertical Takeoff and Landing (VTOL) UAV is presented, and vehicle performance is evaluated for three mid-range UAV Navy missions: Tactical Reconnaissance, Over-the-Horizon Targeting, and Combat Support Reconnaissance. Vehicle performance predictions are presented for hover and low-speed, rotary-wing flight, for conversion between rotary-wing and fixed-wing flight, and for fixed-wing flight. Requirements for shipboard support of the vehicle are outlined. Mission specific equipment is described including size, weight, and power requirements. Standard design methods are applied to conduct a detailed mission performance analysis for the conceptual design. The analysis results indicate that the 1200-1b Tipjet VTOL UAV is a viable candidate vehicle for the specified missions. Moreover, the concept is directly applicable to much larger UAVs that will greatly enhance naval warfare capabilities. Part 1 of Volume 1 presents the conceptual design for the Tipjet VTOL UAV along with vehicle performance analysis for the designed missions. GRA

N89-25998# General Accounting Office, Washington, DC. National Security and International Affairs Div.
STRATEGIC BOMBERS: B-1B COST AND PERFORMANCE REMAIN UNCERTAIN
3 Feb. 1989 60 p
(AD-A206751; GAO/NSIAD-89-55) Avail: NTIS HC A04/MF A01 CSCL 01/3

Early in 1987 The General Accounting Office testified on the B-1B bomber program before the House and Senate Committees on Armed Services. It identified B-1B development deficiencies during the testimonies, and the Chairmen requested that GAO continue to monitor the program. This report updates and assesses the progress of the B-1B program since 1987 and presents other related issues. On October 2, 1981, the President announced his decision to develop and deploy 100 B-1Bs. In selecting the B-1B, DOD believed that the technology, cost, and schedule risks would be low because of the experience gained from the canceled B-1A program. On January 18, 1982, the President certified to the Congress that the B-1B would have an initial operational capability during 1986 and that the development and acquisition baseline cost of B-1B fleet would not exceed $20.5 billion ($27.8 billion escalated dollars). However, to field the B-1B in just 5 years, the program would feature highly concurrent full-scale development, production, and testing schedules. GRA

N89-26000# Federal Aviation Administration, Washington, DC. Advanced System Design Service.
FAA ROTORCRAFT RESEARCH, ENGINEERING AND DEVELOPMENT BIBLIOGRAPHY, 1962-1988: SUPPLEMENT
ROBERT D. SMITH Mar. 1989 103 p
(AD-A207162; AD-E501097; DOT/FAA/DS-89/03) Avail: NTIS HC A06/MF A01 CSCL 01/3

This bibliography of FAA rotorcraft reports published from 1962 to 1988 is a supplement to an earlier bibliography. Both bibliographies are limited to documents in which the research, engineering, and development elements of the FAA were involved as sponsors, participants, or authors. This bibliography contains abstracts on 53 technical reports. The indexes in this document address these 53 reports as well as the 133 reports in the earlier bibliography (FAA/PM-86/47). GRA

N89-26001 Technische Univ., Delft (Netherlands).
DEVELOPMENT AND APPLICATION OF A COMPUTER-BASED SYSTEM FOR CONCEPTUAL AIRCRAFT DESIGN Ph.D. Thesis
CORNELIS BIL 1988 267 p
(ETN-89-94886) Avail: Delft Univ. Press, Stevinweg 1, 2628 CN Delft, Netherlands

A system for computer aided conceptual aircraft design was developed and implemented. Although this system is intended for design education and research in a university environment, it incorporates basic features and capabilities that are considered as representative for computer aided engineering applications in industrial practice. Although an acceptable, optimum design configuration is obtained, verification and validation remains difficult. This is inherent to the use of conceptual design methods. The analysis methods currently implemented in the program library are generally referred to as class 1 methods. They are usually based on statistical/empirical considerations and are generally quite suitable for obtaining absolute answers with very little input information. However, caution must be taken when using these methods in automated design. ESA

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A89-44645#
STEALTH TECHNOLOGY FOR REDUCING AIRCRAFT RECOGNITION
KAY W. DITTRICH and JOACHIM GRASHOF Dornier Post (ISSN 0012-5563), no. 2, 1989, p. 77-80.

Techniques used in developing stealth technology for reducing aircraft recognition are reviewed. The calculation of radar signature by approximation methods and by exact numeric methods is addressed, taking into account the physical optics approximation method and the finite volume method for Maxwell equations. The main types of radar-camouflaging construction are examined, and the measurement of radar backscatter is discussed. C.D.

A89-45105
EXPERIMENTAL LOCALIZED RADAR CROSS SECTIONS OF AIRCRAFT
BERNARD D. STEINBERG, DONALD L. CARLSON, and WOOSUNG LEE (Pennsylvania, University, Philadelphia) IEEE, Proceedings (ISSN 0018-9219), vol. 77, May 1989, p. 663-669. refs
(Contract DAAG29-85-K-0247)

Localized radar cross section (RCS) measurements are presented for the Boeing 727 and the Lockheed L-1011 aircraft. The measurements were made at X band from a few degrees aft of broadside. The elevation angle was approximately 30 deg. Four data sets, each of 128 pulses, were obtained from each airplane examined. The data presented are composites of measurements of five Boeing 727s and three L-1011s. The data exhibit the large variations in observed RCS reported elsewhere. I.E.

A89-45107* Northwestern Univ., Evanston, IL.
REVIEW OF FD-TD NUMERICAL MODELING OF ELECTROMAGNETIC WAVE SCATTERING AND RADAR CROSS SECTION
ALLEN TAFLOVE (Northwestern University, Evanston, IL) and KORADA R. UMASHANKAR (Illinois, University, Chicago) IEEE, Proceedings (ISSN 0018-9219), vol. 77, May 1989, p. 682-699. refs
(Contract F30602-79-C-0039; F19628-82-C-0140; NAG3-635; NSF ECS-85-15777)

Applications of the finite-difference time-domain (FD-TD) method for numerical modeling of electromagnetic wave interactions with structures are reviewed, concentrating on scattering and radar cross section (RCS). A number of two- and three-dimensional examples of FD-TD modeling of scattering and penetration are provided. The objects modeled range in nature from simple geometric shapes to extremely complex aerospace and biological systems. Rigorous analytical or experimental validatons are provided for the canonical shapes, and it is shown that FD-TD predictive data for near fields and RCS are in excellent agreement with the benchmark data. It is concluded that with continuing advances in FD-TD modeling theory for target features

relevant to the RCS problems and in vector and concurrent supercomputer technology, it is likely that FD-TD numerical modeling will occupy an important place in RCS technology in the 1990s and beyond. I.E.

A89-45111
RADAR CROSS SECTION OF ARBITRARILY SHAPED BODIES OF REVOLUTION
TE-KAO WU (Hughes Aircraft Co., El Segundo, CA) IEEE, Proceedings (ISSN 0018-9219), vol. 77, May 1989, p. 735-740. refs

The radar cross section (RCS) of an arbitrarily shaped, homogeneous dielectric body of revolution (BOR) is evaluated by the surface integral equation (SIE) formulation and the method of moments. Method accuracy is verified by the good agreement with the exact solutions for the RCS of a dielectric sphere. To demonstrate the advantages of this method, the RCS for a complex BOR model of human torso is computed with a nonaxially incident plane wave. Seven Fourier modes are considered in the computation. The SIE and approximate integral equation (AIE) formulations are then given for the RCS evaluation of a composite dielectric and conducting BOR. For the cases considered, both formulations give the same surface currents and RCS results. However, significant savings in computer storage and CPU time are realized for the AIE approach, since only one current (electric or magnetic) need be determined for RCS evaluation. I.E.

A89-45329
AN EXPLORATORY STUDY OF THE USE OF MOVEMENT-CORRELATED CUES IN AN AUDITORY HEAD-UP DISPLAY
ROBERT D. SORKIN, GREG C. ELVERS (Florida, University, Gainesville), FREDERIC L. WIGHTMAN, and DORIS S. KISTLER (Wisconsin, University, Madison) Human Factors (ISSN 0018-7208), vol. 31, April 1989, p. 161-166. refs
(Contract F33657-86-C-2221)

The ability of observers to localize targets with an auditory head-up display under different movement conditions is assessed. The observer had to indicate the target's location after listening to a sequence of three signals. The following different conditions relating the observer's head movement to the target's spatial position were tested: (1) a target fixed in physical space, (2) no head movement allowed, and (3) a target fixed in position relative to the observer's head. K.K.

A89-46298#
THE ANALYSIS AND MEASUREMENTS OF RADAR CROSS SECTION (RCS) OF SOME WING STRUCTURE MODELS
JINGZUO YANG, XIONGQING YU (Nanjing Aeronautical Institute, People's Republic of China), and JIANXING YANG (Shanghai Xinhua Radio Factory, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, April 1989, p. B196-B199. In Chinese, with abstract in English.

Three glass fiber composite and aluminum wing structure models, and the measurements of RCS of these models are given. Based upon the results of the measurements, the conceptual analysis of the electromagnetic properties of these wing structure models are discussed. The purposes of this paper are to develop wing structural concepts of low RCS and to select the structural concept to assess the application of advanced materials such as glass fiber and carbon fiber composites for aircraft. Author

A89-46910*# PRC Systems Services Co., Edwards, CA.
PRELIMINARY DEVELOPMENT OF AN INTELLIGENT COMPUTER ASSISTANT FOR ENGINE MONITORING
JAMES D. DISBROW (PRC Systems Services, Inc., Aerospace Technologies Div., Edwards, CA), EUGENE L. DUKE, and RONALD J. RAY (NASA, Flight Research Center, Edwards, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2539)

As part of the F-18 high-angle-of-attack vehicle program, an AI method has been developed for the real-time monitoring of the propulsion system and for the identification of recovery procedures for the F404 engine. The aim of the development program is to provide enhanced flight safety and to reduce the duties of the propulsion engineers. As telemetry data is received, the results are continually displayed in a number of different color graphical formats. The system makes possible the monitoring of the engine state and the individual parameters. Anomaly information is immediately displayed to the engineer. R.R.

07

AIRCRAFT PROPULSION AND POWER

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

A89-43885
PROP-FAN TESTED FOR STRUCTURAL AND ACOUSTIC DATA
Aerospace Engineering (ISSN 0736-2536), vol. 9, June 1989, p. 27-29.

A primary objective of NASA's Propfan Test Assessment (PTA) program was the acquisition of structural and acoustic baseline data during flight, using a modified Gulfstream II aircraft, in order to understand the propfan concept on the scale of the 9-ft diameter SR-7L propfan mated to a 6000-hp engine and modified T56 gearbox. A total of 30 strain gages were mounted on the propfan in order to conduct the structural tests; vibratory response data were acquired over the entire test envelope. After strain-gage data from the flight tests were reduced to a data sample average of total vibratory strain at a stabilized flight condition, selected data points were analyzed harmonically to sort out the amplitude and frequency content of the response. O.C.

A89-44108#
EFFICIENT COMPUTATIONAL TOOL FOR RAMJET COMBUSTOR RESEARCH
S. P. VANKA, J. L. KRAZINSKI (Argonne National Laboratory, IL), and A. S. NEJAD (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 431-437. Research supported by USAF. refs
(AIAA PAPER 88-0060)

A multigrid-based calculation procedure is presented for the efficient solution of the time-averaged equations of a turbulent, elliptic-reacting flow. The equations are solved on a nonorthogonal curvilinear coordinate system. The physical models currently incorporated are a two-equation k-epsilon turbulence model, a four-step chemical kinetics mechanism, and a Lagrangian particle-tracking procedure applicable to dilute sprays. Demonstration calculations are presented to illustrate the performance of the calculation procedure for a ramjet dump combustor configuration. Author

A89-44113#
IMPROVED COMPRESSOR PERFORMANCE USING RECESSED CLEARANCE (TRENCHES)
D. C. WISLER and B. F. BEACHER (General Electric Co., Cincinnati, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 469-475. Previously cited in issue 20, p. 2922, Accession no. A86-42823. refs
(Contract F33615-81-C-2030)

A89-44115*# Analatom, Inc., San Jose, CA.
NUMERICAL SIMULATIONS OF OBLIQUE DETONATIONS IN SUPERSONIC COMBUSTION CHAMBERS
JEAN-LUC CAMBIER (Analatom, Inc., San Jose, CA), HENRY G. ADELMAN, and GENE P. MENEES (NASA, Ames Research Center,

Moffett Field, CA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 482-491. Previously cited in issue 07, p. 950, Accession no. A88-22043. refs

A89-44117#
ADVANCED TURBOFAN ENGINE COMBUSTION SYSTEM DESIGN AND TEST VERIFICATION
J. W. SANBORN, J. E. LENERTZ, and J. D. JOHNSON (Garrett Turbine Engine Co., Phoenix, AZ) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 502-509. Previously cited in issue 20, p. 3154, Accession no. A87-45231.

A89-44362
DYNAMIC STRESS ANALYSIS OF ROTATING TURBO-MACHINERY BLADED-DISK SYSTEMS
V. OMPRAKASH and V. RAMAMURTI (Indian Institute of Technology, Madras, India) Computers and Structures (ISSN 0045-7949), vol. 32, no. 2, 1989, p. 477-488. refs

The steady state dynamic stress and deformation analysis of high pressure stage turbomachinery bladed-disks is carried out taking into account all the geometric complexities involved. The contributions due to initial stress and membrane behavior are included. Only one substructure is used for finite element modeling and analysis, taking advantage of rotational periodicity. A triangular shell element with six degrees of freedom per node is employed for this purpose. The blade and disk attachment is established by a set of constraint equations obtained by the Love-Kirchhoff hypothesis. The final set of equations are solved by an out of core submatrices elimination method. The influence of different levels of approximations and various geometric parameters on the stresses and deformations is discussed. Author

A89-45031
CIVIL SUPERSONICS - PROPULSION IS THE KEY
JULIAN MOXON Flight International (ISSN 0015-3710), vol. 135, June 10, 1989, p. 116, 117, 119, 122.

Of the three most important environmental problems facing next-generation SST designers, including sonic boom overpressures. NOx pollution of the stratosphere, and airport noise, the latter two are directly addressable by propulsion system design efforts. Attention is presently given to the variable-cycle engine (VCE) efforts of three major aircraft propulsion system manufacturers in the U.S. and Britain; their VCE configurations address the aforementioned problems by varying the amount of turbofan-bypass air from a high flow rate at subsonic speeds to a low one in supersonic cruise. Cooler combustion temperatures reduce NOx, and lower exhaust velocities associated with high-bypass subsonic flow reduce takeoff and landing noise-generating exhaust stream velocities. O.C.

A89-45042
EUROPEAN GAS TURBINE ENGINES [LES TURBOMOTEURS EUROPEENS]
JEAN BERNARD COCHETEUX L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 79-88. In French.

The European-made RTM 322 and MTR 390 helicopter turboshaft engines are described. The RTM 322, employed in the EH101, NH90, and Sikorsky H60 helicopters, uses a compressor composed of three axial stages and one centrifugal stage, a high-efficiency two-stage turbine generator, and a light combustion chamber. The MTR 390, employed in the Westland Lynx and PAH2-HAC/HAP helicopters, uses a double-centrifuge compressor, an inverse-flux combustion chamber, and a cooled single-stage turbine generator. The introduction of new techologies has resulted in gains in mass, size, performance, flexibility, and specific fuel consumption for the MTR 390 over previous helicopter engines. R.R.

A89-45556#
AN EXPERIMENTAL RESEARCH ON MIXTURE PRESSURE LOSS IN COMBUSTOR
LIXIAO MO (Gas Turbine Establishment, Sichuan, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 130-132, 199. In Chinese, with abstract in English.

Mixture of cold air flow from annular pass-through holes with main flow (cold or hot stream) has been researched experimentally. The momentum exchange for annular pass air flow through plain or plunging circular holes into main flow has been studied experimentally on a rectangular test section in a simulated combustion chamber. The momentum exchange increases the pressure loss of the main air stream near the jet holes. The results show that the mixture pressure loss of combustor with plunging circular holes is 1 to 1.5 times as large as that of the combustor with plain circular holes. Therefore, the combustor with plunging circular holes is favorable to combustion, and may reduce the length of the combustor. Author

A89-45557#
COLD FLOW MEASUREMENTS FOR A DOUBLE SWIRLER COMBUSTOR
QINGFAN ZHANG, QINGPING ZHENG, YIMING SAO, and XIAOMEI ZANG (Nanjing Aeronautical Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 133, 134, 199. In Chinese, with abstract in English. refs

THe cold flow patterns in a double swirler combustor have been measured by using a six-orientation hot-wire probe technique. The results show that the central recirculation zone for counterrotating swirling is different from that of corotating swirling. A better pattern in the central recirculation zone for combustion will be obtained if the swirler angles of both the outer swirler and the center swirler are chosen reasonably. Author

A89-45558#
EXPERIMENTAL RESEARCH ON SWIRLING COMBUSTION EFFICIENCY
XIANJIAN HUANG, HAOYUAN TAN, and WEI CUI (Nanjing Aeronautical Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 135, 136, 199. In Chinese, with abstract in English.

This paper describes the experiments of combustion performances in two kinds of swirling augmentor models. The combustion efficiencies and stabilizing limits have been measured. The length of flame have been observed. The experiments of swirling combustion under small swirl angles have been completed, in which the flame could not be stabilized in recirculation zone. Results show that the efficiency of swirling combustion increases approximately 20 percent in comparison with that of V-flameholder and the length of flame is obviously shortened. Author

A89-45559#
A DYNAMIC DIGITAL MODEL FOR THE TURBOJET WITH PULSE-MONITORED FUELER
DIYI TANG and YUANHU CAI (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 137-140, 194. In Chinese, with abstract in English.

The ingestion of the hot gas from armanent firing or recirculation of exhaust gas from VTOL- and STOL-type aircraft will bring engine into unstable and cause troubles for flight. It is good practice to use a pulse-monitored fueler for improving the engine stability. A digital model for this purpose is presented, which consists of a first-order fuel-feed model, a components volume model, and a rotor-dynamic model. The steady-state performance and transient behavior of a double spool turbojet are predicted on the basis of this model. Then, the steady-state performance is compared with the sea-level acceptance curve to check the validity of the model in specific case of steady state. The transient behaviors, such as the time histories of the secondary fuel line pressure, the speeds of two spools and the thrust, are also calculated and compared with the experimental curves of the same behaviors of another engine. The results indicate that the simulation effect of this model is satisfactory. Author

A89-45567#
EXPERIMENTAL INVESTIGATION ON CHARACTERISTICS OF SINGLE AND TANDEM BLADE CASCADES WITH DOUBLE-CIRCULAR ARC PROFILE
BIAONAN ZHUANG and BINGHENG GUO (Nanjing Aeronautical Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 169-172, 197. In Chinese, with abstract in English.

A single cascade and a tandem cascade with double-circular arc profile have been designed and investigated, which have same total cord, total camber, constructional inlet and exit angles, and solidity, as the reference tandem compressor stator blade of an existing gas turbine engine. The inlet Mach number is 0.3. The characteristics of both single and tandem cascades, such as the dependence of turning angle Delta-beta and coefficient of total pressure loss omega on incidence angle i have been obtained. The experimental data are compared and analyzed. The tandem cascade features large fluid turning angle and small loss coefficient. For incidence angle from -6.5 to +3.5 deg, Detla-beta of the tandem cascade is larger than Delta-beta of the single cascade 2-5 deg, and omega the tandem cascade is smaller than omega of the single cascade. For example, when i = 1 deg, for the tandem cascade Delta-beta = 55.4 deg, omega = 0.04, for the single cascade Delta-beta = 49.6, omega = 0.076. Author

A89-46025#
THE INVESTIGATION OF JET ENGINE STARTING
HONGMIN WANG (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Propulsion Technology (ISSN 1001-4055), June 1989, p. 70-74. In Chinese, with abstract in English. refs

The process of starting a jet engine requires that the engine rotates up to idle reliably and satisfactorily. The starting performance is modified based on the test of a flight evaluation schedule of a sample engine. The measurement and the data acquisition for a small single-spool engine are conducted on a sea-level test bench first. It is shown that, as main fuel is ignited, flame with temperature above 1250 C occurs at blade tips, while the average exhaust gas temperature is 400 to about 500 C. The mechanism and the criteria for overheating turbine blades during starting are presented in this paper. By using heat releasing ratio as the criteria to measure the overheating, the effects of FAR, fuel droplet size, fuel evaporation constant, and air density on it are discussed. Author

A89-46600#
PERFORMANCE ANALYSIS OF SCRAMJET ENGINES
YOSHIHARU TSUJIKAWA (Osaka Prefecture, University, Sakai, Japan), YUJIRO TSUKAMOTO (Mitsubishi Heavy Industries, Ltd., Komaki, Japan), and SHOICHI FUJII (National Aerospace Laboratory, Chofu, Japan) Osaka Prefecture, University, Bulletin, Series A - Engineering and Natural Sciences (ISSN 0474-7844), vol. 37, no. 1, 1988, p. 1-13. refs

The quasi-one-dimensional model for the flow through a scramjet engine is proposed, and the performance of the components is analyzed thermodynamically. In the analysis, there are severe difficulties in the combustor due to problems such as turbulent diffusion and mixing at supersonic speed. For the combustion reaction, a global hydrogen-air combustion model with two-step reaction schemes is introduced. Author

A89-46704#
NUMERICAL CODES FOR UNSTEADY SIMULATION OF TURBOJET, TURBOFAN AND TURBOPROP ENGINES FOR TRAINING PURPOSES
G. TORELLA (Accademia Aeronautica, Naples, Italy) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2259)

An integrated package for simulating the transient behavior of jet engine with different configurations is presented. The package is divided in two parts. The first is based on suitable codes for managing large DATABASE and uses the results of available calculations for evaluating the performance of engine with desired control laws. The second part uses complete numerical codes for simulating the transient operations of engines. Both iterative and volume methods are used. Moreover the secondary transient effects may be taken into account. Author

A89-46751#
ENVIRONMENTAL ICING TEST OF T800 HELICOPTER ENGINE WITH INTEGRAL INLET PARTICLE SEPARATOR
WILLIAM R. STIEFEL (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.
(AIAA PAPER 89-2324)

An environmental icing test was conducted during the Preliminary Flight Rating phase of the LHTEC T800 development program. This 1200 shp class turboshaft engine features an integral inlet particle separator which challenges the task of anti-icing because of the large surface area to be protected, particularly in light of the stringent limits on the allowable performance decrement associated with anti-icing system operation. Further, the inlet particle separator configuration denies line-of-sight visual access to most of the ice-sensitive flow path, thereby complicating evaluation of anti-icing system functional performance. This paper describes the engine and anti-icing system and discusses the selection of an icing test facility, the configuring and calibration of an icing simulation system, and the optical/video techniques used for on-line visual access to the internal flow-path surfaces of the inlet particle separator for monitoring potential ice formations. Author

A89-46752#
VALIDATION OF A FREE-JET TECHNIQUE FOR EVALUATING INLET-ENGINE COMPATIBILITY
D. K. BEALE (Sverdrup Technology, Inc., Arnold AFB, TN) and M. S. COLLIER (USAF, Arnold Engineering Development Center, Arnold AFB, TN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 19 p.
(AIAA PAPER 89-2325)

A free-jet test technique for the assessment of inlet-engine compatibility has undergone validation tests based on comparisons between the free-jet results and wind tunnel test results obtained with a 16.29-percent scale F-15 fighter inlet model. Free-jet measurements have been found to be in good agreement with wind tunnel test results, indicating that the freestream reference plane flow-field characteristics can be simulated in a free-jet facility. In addition, a short forebody simulator can be used to simulate inlet influences on inlet flow, and inlet reference plane flow-field measurements can be used to determine free-jet settings required for the simulation. O.C.

A89-46770#
PRELIMINARY ASSESSMENT OF EXHAUST SYSTEMS FOR HIGH MACH (4 TO 6) FIGHTER AIRCRAFT
A. P. KUCHAR and J. P. WOLF (GE Aircraft Engines, Cincinnati, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p.
(AIAA PAPER 89-2356)

While current-technology supersonic aircraft operate with maximum nozzle pressure ratios (NPRs) in the 15-20 range, NPRs of nearly 100 for Mach 4 and over 600 for Mach 6 are anticipated; these far higher values require commensurately higher nozzle expansion ratios, resulting in substantially higher nozzle sizes and weights relative to current systems. Conventional axisymmetric nozzles, two-dimensional convergent-divergent nozzles, and single expansion-ramp nozzles have been investigated: the latter two types are found to achieve the requisite levels of performance at the expense of considerable size and weight, while the axisymmetric nozzle has geometric constraints that limit its performance capability. O.C.

A89-46774#
RE-ENGINING STAGE TWO AIRCRAFT WITH THE TAY

J. B. HODSON (Rolls-Royce, Inc., Sherman Oaks, CA) and V. M. SZEWCZYK (Rolls-Royce, PLC, Derby, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2361)

The Tay 670 variant of the Tay family of high-bypass turbofan engines is of 18,000-lb takeoff thrust class, and is undergoing development as a replacement powerplant for the B737-200, B727-200, and DC-9 airliners, with a view to the significant airport community noise reductions thus obtainable. It is also noted that 'hushkits' currently comtemplated for the JT8D low-bypass turbofan engines powering the aforementioned aircraft will result in only a marginal meeting of new noise requirements while involving significant performance degradation by comparison with the reengining that can be achieved with the Tay 670. O.C.

A89-46776#
THE CHALLENGE OF REDUCING SUPERSONIC CIVIL TRANSPORT PROPULSION NOISE
A. M. STERN and A. A. PERACCHIO (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p. refs
(AIAA PAPER 89-2363)

Achievement of FAR 36 Stage 3 noise levels presents a challenge. Techniques such as, for example, the use of inverted velocity profile jet exhausts, suppressor/ejectors, thermo-acoustic shields, are shown to provide significant suppression, but not enough to meet Stage 3. Additional suppression is required and achievement is suggested through the use of devices that increase exhaust flow, aircraft operational techniques and engine/airframe integration. Needed additional experimental programs on noise suppression and analytical studies are identified. Author

A89-46777*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Center, Edwards, CA.
MEASUREMENT EFFECTS ON THE CALCULATIOPN OF IN-FLIGHT THRUST FOR AN F404 TURBOFAN ENGINE
TIMOTHY R. CONNERS (NASA, Flight Research Center, Edwards, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 22 p. refs
(AIAA PAPER 89-2364)

A study has been performed that investigates parameter measurement effects on calculated in-flight thrust for the General Electric F404-GE-400 afterburning turbofan engine which powered the X-29A forward-swept wing research aircraft. Net-thrust uncertainty and influence coefficients were calculated and are presented. Six flight conditions were analyzed at five engine power settings each. Results were obtained using the mass flow-temperature and area-pressure thrust calculation methods, both based on the commonly used gas generator technique. Thrust uncertainty was determined using a common procedure based on the use of measurement uncertainty and influence coefficients. The effects of data nonlinearity on the uncertainty calculation procedure were studied and results are presented. The advantages and disadvantages of using this particular uncertainty procedure are discussed. A brief description of the thrust-calculation technique along with the uncertainty calculation procedure is included.
Author

A89-46837#
A REVIEW OF PROPULSION APPLICATIONS OF THE PULSED DETONATION ENGINE CONCEPT
S. EIDELMAN, W. GROSSMANN, and I. LOTTATI (Science Applications International Corp., McLean, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. Research supported by DARPA. refs
(Contract N66001-88-D-0088)
(AIAA PAPER 89-2446)

The present evaluation of the development status of pulsed detonation propulsion concepts gives attention to the results of experiments performed at the U.S. Naval Postgraduate School, using a self-aspirating mode of operation for a pulsed detonation thruster, which suggest a promising path towards practical propulsion systems having variable thrust levels which are not only controllable but scalable. A numerical-simulation code suitable for the design, analysis, and evaluation of self-aspirating detonation engines has been developed; candidate detonation chamber flow properties verify the total dominance of unsteady gasdynamics.
O.C.

A89-46838#
SEMI-CONSTANT VOLUME PULSE COMBUSTION FOR GAS TURBINE ENGINE STARTING
R. B. BLACKBURN and J. L. MOULTON (Sunstrand Corp., Sunstrand Advanced Technology Group, Rockford, IL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2449)

Conventional external start power systems make up approximately 40 to 50 percent of the installed weight and volume of small gas turbine engines. A self-start concept based on nonresonant pulse combustion could eliminate all or most of any external start power system. A case is made for a self-starting engine using electronic fuel injection and unique flapper valving in the diffuser of the engine compressor. Preliminary analysis indicates net rotor acceleration occurs when using low speed performance of an actual compressor and turbine. A functional flapper valve demonstrator and timed fuel injection pulses constitute 'a priori' feasibility. Author

A89-46851#
ENGINE LIFE MATURATION PROCESS
F. M. CASSIDY, S. I. VUKELICH (USAF, Wright-Patterson AFB, OH), and J. SAMMONS (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.
(AIAA PAPER 89-2464)

Aircraft engine structural safety, increased service readiness, and reduced life-cycle costs, are the factors addressed by the Engine Life Maturation Process (ELMP) methodology encompassing such engines' design, development, production, and deployment. ELMP attempts to achieve early engine maturation by developing initial maintenance-planning factors in the initial design stages, in conjunction with active data-gathering and updates of the planning factors throughout the engine system's service life. A controlled methodology for progressively increasing inspection intervals until the ultimate engine design life is achieved is the result of ELMP, as presently illustrated for the case of the variants of the F100 fighter aircraft turbofan. O.C.

A89-46854#
ROLE OF DYNAMIC SIMULATION IN FIGHTER ENGINE DESIGN AND DEVELOPMENT
S. J. KHALID (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(AIAA PAPER 89-2467)

Representative engine models have been developed which can accurately account for off-design and dynamic effects very early in aircraft engine configuration and control design phases, ensuring favorable component matching. Attention is presently given to the use of such models in the case of specific flowpath design considerations in a fast-response twin-spool afterburning turbofan, the F100-PW-229. In addition to flowpath design, simulation tradeoff studies are used to optimize the control system; novel control modes can be analytically evaluated across the operational spectrum with appropriate activation criteria that are readily implementable in digital-control logic. O.C.

A89-46861#
ADVANCED PROPULSION SYSTEMS FOR LARGE SUBSONIC TRANSPORTS
N. J. PEACOCK and J. H. R. SADLER (Rolls-Royce, PLC, Derby,

England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.
(AIAA PAPER 89-2477)

This paper will examine the parameters that influence the design of new engines for large transport aircraft. The search for the lowest installed specific fuel consumption has produced a variety of proposals under the label of Ultra High Bypass engines. A number of these designs are examined and the factors controlling their installed performance are reviewed. Weight and cost effects are also considered. The technology necessary to achieve a competitive product is identified. This is then related to the current new engine proposals which are largely derivative with little change in bypass ratio from current products. Author

A89-46862#
DUCTED ULTRA-HIGH BYPASS ENGINE CONFIGURATION DEFINITION
H. A. GEIDEL (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) and D. E. GRAY (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p.
(AIAA PAPER 89-2478)

In the course of the 1980s, as fuel costs declined from their exorbitant 1970s levels, the overall economics of prospective passenger aircraft engine designs rather than the reduction of their specific fuel consumption became the primary factor in evaluating comparative merit. Attention is presently given to the justification of Advanced Ducted Engine (ADE) designs on the basis of such a direct operating cost-oriented comparative study. ADEs possess performance characteristics intermediate between conventional turbofans and 'unducted fan' configurations, but achieve overall economic superiority on the basis of their essential simplicity of design and construction. O.C.

A89-46863#
***TECHNOLOGY* READINESS FOR ADVANCED DUCTED ENGINES**
D. ECKARDT (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) and G. L. BRINES (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2479)

The Advanced Ducted Engines (ADEs) currently undergoing development for next-generation passenger aircraft typically possess bypass ratios of the order of 12-25 and specific fuel consumption figures 12-17 percent lower than current advanced turbofans. An extensive technology-readiness program has been mounted on behalf of ADE design definition over the last two years, encompassing among its concerns aircraft/engine-installation interference, low pressure-ratio fan aerodynamics, fan/nacelle interactions (including windmilling and thrust-reversal), acoustic characteristics, transonic-drive turbines, and slender nacelle aerodynamic and mechanical design. Both turbine-driven and geared ADE fans, which may be of single-rotating or contrarotating type, are discussed. O.C.

A89-46865#
HIGH PERFORMANCE GEAR SYSTEMS AND HEAT MANAGEMENT FOR ADVANCED DUCTED SYSTEMS
K. RUED, H. A. GEIDEL, A. ROHRA, and K. BRITZ (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2482)

Recent design studies on gear systems and corresponding gearbox cooling concepts are presented. Investigations are based on MTU's Advanced Ducted Engine concept CRISP (Counter Rotating Integrated Shrouded Propfan) which develops shaft powers up to 17 MW for a short/medium range twin aircraft. Three different in-line gear arrangements, i.e. differential planetary, split star/planetary and compound star, have been evaluated and compared on the basis of power transmission and speed reduction capabilities, weight and size, design complexity, efficiency and reliability. Suitable gearbox air-to-oil cooler concepts were developed and optimized for highly compact incorporation within the propfan hub. Cooling performance is analyzed relative to the flight mission including hot day effects. The detrimental impact of cooling air extraction on engine performance is also examined. The results presented are typical for both single and counterrotating gearbox heat rejection problems. Author

A89-46868#
ENSURING SURGE-FREE ENGINE OPERATION ON TODAY'S TURBOFAN POWERED BUSINESS JETS
F. NAWROCKI (Gulfstream Aerospace Corp., Savannah, GA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 22 p.
(AIAA PAPER 89-2487)

Surge-free operation in accordance with FAA requirements has been addressed in the course of flight tests for the Gulfstream G IV business aircraft with respect to ten distinct engine operational factors. The engine in question is the Tay Mk 610-8 turbofan; the factors addressed were engine service deterioration; the worst combinations of compressor and/or turbine matching, rigging tolerances, and slew rates, respectively; Mach number; heavy rainfall ingestion; runway water ingestion; snow and ice slug ingestion; altitude-dependent Reynolds number effects; and inlet distortion effects. O.C.

A89-46869#
THE ROLLS ROYCE ALLISON RB580 TURBOFAN - MATCHING THE MARKET REQUIREMENT FOR REGIONAL TRANSPORT
J. H. R. SADLER, N. J. PEACOCK (Rolls-Royce, PLC, Derby, England), and L. SNYDER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2488)

The RB580 high bypass turbofan engine has a thrust growth capability to 10,000 lb and has been optimized for efficient operation in regional markets involving 50-70 seat airliners with higher-than-turboprop cruise speeds. The two-spool engine configuration achieves an overall pressure ratio of 24 and features a single-stage wide-chord fan for high efficiency/low noise operation. The highly modular design of the configuration facilitates maintenance and repair; a dual-redundant full-authority digital electronic control system is incorporated. An SFC reduction of the order of 10 percent at cruise thrust is achieved, relative to current engines of comparable thrust class. O.C.

A89-46898*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EVALUATION OF PARALLEL INJECTOR CONFIGURATIONS FOR SUPERSONIC COMBUSTION
G. BURTON NORTHAM (NASA, Langley Research Center, Hampton, VA), I. GREENBERG, and C. S. BYINGTON (Joint Institute for Advancement of Flight Sciences, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. refs
(AIAA PAPER 89-2525)

Techniques for the enhancement of mixing in a scramjet combustor are presently investigated experimentally with wall-mounted parallel injector ramps that are speculated to prove useful at high speeds in the extraction of thrust from engine- or airframe-coolant hydrogen. The injector ramps were designed to generate a reflected shock wave from the duct top wall which will pass just downstream of the fuel injectors' barrel shock; fuel injector Mach number is 1.7, in virtue of which an underexpanded fuel flow is generated. Shadowgraph and UV-TV flow visualizations were conducted for three duct configurations. O.C.

A89-46926#
A NUMERICAL INVESTIGATION OF SCRAMJET COMBUSTORS
H. H. KLEIN and P. C. CHAN (JAYCOR, San Diego, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. Research supported by JAYCOR. refs
(AIAA PAPER 89-2561)

The propulsion system for hypersonic vehicles will rely heavily on computational fluid dynamics for its design. JAYCOR has developed the EITACC code to solve the Navier-Stokes Equations over a wide range of flow conditions. The code has successfully modeled the types of flows found in scramjet engines, including: supersonic flow with imbedded subsonic regions, complex shock and expansion fields, turbulent mixing and transport, flow separation and reattachment, and combustion. In this paper the EITACC code is described and the results of flow in a generic scramjet combustor are presented. Author

A89-46927#
EFFECTIVENESS OF PLASMA TORCHES FOR IGNITION AND FLAMEHOLDING IN SCRAMJET
YUKINORI SATO, MASAMI SAYAMA, KATSURA OHWAKI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), GORO MASUYA, TOMOYUKI KOMURO (National Aerospace Laboratory, Chofu, Japan) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2564)

A plasma torch with a feed stock of air or oxygen was studied experimentally to determine its effect on ignition and flameholding in a scramjet combustor. Consideration was given to fuel injection from one orifice, from four orifices on one wall, and from all nine orifices on both walls. This plasma torch was capable of stable operation without any support gas. In the case of single wall injection, the plasma torch ignited the fuel jet located directly downstream and the flame formed ignited adjacent fuel jets. In double wall injection, ignition of the fuel injected from the wall opposite the plasma torch was unsuccessful. K.K.

A89-46932#
TURBINE ENGINE STRUCTURAL EFFICIENCY DETERMINATION
A. F. STORACE (GE Aircraft Engines, Cincinnati, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(Contract F33615-87-C-2843)
(AIAA PAPER 89-2571)

Studies performed for advanced turbine engine concepts show that major increases in thrust/weight performance and structural efficiency can be obtained by adapting structural geometry to take full advantage of material characteristics. This paper focuses on analytical methods and design concepts developed to enhance the structural efficiency of turbine engines. Turbine engine structural efficiency is quantified through the improvements obtainable in engine system vibration, turbomachinery clearance closures, and specific strength. Author

A89-46936# Pratt and Whitney Aircraft Group, West Palm Beach, FL.
APPLICATION OF A MULTI-STAGE 3-D EULER SOLVER TO THE DESIGN OF TURBINES FOR ADVANCED PROPULSION SYSTEMS
F. W. HUBER (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) and R. R. NI (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p. Research supported by USAF, U.S. Army, NASA, General Dynamics Corp., and United Technologies Corp.
(AIAA PAPER 89-2578)

The present three-dimensional Euler solver for iterative design of multistage gas turbine aerodynamic contours allows the optimization of turbine airfoil, endwall, inlet, and exit flow passage surfaces as a cohesive system, and facilitates the evaluation of potential changes to an individual surface contour during the design process. This evaluation encompasses not only flow property changes around the component being modified, but also around all upstream and downstream components in the complete turbine system. Illustrative examples of this system's application to advanced turbines for airbreathing and rocket-propellant turbines are presented. O.C.

A89-46938#
TESTING OF THE 578-DX PROPFAN PROPULSION SYSTEM
D. C. CHAPMAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), R. E. FLEURY (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT), and D. E. SMITH (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p.
(AIAA PAPER 89-2581)

The 578-DX Propfan Demonstrator Propulsion System, whose flight testing on an MD-80 airliner testbed was recently completed, has a powerplant encompassing a gas generator developed from engines currently used in marine and industrial applications, a novel compressor, a reduction-gear system developed under NASA auspices, a contrarotating propfan, a specialized nacelle, and a full-authority digital electronic control system. The flight test program has yielded data on (1) near- and far-field acoustic data to assess FAR36 Stage III conditions compliance; (2) data useful in the resolution of aircraft/engine integration problems; and (3) data suitable for guiding future geared propfan propulsion system development decisions. O.C.

A89-46939#
UHB DEMONSTRATOR FLIGHT TEST PROGRAM - PHASE 2
JOHN E. DONELSON, WILLIAM T. LEWERENZ, and ROGER T. DURBIN (Douglas Aircraft Co., Long Beach, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p.
(AIAA PAPER 89-2582)

The second phase of the MD-80 airliner testbed-based Ultrahigh Bypass (UHB) demonstrator flight-test program has expanded technical knowledge in the areas of passenger comfort, airport community noise, airframe structural design, engine operability, and aircraft/engine integration. This deeper technical understanding of geared/contrarotating rotor noise and vibration characteristics will be applied to the design of UHB-incorporating MD-91 and -92 aircraft, in order to achieve passenger cabin noise and airport vicinity noise levels comparable to those of current-generation high bypass turbofan powered airliners. O.C.

A89-46940#
ESTIMATING IN-FLIGHT ENGINE PERFORMANCE VARIATIONS USING KALMAN FILTER CONCEPTS
R. H. LUPPOLD, J. R. ROMAN (United Technologies Optics and Applied Technology Laboratory, West Palm Beach, FL), G. W. GALLOPS, and L. J. KERR (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2584)

This paper describes an algorithm for estimating both the cause and level of off-nominal engine performance. A state variable model for an advanced tactical turbofan engine configuration was developed which models explicitly the effects of engine performance variations. A Kalman filter algorithm based on this model is used to estimate five engine factors that fully characterize off-nominal performance. The Kalman filter inputs are measurements from a standard engine control instrumentation suite. Proof-of-concept tests using nonlinear engine simulation data as well as actual data are presented. Potential applications of this concept include in-flight and maintenance diagnostics, in-flight aircraft/engine performance integration, and adaptive engine control laws. Author

A89-46941#
DIAGNOSTIC EXPERT SYSTEMS FOR GAS TURBINE ENGINES - STATUS AND PROSPECTS
DAVID L. DOEL (GE Aircraft Engines, Evendale, OH) and LEE R. LAPIERRE (GE Aircraft Engines, Lynn, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p. refs
(AIAA PAPER 89-2585)

The status of condition monitoring algorithm development is discussed with attention given to recent work with artificial intelligence. The use of expert systems for gas path analysis and for on-wing fan trim balance is discussed. It is noted that tools like GEN-X address the need to eliminate the knowledge engineer. K.K.

A89-46942#
LOW COST CONTROL SYSTEM FOR EXPENDABLE TURBINE ENGINES
K. BILL SWONGER (Teledyne CAE, Toledo, OH) and MARTIN F. HUFFMAN (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 21 p.
(AIAA PAPER 89-2586)

The design and development of a new low cost control system for nonman-rated engines are discussed. Consideration is given to control mode selection, fuel pump and metering device evaluation, fuel pump evaluation, engine shaft integrated liquid ring pump, fuel metering device evaluation, engine sensor evaluation, reliability analysis, and electronic hardware fabrication. The engine tests demonstrated N-dot control law operation/stability, digital engine control hardware operation, and compatibility with the liquid ring pump engine system. K.K.

A89-46944#
EVALUATION OF A FAULT TOLERANT DIGITAL ENGINE CONTROLLER
WILLIAM E. WRIGHT, JAMES C. HALL (GE Aircraft Engines, Cincinnati, OH), JOHN J. DEYST, JR., and RICHARD E. HARPER (Charles Stark Draper Laboratory, Inc., Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. refs
(Contract F33657-82-C-2265; F33657-85-C-2131; N00140-83-C-9046)
(AIAA PAPER 89-2589)

Two programs initiated by the USAF (INTERFACE I and II-L) to address aircraft engine control reliability and redundancy issues associated with advanced aircraft are described. INTERFACE I incorporated a military standard 1750A 16-bit processor architecture programmed in Jovial and INTERFACE II-L utilizes military standard 1815 Ada in combination with a 32-bit processor. After evaluating these types of engine control, the results of studies on fault-tolerant parallel processing for engine controls are presented. K.K.

A89-47006#
A COMPARISON OF SCRAMJET ENGINE PERFORMANCES OF VARIOUS CYCLES
TAKESHI KANDA, GORO MASUYA, YOSHIO WAKAMATSU, NOBUO CHINZEI, and AKIO KANMURI (National Aerospace Laboratory, Kakuda, Japan) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2676)

An airframe-integrated hydrogen fueled scramjet engine is assumed in order to compare engine performances of various engine cycles: an expander cycle, a staged-combustion cycle, a coolant-bleed cycle, and a gas-generator cycle. Each engine was regeneratively cooled by liquid hydrogen. Effects of flight Mach number, flight dynamic pressure, and fuel injection-to-air dynamic pressure ratio were examined as related to propellant feed-line power balance. The system pressure of the closed loop cycle becomes high, while the specific impulse of the open loop cycle becomes low, when the flight Mach number, the flight dynamic pressure, or the fuel injection to air dynamic pressure are high, i.e., when the fuel injector manifold pressure is high. Of the four cycles, the coolant-bleed cycle shows the most well-balanced performance. Author

A89-47015#
SUPERSONIC TURBOMACHINE ROTOR FLUTTER CONTROL BY AERODYNAMIC DETUNING
KAREN M. SPARA and SANFORD FLEETER (Purdue University, West Lafayette, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2685)

A mathematical model is developed to analyze the flutter stability characteristics of an aerodynamically detuned rotor operating in a supersonic inlet flow field with a supersonic axial component. Alternate blade aerodynamic detuning is considered, accomplished by alternating the circumferential spacing of adjacent rotor blades. The unsteady aerodynamics are determined by developing an influence coefficient technique which is appropriate for both aerodynamically tuned and detuned rotor configurations. The effects of this detuning on the flutter stability characteristics of supersonic axial flow rotors are then demonstrated by applying this model to baseline twelve bladed rotors. Results show that, dependent on the specific blade row and flow field geometry, alternate blade aerodynamic detuning is a viable flutter control mechanism for supersonic throughflow rotors. Author

A89-47019#
DYNAMIC TURBINE BLADE TEMPERATURE MEASUREMENTS
WILLIAM J. BECKER, RICHARD J. ROBY, WALTER F. O'BRIEN (Virginia Polytechnic Institute and State University, Blacksburg), and GERALD K. BENSING (Rosemount, Inc., Aerospace Div., Eagan, MN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. Research supported by Rosemount, Inc. refs
(AIAA PAPER 89-2689)

Turbine blade surface measurements were obtained during transient operation of a turbofan engine test rig. A single-fiber radiation pyrometer was employed to image the suction side of the blades from about 60 percent axial chord to the trailing edge at an average radial location of 70 percent blade height. During the starting and acceleration transients, the blade surface was shown to reverse, with large temperature gradients appearing during starting. During the deceleration transients, the trailing edge cooled more rapidly than the 60-percent chord location, resulting in larger temperature gradients than were noted in steady operation. The observed temperature gradients and profile inversions indicate a cycling of thermally-induced stresses which may contribute to low cycle fatigue damage. A simple one-dimensional heat transfer model is proposed to explain the different heating rates found during the transients. R.R.

A89-47023#
ADVANCED MATERIAL APPLICATIONS FOR TURBINE AIRFOILS
F. O. SOECHTING (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 5 p.
(AIAA PAPER 89-2693)

A comparative study has been conducted to ascertain the strength requirements of 20 monolithic ceramic materials applicable to high-temperature turbine airfoils in both cooled and uncooled operating environments. Fused silica, TiN, TiB2, AlN, ZrO2, SiC, BeO, Si3N4, and HfO2 were among the materials studied. The amount of cooling that may be required by each of the materials is determined, and it is found that maximum tensile stress levels are enhanced when a turbine airfoil material is cooled. High thermal conductivity materials are desirable due to their minimization of thermal stresses in uncooled applications and of coolant flow requirements in cooled applications. O.C.

A89-47024#
PREDICTION OF PERIODIC LOADINGS ON SINGLE ROTATION PROPFAN WITH OFF-AXIS INFLOW
SHIH H. CHEN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2694)

A 3D Green's function potential paneling method is used to predict the propfan unsteady load in a yawed flow condition when the axis of blade rotation is inclined to the free stream. Unsteady response is predicted in a frequency domain with proper predetermined interblade phase angle. The method is shown to be accurate and efficient in computation comparing to a time domain calculation. Single rotation propfan blade SR2 is used to demonstrate the capability. The effects of shaft angle of attack, advance ratio, number of blades, and Mach number on the response due to the off-axis inflow are studied. The results indicate that the shaft angle of attack has a major effect on the unsteady blade loading. Author

A89-47061#
A PROPULSION DEVELOPMENT STRATEGY FOR THE NATIONAL AERO-SPACE PLANE
RAYMOND H. MOSZEE and CURTIS D. SNYDER (USAF, National Aero-Space Plane Joint Program Office, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p.
(AIAA PAPER 89-2751)

The National Aero-Space Plane (NASP) Program, which is a joint DOD-NASA effort to develop and demonstrate technologies applicable to a new generation of transatmospheric vehicles, is described. In connection with the vehicle engine design, consideration is given to several propulsion related issues, concerns, and a risk reduction approach that incorporates rocket augmentation. As part of the NASP Program, an experimental aircraft called the X-30 has been constructed. Through the use of this facility, propulsive concepts have been proven at speeds up to Mach 25. K.K.

A89-47084#
COMBUSTION ENHANCEMENT IN SUPERSONIC COAXIAL FLOWS
E. GUTMARK, K. J. WILSON, K. C. SCHADOW, T. P. PARR, and D. M. HANSON-PARR (U.S. Navy, Naval Weapons Center, China Lake, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p. refs
(AIAA PAPER 89-2788)

Mixing enhancement of supersonic combusting jets was obtained by using noncircular and multistep nozzles. The tests were performed with free and coaxial supersonic jets in a wide range of parameters, including convective Mach numbers (0.25 to 2.25), temperature variation, velocity and density ratios and design and off-design conditions. The measurements included total pressure in nonreacting flows, temperature and radiance using infrared imaging, and combustion zone mapping using planar laser induced fluorescence. The tests showed increased spreading rate of rectangular jets relative to a circular jet. This improvement was dependent on the nozzle inner design and outer flow conditions. Interaction of shock and shear layer instabilities at off-design conditions further enhanced mixing in the absence of coaxial flow. The multistep nozzle increased small-scale mixing, thus enhancing heat release and improved the flameholding characteristics of the combustion. Author

A89-47088*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MIXING ENHANCEMENT IN A SUPERSONIC COMBUSTOR
J. PHILIP DRUMMOND, MARK H. CARPENTER, DAVID W. RIGGINS, and MARY S. ADAMS (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 16 p. refs
(AIAA PAPER 89-2794)

Research has been conducted for a number of years at the NASA Langley Research Center to develop a supersonic combustion ramjet (scramjet) capable of propelling a vehicle at hypersonic speeds in the atmosphere or beyond. Recently, that research has been directed toward the optimization of the scramjet combustor, and in particular the efficiency of fuel-air mixing and reaction in the engine. This paper describes a numerical study of fuel-air mixing and reaction in a supersonic combustor, and discusses the analysis of a technique that was used to enhance the mixing processes and overall combustion efficiency in the flow. Based on the results of that study, conclusions are drawn regarding the applicability of the technique to enhance mixing in a scramjet combustor. Author

A89-47091#
NUMERICAL STUDY OF REACTIVE RAMJET DUMP COMBUSTOR FLOWFIELDS WITH A PRESSURE BASED CFD METHOD
TEN-SEE WANG, YEN-SEN CHEN, and RICHARD C. FARMER (SECA, Inc., Huntsville, AL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(AIAA PAPER 89-2798)

The formulation and verification of a numerical model for simulating reactive dump combustor flowfields by solving the Navier-Stokes equations are presented. A pressure-based solution algorithm which uses time-centered, time-marching, central spatial discretization, and adaptive dissipation was developed for this analysis. A one-step reversible finite rate hydrogen/oxygen chemical kinetics model and a point implicit method were used to evaluate the reaction source terms in the species equations. The temperature dependency of the dissipation rate on the combustion process is studied. Author

A89-47092#
RAMJET COMBUSTOR MODELING FOR ENGINEERING DESIGN
L. S. CARETTO and A. K. RUNCHAL (Analytic and Computational Research, Inc., Los Angeles, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(Contract F33615-84-C-2440)
(AIAA PAPER 89-2799)

A mathematical model was used as an integral part of the design process for a ramjet dump combustor. The model solved the two-dimensional, axisymmetric Navier-Stokes equations and differential equations for swirl, fuel mass fraction, and turbulence quantities. It was used for initial studies of cold flow modeling and comparisons of combustion tests. The trends predicted by the model compared favorably with those found in the experimental program and provided useful information for the design process. The computer model represented the important details of the combustion process, but was kept simple so that all computer runs could be made on an IBM PC/AT. Author

A89-47094#
IMPROVING THE DEVELOPMENT PROCESS FOR MAIN COMBUSTOR EXIT TEMPERATURE DISTRIBUTION
STANLEY K. WIDENER (GE Aircraft Engines, Cincinnati, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2804)

The development and treatment of the gas temperature distribution exiting a gas turbine main combustor is aided by the application of available data for dilution jet penetration and mixing characteristics. This paper presents a method for predicting the results of changes in dilution features, and provides examples of application of this method. The method applies laws of mass and energy conservation to determine local changes in temperature resulting from changes in stoichiometry as the dilution jets mix with the main stream. Predictions are compared with measurements taken during a typical combustor development program. This approach has been shown to effectively reduce the number of

test iterations required to achieve a satisfactory temperature distribution. Author

A89-47098*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PARAMETRIC STUDY OF A SIMULTANEOUS PITCH/YAW THRUST VECTORING SINGLE EXPANSION RAMP NOZZLE
ALBERTO W. SCHIRMER (NASA, Langley Research Center; George Washington University, Hampton, VA) and FRANCIS J. CAPONE (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(AIAA PAPER 89-2812)

In the course of the last eleven years, the concept of thrust vectoring has emerged as a promising method of enhancing aircraft control capabilities in post-stall flight incursions during combat. In order to study the application of simultaneous pitch and yaw vectoring to single expansion ramp nozzles, a static test was conducted in the NASA-Langley 16 foot transonic tunnel. This investigation was based on internal performance data provided by force, mass flow and internal pressure measurements at nozzle pressure ratios up to 8. The internal performance characteristics of the nozzle were studied for several combinations of six different parameters: yaw vectoring angle, pitch vectoring angle, upper ramp cutout, sidewall hinge location, hinge inclination angle and sidewall containment. Results indicated a 2-to- 3-percent decrease in resultant thrust ratio with vectoring in either pitch or yaw. Losses were mostly associated with the turning of supersonic flow. Resultant thrust ratios were also decreased by sideways expansion of the jet. The effects of cutback corners in the upper ramp and lower flap on performance were small. Maximum resultant yaw vector angles, about half of the flap angle, were achieved for the configuration with the most forward hinge location. Author

A89-47100#
ADVANCED COOLING CONCEPTS FOR MULTI-FUNCTION NOZZLE DURABILITY
STEPHEN A. PAUL (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) and ALEX J. GIESE (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(AIAA PAPER 89-2814)

Advanced cooling techniques, and such improved refractory materials as a Ni-based superalloy and carbon/carbon composites, have been used to maximize the projected performance and durability levels of a baseline vectoring/reversing single-expansion ramp nozzle (SERN) for year-2000 fighter aircraft. Impingement cooling is identified as the optimal cooling technique for both metallic and carbon-composite materials, yielding significant cooling airflow reductions without durability reduction. SERN-type nozzles incorporating the improvements presently discussed do not entail significant increases in aircraft takeoff gross weight. O.C.

A89-47102#
ADVANCED THRUST VECTORING NOZZLES FOR SUPERCRUISE FIGHTER AIRCRAFT
J. MACE, P. SMERECZNIAK, G. KREKELER (McDonnell Aircraft Co., Saint Louis, MO), D. BOWERS (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH), M. MACLEAN (GE Aircraft Engines, Cincinnati, OH) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2816)

The role of advanced pitch/yaw thrust vectoring nozzles in expanding the performance envelope of future fighter aircraft has been examined. Two nozzle concepts were designed and integrated into a supercruise aircraft and their static performance quantified. Analytical and experimental data bases were developed and used to identify payoffs and penalties associated with using these advanced nozzles. Advanced nozzles having combined pitch and yaw thrust deflection capability are shown to provide significant maneuver benefits for future supercruise fighters. Author

A89-47103#
DEVELOPMENT TESTING OF THE 578 PROPFAN GEAR SYSTEM
N. E. ANDERSON and D. A. WAGNER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2817)

Development testing of the first high-power counterrotating gear system for use in propfan propulsion systems is described in this paper. In preparation for flight tests aboard a McDonnell Douglas MD-80 aircraft, extensive rig and propulsion system integration tests were conducted. This discussion focuses on the development testing leading to the highly successful flight tests. Author

A89-47106#
DESIGN OF A GEAR DRIVE FOR COUNTER-ROTATING FAN ROTORS
D. C. HOWE and A. H. MCKIBBIN (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p.
(AIAA PAPER 89-2820)

Improved gearbox efficiency, durability, and structural weight are sought in the development of advanced-technology design features for in-line, differential planetary gear drive systems for contrarotating propfan rotors. Attention is presently given to a 12,000 SHP nominal-rating gearbox of this type that is projected to possess a growth margin extending to 15,000 SHP, in conjunction with a durability goal of 30,000 hr (mean-time between unplanned removals) and an efficiency goal of 99 percent at cruise power; also discussed is the fully automated gearbox-testing facility enployed, whose capabilities encompass simulated fan rotor torque, thrust, and side loads, as well as simulated aircraft attitudes. O.C.

A89-47107#
DESIGN CRITERIA AND ANALYSIS OF DYNAMIC STRESSES OF A PROPELLER GEAR SYSTEM
KAYAALP BUYUKATAMAN (GE Aircraft Engines, Lynn, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs
(AIAA PAPER 89-2822)

The turboprop engine gearbox design effort that has been undertaken for the USN's Long-Range Air ASW-Capable Aircraft has emphasized the use of advanced gear-design methods, including the employment of a computer model incorporating most knowledge accumulated in the field of gear manufacturing and system simulation to date. The theoretical basis of the simulation model assumes that the system consists of a series of springs, and that it responds to input data through time-dependent variable and nonlinear spring rates. Gear impact locations, temperature distributions, dynamic surface stresses and bending stresses, lubricant film thicknesses, gear profile errors, and operating speeds, are among the factors addressed. O.C.

A89-47125#
TRANSFERRING JET ENGINE DIAGNOSTIC AND CONTROL TECHNOLOGY TO LIQUID PROPELLANT ROCKET ENGINES
JOSEPH F. ALCOCK and STEVEN K. HAGAR (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 15 p.
(AIAA PAPER 89-2851)

This paper presents the methodology for developing a diagnostic and control system for a current, operational jet engine. A description is given of each development stage, the system components and the technologies which could be transferred to liquid propellant rocket engines. Finally, the operational impact is described in terms of cost and maintenance based on actual jet engine experience. Efforts are continuing to develop new diagnostic techniques under IR&D for application on the advanced technical fighter. Already improved techniques and application methods are

becoming available. This technology is being evaluated and may also be transferred to rocket engine diagnostic and control system development. Author

A89-47150#
THE INFLUENCE OF SWIRL AND FUEL COMPOSITION OF BORON-CONTAINING FUELS ON COMBUSTION IN A SOLID FUEL RAMJET COMBUSTION CHAMBER
R. PEIN and F. VINNEMEIER (DLR, Institut fuer chemische Antriebe und Verfahrenstechnik, Hardthausen am Kocher, Federal Republic of Germany) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2885)

Investigations in the field of boron combustion were carried out at the ramjet test facility. A solid fuel ramjet combustor was used which was directly connected with an air heater and an air supply. The experiments were conducted with and without inlet flow swirl. HTPB fuels containing boron or boron carbide in varying compositions were applied. The effects of swirl flow and fuel composition on boron combustion efficiency, fuel regression and thrust were measured. An exhaust particle sampling technique in connection with a chemical analysis method was developed in order to measure the composition of the condensed combustion products. Author

A89-47151#
EFFECTS OF BYPASS AIR ON THE COMBUSTION OF BORON PARTICLES IN A SOLID FUEL RAMJET
B. NATAN and A. GANY (Technion - Israel Institute of Technology, Haifa) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 5 p. refs
(AIAA PAPER 89-2886)

The research deals with a theoretical prediction of the combustion behavior of individual boron particles in a solid fuel ramjet (SFRJ) motor. The results indicate that boron particles can not complete their burning inside the main combustor. The idea of using an after-burner, where bypass air is added, as a possible solution to achieve better combustion efficiencies has been examined. The results reveal that most of the particles can burn efficiently in a 0.5 m length after-burner. Author

A89-47153#
A 3-D ANALYSIS OF GAS TURBINE COMBUSTORS
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2888)

In order to achieve the required performance goals and structural durability of gas-turbine combustion systems, a design approach was formulated to guide the development effort of the combustor. The approach combines the capabilities of the analytical tools with well established empirical correlations. By this means, the impact of systematic modification to the details of the burner is easily determined. The validation effort of the developed model included the utilization of the data obtained for a number of production combustors that significantly varied in design and concept. Fuels used in these combustors included typical aviation fuels such as JP-4 and DF-2 as well as specially prepared high density fuels. Model validation also involved the application of the model in the development phases of an annular combustor. Several modifications to the dome and primary zone features were proposed in this effort. The predictions of the combustor performance and wall temperatures made using the present approach were found to be in good agreement with the measurements. Author

A89-47155#
COMBUSTION CHARACTERISTICS OF GASEOUS FLAMES IN A GAS TURBINE COMBUSTOR
A. M. ATTYA, M. A. HABIB, and M. R. TAHA (Cairo University, Giza, Egypt) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2892)

The measurement methods and calculations of the flow and the combustion characteristics of the jet-engine-combustor flame are described for experiments conducted in an actual combustion chamber of a jet engine, and the results of calculations, which were made using a two-equation turbulence model, were compared with the measuremets. The flame structure inside the combustor and the effects of the air/fuel ratio on the flame properties were determined using measurements of temperature and species concentration of CO2, CO, and O2 at four different air-to-fuel ratios. It was found that the calculated temperature and species concentrations were predicted reasonably well, particularly at the downstream locations and away from the centerline region, where the temperature and the CO2 concentration were overpredicted and the oxygen concentration was underpredicted. I.S.

A89-47162#
NUMERICAL INVESTIGATION OF THRUST-REVERSING NOZZLE USING AN IMPLICIT TVD SCHEME
S. M. LIANG (National Cheng Kung University, Tainan, Republic of China) and C. L. HU AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. Sponsorship: National Science Council of the Republic of China. refs
(Contract NSC-77-0401-E006-33)
(AIAA PAPER 89-2899)

A compressible Navier-Stokes solver using an implicit TVD scheme has been developed to study the performance and internal flowfield of a two-dimensional thrust-reversing nozzle. It is noted that the present TVD scheme overcomes numerical instablity error created near the corners and satisfies the entropy condition so that no expansion shock is captured. Results for the reverse thrusts, discharge coefficients, and pressure distributions along the flap and the blocker at different nozzle pressure ratios are found to agree well with experimental data. It is shown that a supersonic bubble terminated by a weak shock and an induced separated flow exist near the corners, and that there are high and low temperature regions on the flap and a low temperature region on the blocker. R.R.

A89-47170#
A TECHNIQUE FOR THE MEASUREMENT OF BLADE TIP CLEARANCE IN A GAS TURBINE
J. W. H. CHIVERS (Rolls-Royce, PLC, Derby, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 13 p. refs
(AIAA PAPER 89-2916)

A technique for measuring the steady and the transient blade-tip clearances in a gas turbine was developed. Problems associated with obtaining such a measurement in a gas turbine environment are discussed, and a measurement specification is derived which is applicable to sea-level bench engine testing. Results are presented on the performance of a prototype clearance system, which was evaluated in the laboratory, and then was used on an engine turbine. I.S.

A89-47178#
SUPERSONIC NOZZLE MIXER EJECTOR
T. G. TILLMAN, R. W. PATERSON (United Technologies Research Center, East Hartford, CT), and W. M. PRESZ, JR. (Western New England College, Springfield, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. Research supported by United Technologies Corp. refs
(AIAA PAPER 89-2925)

Experimental results are presented for the performance of a supersonic nozzle mixer-ejector representative of candidate devices for commercial SST noise attenuation during takeoff and landing. In this mixer-ejector configuration, an array of large-scale, low-intensity streamwise vortices is introduced into the downstream mixing duct; these enhance mixing through an inviscid-mixing process yielding enhanced ejector pumping. A convergent/divergent, suitably lobed mixer nozzle was tested and its results compared with those for a conventional slot-nozzle

ejector. The lobed nozzle is able to increase ejector pumping performance by 75 percent over the conventional nozzle. O.C.

A89-47179#
EXPENDABLE SUPERSONIC EXHAUST NOZZLE CONCEPTS
V. D. BAKER, O. KWON, B. V. R. VITTAL, and T. F. MCKAIN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2927)

The minimization of propulsion system size, weight, cooling requirements, and complexity/cost for a supersonic unmanned aircraft is presently undertaken in the specific case of the expendable nozzle employed by the powerplant. A series of supersonic nozzle scale model configurations was designed with a view to eventual wind-tunnel testing; attention is given to the results of detailed analyses of their complex internal and external flow fields using a fully viscous compressible code. The code is shown to be capable of predicting the complex interaction between external and internal flows. O.C.

A89-47180*# General Electric Co., Cincinnati, OH.
A STATIC INVESTIGATION OF SEVERAL STOVL EXHAUST SYSTEM CONCEPTS
B. M. ROMINE, JR., B. E. MEYER (GE Aircraft Engines, Cincinnati, OH), and R. J. RE (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.
(AIAA PAPER 89-2928)

A static cold flow scale model test was performed in order to determine the internal performance characteristics of various STOVL exhaust systems. All of the concepts considered included a vectorable cruise nozzle and a separate vectorable vertical thrust ventral nozzle mounted on the tailpipe. The two ventral nozzle configurations tested featured vectorable constant thickness cascade vanes for area control and improved performance during transition and vertical lift flight. The best transition performance was achieved using a butterfly door type ventral nozzle and a pitch vectoring 2DCD or axisymmetric cruise nozzle. The clamshell blocker type of ventral nozzle had reduced transition performance due to the choking of the tailpipe flow upstream of the cruise nozzle. R.R.

A89-47186*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INVESTIGATION OF LOW NOX STAGED COMBUSTOR CONCEPT IN HIGH-SPEED CIVIL TRANSPORT ENGINES
HUNG LEE NGUYEN, DAVID A. BITTKER, and RICHARD W. NIEDZWIECKI (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. Previously announced in STAR as N89-22606. refs
(AIAA PAPER 89-2942)

Levels of exhaust emissions due to high temperatures in the main combustor of high-speed civil transport (HSCT) engines during supersonic cruise are predicted. These predictions are based on a new combustor design approach: a rich burn/quick quench/lean burn combustor. A two-stage stirred reactor model is used to calculate the combustion efficiency and exhaust emissions of this novel combustor. A propane-air chemical kinetics model is used to simulate the fuel-rich combustion of jet fuel. Predicted engine exhaust emissions are compared with available experimental test data. The effect of HSCT engine operating conditions on the levels of exhaust emissions is also presented. The work described in this paper is a part of the NASA Lewis Research Center High-Speed Civil Transport Low NO(x) Combustor program. Author

A89-47188#
EVALUATION OF NOVEL IGNITERS IN A TURBULENT BOMB FACILITY AND A TURBO-ANNULAR GAS TURBINE COMBUSTOR
H. C. LOW, C. W. WILSON (Rolls-Royce, PLC, Bristol, England), R. G. ABDEL-GAYED, and D. BRADLEY (Leeds, University, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(AIAA PAPER 89-2944)

An evaluation has been conducted of the ignition characteristics of a novel plasma jet igniter and a conventional surface-discharge igniter, at both atmospheric and subatmospheric pressures, for turbulence levels representative of gas turbine combustion chambers; an isooctane-fueled combustion bomb was employed in these comparative performance tests. Observed lean ignition limits at different turbulence levels were found to be less restrictive in the case of the plasma jet igniter. Quench-regime ignitions have been obtained with the plasma jet, due to chemically-enhanced flame propagation. A subsequent evaluation of both igniters in a kerosene-fueled gas turbine engine's turboannular combustor has verified the combustion-bomb's finding of considerably enhanced altitude-relight capability with the plasma jet. O.C.

A89-47191#
COMPRESSOR EXIT TEMPERATURE ANALYSIS
PAUL D. NELSON, NORMAN D. POTI, and JEFFREY M. STRICKER (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2947)

An analytical study has been performed to ascertain the effect of compressor exit temperature or pressure ratio, turbine inlet temperature, and turbine blade and vane structure temperatures will have on the takeoff gross weight of a Mach-3, 50,000-ft ceiling dry turbojet-powered interceptor. Engine performance data were integrated with a projected mission profile having realistic anticipated constraints. The results obtained indicate that these mission constraints play an important role in the determination of optimum design points; in addition, inlet flow matching has a substantial effect on the acceleration rate. Compressor exit temperature must be of the order of 1400-1500 F, with a corresponding pressure ratio in the 20-30 range. O.C.

A89-47198#
DISTORTION TEST CAPABILITIES FOR FUTURE FIGHTER AIRCRAFT ENGINES
MARK H. AMUNDSON (USAF, Arnold Engineering Development Center, Arnold AFB, TN) and RAYMOND G. HOLM (GE Aircraft Engines, Cincinnati, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. refs
(AIAA PAPER 89-2956)

Limitations currently exist in the ability of fighter aircraft engine test facilities to simulate inlet pressure-distortion fields due to maneuvering and inlet temperature-distortion fields due to the ingestion of plumes from missile firings. The suitability of the Aeropropulsion Systems Test Facility Test Cell C-1 for engineering evaluations of pressure and temperature distortion simulations has been evaluated in conjunction with the Airjet Distortion Generator employed by this test facility. Attention was also given to the facility's ability to produce time-dependent inlet pressure and temperature distortions. O.C.

A89-47199#
NORMAL IMPINGING JET IN CROSSFLOW - A PARAMETRIC INVESTIGATION
D. BRAY and K. KNOWLES (Royal Military College of Science, Shrivenham, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2957)

The flowfield of a single round impinging jet in crossflow has been experimentally studied, with special attention given to parametric effects on ground vortex penetration. It is found that application of a moving ground plane decreased penetration by about 20 percent, and that increased nozzle height increased wall jet momentum and ground vortex penetration. For the case of the nozzle height being above the vortex height, deflection of the jet

axis is found to occur, moving back the impingement point and leading to reductions in penetration (as measured from the nozzle centerline). R.R.

N89-25165*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
STRUCTURAL TAILORING OF COUNTER ROTATION PROPFANS
KENNETH W. BROWN (Pratt and Whitney Aircraft, East Hartford, CT.) and D. A. HOPKINS *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 389-402 Apr. 1989
(Contract NAS3-23941)
Avail: NTIS HC A23/MF A01 CSCL 21/5

The STAT program was designed for the optimization of single rotation, tractor propfan designs. New propfan designs, however, generally consist of two counter rotating propfan rotors. STAT is constructed to contain two levels of analysis. An interior loop, consisting of accurate, efficient approximate analyses, is used to perform the primary propfan optimization. Once an optimum design has been obtained, a series of refined analyses are conducted. These analyses, while too computer time expensive for the optimization loop, are of sufficient accuracy to validate the optimized design. Should the design prove to be unacceptable, provisions are made for recalibration of the approximate analyses, for subsequent reoptimization. Author

N89-25207*# Textron Lycoming, Stratford, CT.
PROCEDURES FOR SHAPE OPTIMIZATION OF GAS TURBINE DISKS
TSU-CHIEN CHEU *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1097-1108 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 21/5

Two procedures, the feasible direction method and sequential linear programming, for shape optimization of gas turbine disks are presented. The objective of these procedures is to obtain optimal designs of turbine disks with geometric and stress constraints. The coordinates of the selected points on the disk contours are used as the design variables. Structural weight, stress and their derivatives with respect to the design variables are calculated by an efficient finite element method for design senitivity analysis. Numerical examples of the optimal designs of a disk subjected to thermo-mechanical loadings are presented to illustrate and compare the effectiveness of these two procedures. Author

N89-25238*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FUEL PROPERTIES EFFECT ON THE PERFORMANCE OF A SMALL HIGH TEMPERATURE RISE COMBUSTOR
WALDO A. ACOSTA and STEPHEN A. BECKEL (Pratt and Whitney Aircraft, West Palm Beach, FL.) Jul. 1989 12 p Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; sponsored in part by AIAA, ASME, SAE, and ASEE
(Contract N00140-83-C-8899)
(NASA-TM-102096; AVSCOM-TR-89-C-004; E-4857; NAS 1.15:102096; AIAA-89-2901) Avail: NTIS HC A03/MF A01 CSCL 21/5

The performance of an advanced small high temperature rise combustor was experimentally determined at NASA-Lewis. The combustor was designed to meet the requirements of advanced high temperature, high pressure ratio turboshaft engines. The combustor featured an advanced fuel injector and an advanced segmented liner design. The full size combustor was evaluated at power conditions ranging from idle to maximum power. The effect of broad fuel properties was studied by evaluating the combustor with three different fuels. The fuels used were JP-5, a blend of Diesel Fuel Marine/Home Heating Oil, and a blend of Suntec C/Home Heating Oil. The fuel properties effect on the performance of the combustion in terms of pattern factor, liner temperatures, and exhaust emissions are documented. Author

N89-26004*# Sverdrup Technology, Inc., Cleveland, OH.
TURBOFAN ENGINE CONTROL SYSTEM DESIGN USING THE LQG/LTR METHODOLOGY Final Report
SANJAY GARG Jun. 1989 24 p Presented at the American Control Conference, Pittsburgh, PA, 21-23 Jun. 1989; sponsored by American Automatic Control Council
(Contract NAS3-25266)
(NASA-CR-182303; E-4765; NAS 1.26:182303) Avail: NTIS HC A03/MF A01 CSCL 21/5

Application of the Linear-Quadratic-Gaussian with Loop-Transfer-Recovery methodology to design of a control system for a simplified turbofan engine model is considered. The importance of properly scaling the plant to achieve the desired Target-Feedback-Loop is emphasized. The steps involved in the application of the methodology are discussed via an example, and evaluation results are presented for a reduced-order compensator. The effect of scaling the plant on the stability robustness evaluation of the closed-loop system is studied in detail. Author

N89-26005# United Technologies Research Center, East Hartford, CT.
THREE DIMENSIONAL FLOW AND TEMPERATURE PROFILE ATTENUATION IN AN AXIAL FLOW TURBINE Final Report, 15 Dec. 1985 - 15 Mar. 1989
DAVID H. JOSLYN and ROBERT P. DRING 15 Mar. 1989 136 p
(Contract F49620-86-C-0020)
(AD-A206736; AFOSR-89-0439TR) Avail: NTIS HC A07/MF A01 CSCL 21/5

While strongly three dimensional and highly unsteady nature of the flow in axial turbines has, until recently, defied in-depth analysis, the benefits that can be realized from an improved capability to predict the aerodynamics and heat transfer in turbines are numerous. These benefits include improved performance through higher efficiency, higher thrust-to-weight ratio through higher turbine inlet temperature, and improved durability through more precise predictions of local heat load. This program was particularly interested in the aerodynamic mechanisms affecting attenuation of a radial temperature profile in the flow as it passed through the turbine. The radial temperature profile in the flow exiting a combustor and entering a turbine can range from compressor exit temperature (approx = 1100 F) near the hub and tip end walls to a maximum (as high as 3200 F) in the midspan region. The heat load at any location on the turbine airfoils or end walls depends strongly on the local gas temperature at that location; hence the mixing, or attenuation, of the inlet temperature profile is of critical importance. This program has advanced the state-of-the-art by providing: (1) an exhaustive aerodynamic data base for the three dimensional flow in a large scale axial turbine; (2) an exhaustive data base documenting the mixing of a simulated combustor exit temperature profile as it passed through the turbine; and (3) an assessment of state of the art three dimensional time accurate, Navier-Stokes prediction of the flow in the turbine stage. GRA

N89-26006# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Turbine Engine Div.
TWO AXIAL COMPRESSOR DESIGNS FOR A STAGE MATCHING INVESTIGATION Final Interim Report, 1 Jan. - 30 Sep. 1988
C. HERBERT LAW Mar. 1989 281 p
(AD-A206951; AFWAL-TR-89-2005) Avail: NTIS HC A13/MF A01 CSCL 13/11

The design of two single-stage axial-flow compressors for a stage matching investigation are described. The purpose of the investigation is to develop a data base and design techniques necessary to match supersonic blade rows in turbomachinery compression systems. Two compressor designs are required to investigate both fan-type and core-type compression systems, since each configuration has unique aerodynamic and performance characteristics. The latest state-of-the-art aerodynamic and mechanical design techniques were used to design two supersonic

stages to be tested in an environment typical of the second-stage of an advanced military fan and an advanced military core compressor. This report presents the results of the detailed aerodynamic design of the two compressor stages. GRA

N89-26008*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AERONAUTICAL APPLICATIONS OF HIGH-TEMPERATURE SUPERCONDUCTORS
GEORGE E. TURNEY, ROGER W. LUIDENS, KENNETH UHERKA, and JOHN HULL (Argonne National Lab., IL.) Aug. 1989 15 p Presented at the Aircraft Design, Systems and Operations Conference, Seattle, WA, 31 Jul. - 2 Aug. 1989; sponsored in part by AIAA, AHS, and ASEE
(NASA-TM-102311; E-4951; NAS 1.15:102311) Avail: NTIS HC A03/MF A01 CSCL 21/5

The successful development of high-temperature superconductors (HTS) could have a major impact on future aeronautical propulsion and aeronautical flight vehicle systems. A preliminary examination of the potential application of HTS for aeronautics indicates that significant benefits may be realized through the development and implementation of these newly discovered materials. Applications of high-temperature superconductors (currently substantiated at 95 K) were envisioned for several classes of aeronautical systems, including subsonic and supersonic transports, hypersonic aircraft, V/STOL aircraft, rotorcraft, and solar, microwave and laser powered aircraft. Introduced and described are the particular applications and potential benefits of high-temperature superconductors as related to aeronautics and/or aeronautical systems. Author

08

AIRCRAFT STABILITY AND CONTROL

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

A89-45048
SIMULATION METHODOLOGY FOR HELICOPTER AUTOMATIC FLIGHT CONTROL SYSTEMS [METHODOLOGIE DE SIMULATION DES SYSTEMES DE COMMANDES AUTOMATIQUES DE VOL D'UN HELICOPTERE]
MARC ACHACHE (Aerospatiale, Division Helicopteres, Marignane, France) (Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Colloque International sur la Simulation - INFAUTOM 89, 5th, Toulouse, France, Mar. 2, 1989) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 128-134. In French.

The application of different types of simulators for studying the various phases of the development and testing of helicoptor automatic FCSs is considered, and three simulator tools are described in detail. The Rebeca tool treats the frequential aspects of the automatic FCS, and it is used to derive the helicopter control laws. The delayed-time simulation tool Smash was developed for such helicopters as Dauphin, HAP, and NH90. Smash performs closed-loop simulations which are capable of integrating different helicopter, sensor, or actuator models. The Sisyphe tool simulates the real-time functioning of automatic FCS software. R.R.

A89-45064
ASYMPTOTICALLY DECOUPLED DISCONTINUOUS CONTROL OF SYSTEMS AND NONLINEAR AIRCRAFT MANEUVER
SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 25, May 1989, p. 380-391. refs
(Contract DAAL03-87-G-0004)

The question of control of a class of nonlinear systems that can be decoupled by state-variable feedback is considered. Based on variable-structure system theory, a discontinuous control law is derived that accomplishes asymptotic decoupled output trajectory-following in the presence of uncertainty in the system. In the closed-loop system, the trajectories are attracted toward a chosen hypersurface in the state space and then slide along it. During the sliding phase the motion is insensitive to parameter variations. Based on this result, a control law for asymptotically decoupled control of roll angle, angle of attack, and sideslip in rapid, nonlinear maneuvers is derived. Simulation results are presented to show that large, simultaneous lateral and longitudinal maneuvers can be performed in spite of uncertainty in the stability derivatives. I.E.

A89-45151
1988 REPORT TO THE AEROSPACE PROFESSION; SOCIETY OF EXPERIMENTAL TEST PILOTS, SYMPOSIUM, 32ND, BEVERLY HILLS, CA, OCT. 13-15, 1988, PROCEEDINGS
Symposium sponsored by the Society of Experimental Test Pilots. Lancaster, CA, Society of Experimental Test Pilots, 1988, 371 p. For individual items see A89-45152 to A89-45168.

Various papers on aerospace topics are presented. The subjects addressed include: testing for agility, F-14/F-110 high angle of attack flight tests, results and lessons learned from X-29A performance flight test, F-18 Hornet-LEX Fence flight test results, progress on the ATF, initial flight test results of F-15 STOL/Maneuvering Technology Demonstrator, F/A 18 Digital Flight Control System degraded modes flight evaluation, and methodology of FAA handling qualities assessment. Also discussed are: digital flight and inlet control in the SR-71, aspects of the development of the longitudinal control system of the Fokker 100, B-1B high AOA testing, model 360 development, requirements and testing of manual CAT IIIa with A HUD, tactical significance of helicopter aerobatic flight, B-1B development testing, Space Shuttle crew escape, supersonic cruise fighter design, and X-15 pilot-in-the-loop and redundant/emergency systems evaluation. C.D.

A89-45152
TESTING FOR AGILITY - A PROGRESS REPORT
ALAN D. HOOVER (USAF, Research Projects Office, Edwards AFB, CA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 3-22.

Progress made to date in defining metrics for aircraft agility is reviewed. Simplified comparisons are made between aircraft. A case study in agility design is examined. C.D.

A89-45153
F-14/F110 HIGH ANGLE OF ATTACK FLIGHT TESTS
JOE EDWARDS (U.S. Navy, Naval Air Test Center, Patuxent River, MD) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 23-49.

The F-14 Tomcat has been plagued throughout its service life by a series of engine operability and reliability problems, particularly in the high angle of attack (AOA) flight regime. This paper reports flight tests results for the F110-GE-400 engine which will be incorporated into the F-14D in 1990. The present version of the F-14, called the F-14A(PLUS), the flight control system, and the test aircraft are reviewed, and the scope of the tests is examined. The AOA flight characteristics exhibited by the F-14 are described, including directional stability, dihedral effect, kinematic coupling, stores effect, stalls, and spins. Departures that occurred during AOA tests, including lateral control-induced departures, rudder and cross control-induced departures, asymmetric thrust-induced departures, vertical stalls, and inertia-coupled departures are addressed, Engine performance during the tests and recovery from departures are discussed. C.D.

A89-45154
X-29A PERFORMANCE FLIGHT TESTS - RESULTS AND LESSONS LEARNED

HARRY C. WALKER, III (USAF, Flight Test Center, Edwards AFB, CA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 50-71. refs

The X-29 was developed to perform flight tests of advances in aerodynamics that are thought to hold promise for increasing performance. The major resources used to such flight tests are summarized, and the objectives, techniques, and data reduction used in performance testing are discussed. Results of X-29 performance testing with regard to the effects of variable camber control, maneuver dynamic effects, and other effects on performance are examined, and a comparison is made between the forward swept wings of the X-29 and conventional aft-swept wing fighter aircraft. Engineering disciplines related to performance that were tested during the course of the X-29 flight test are considered. C.D.

A89-45155
F-18 HORNET - LEX FENCE FLIGHT TEST RESULTS
F. ALAN FRAZIER (McDonnell Aircraft Co., Saint Louis, MO) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 72-89. refs

The F/A-18 Hornet in operational service has exhibited extraordinary high angle of attack performance. The severe penalty paid for this often-used capability is the high dynamic load environment experienced by the empennage during high speed high angle of attack maneuvering. In 1985, flight testing was completed that initially defined the dynamic load environment and qualified an interim structural modification of the vertical tail structure. Subsequent engineering investigations and wind tunnel testing have identified an aerodynamic solution, the LEX Fence, which alters the high energy vortex shed from the Leading Edge Extension (LEX) prior to its impingement on the vertical tail surfaces. Conclusion of the LEX Fence flight test program has since resulted in NAVAIR approval of the LEX Fence modification of all F/A-18 aircraft. This paper reports in detail the conduct and results of this flight test program. Author

A89-45157
F-15 STOL/MANEUVERING TECHNOLOGY DEMONSTRATOR - INITIAL FLIGHT TEST RESULTS
LAURENCE A. WALKER (McDonnell Aircraft Co., Saint Louis, MO) and WILLIAM R. NEELY (USAF, Wright-Patterson AFB, OH) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 110-127.

The technologies and testing involved in the development of the F-15 STOL/Maneuvering Technolgoy Demonstrator are examined. Four key technologies are described: the two-dimensional thrust vectoring and reversing nozzle, the integrated flight/propulsion control system, the rough field landing gear, and the plot-vehicle interface. The role of simulation is the system development and the flight test program status are summarized, and initial flight test results are discussed. C.D.

A89-45158
F/A-18A DIGITAL FLIGHT CONTROL SYSTEM DEGRADED MODES FLIGHT EVALUATION
TERRY M. HOFFART and MARC G. STEVENS (U.S. Navy, Naval Air Test Center, Patuxent River, MD) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 130-148.

The F/A-18 aircraft utilizes a four-channel digital fly-by-wire flight control system (FCS) with a control augmentation system as its primary FCS mode. Backup or degraded FCS modes are provided in the event of specific system failures to the FCS and include the direct electrical linkage and the mechanical backup modes. This paper discusses the flight test techniques and mission tasks utilized to evaluate the F/A-18 degraded digital FCS and highlights some of the results obtained. C.D.

A89-45159
FAA HANDLING QUALITIES ASSESSMENT - METHODOLOGY IN TRANSITION
COLLET E. MCELROY (FAA, Seattle Aircraft Certification Office, WA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 149-166.

Changes in FAA methodology for handling qualities assessment called for by the introduction of maneuver demand/fly-by-wire technology into civil air transport are discussed. The new FAA handling qualities rating method (HQRM) and a new ratings methodology that has been developed are discussed. Operational considerations are addressed. C.D.

A89-45161
FOKKER 100, SOME ASPECTS OF THE DEVELOPMENT OF THE LONGITUDINAL CONTROL SYSTEM
WIM J. HUSON (Fokker Aircraft, Amsterdam, Netherlands) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 182-197.

Some of the problem areas that were encountered during the development and certification process for the longitudinal control in the Fokker 100 aircraft are reviewed. It is shown that predictions made at the first flight were not completely correct for low-speed stall and for ground effect. Certification issues are discussed. C.D.

A89-45162
B-1B HIGH AOA TESTING
ADDISON S. THOMPSON (Rockwell International Corp., Pittsburgh, PA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 198-204.

Changes made in the B-1B aircraft resulted in performance being constrained by angle of attack (AOA) limits during some mission phases. Since B-1A testing had shown that there was more lift available if it could be utilized, a flight control system modification called Stall Inhibitor System (SIS) was developed to enable the envelope to be more fully realized. The flight control system with the SIS is described here, and some flight test methods and results with the SIS are reported. C.D.

A89-45164
MANUAL CAT IIIA WITH A HUD - REQUIREMENTS AND TESTING
HOWARD B. GREENE (FAA, Seattle, WA) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 223-238.

Test requirements have been developed and used to demonstrate the HUD/aircraft/human pilot system capability to perform reliably the manual landing task in low-visibility conditions. The use of a HUD in the manual CAT IIIa landing task is discussed in detail. Performance test results are reviewed, and visual and fixation lessons learned from the tests are addressed. C.D.

A89-45165
B-1B DEVELOPMENT TESTING
DAVID J. EICHHORN and HAROLD R. GASTON (USAF, Washington, DC) IN: 1988 report to the aerospace profession; Society of Experimental Test Pilots, Symposium, 32nd, Beverly Hills, CA, Oct. 13-15, 1988, Proceedings. Lancaster, CA, Society of Experimental Test Pilots, 1988, p. 255-277.

The flight test results of the B-1B Terrain following (TF) System

and the B-1B Weapons Certification Program are discussed. The TF system and the certification program are described along with the test objectives and methods. Typical weapon separations are shown. C.D.

A89-45179#
THE INFLUENCE OF ALTITUDE AND SPEED VARIATIONS ON THE AEROPLANE'S LOAD COMPONENTS IN LONGITUDINAL NONLINEAR MANOEUVRES
I. TEPOSU (Institutul National pentru Creatie Stiintifica si Tehnica, Bucharest, Rumania) Revue Roumaine des Sciences Techniques, Serie de Mecanique Appliquee (ISSN 0035-4074), vol. 34, Mar.-Apr. 1989, p. 131-149. refs

The aerodynamic and inertial load components in the xyz reference system are determined for the case of longitudinal maneuvers with large variations of incidence angle, altitude, and speed. It is shown that maneuvers with incidence changes up to the stall point and about 1,500-m altitude variations can be described with a precision of 2-3 percent in the load estimation. The results may be used in the determination of the nonlinear response of an aircraft and the maneuvering loads on an aircraft's components. R.B.

A89-45294#
A PILOT'S VIEW OF INTELLIGENT SYSTEMS
DOUGLAS M. HOSMER (Lockheed Aeronautical Systems Co., Burbank, CA) Aerospace America (ISSN 0740-722X), vol. 27, July 1989, p. 32, 33.

The current trend toward single-seat combat aircraft and the accompanying evolution of avionics and complex subsystems have increased pilot workloads to a degree that is unacceptable in combat. An interactive/cooperative real-time expert system functioning as 'pilot's associate' is therefore proposed which can alternatively either assess a situation and advise the pilot as to possible courses of action or, in the event of the pilot's delegation of the requisite authority, take appropriate action. The greatest anticipated payoff from a pilot's associate system lies in the sorting, filtering, and fusing of information destined for the pilot's attention and decisionmaking. O.C.

A89-46546
MODELING OF CONTROLLED FLIGHT DYNAMICS USING IN-FLIGHT SIMULATORS [MODELIROVANIE DINAMIKI UPRAVLIAEMOGO POLETA NA LETAIUSHCHIKH LABORATORIIAKH]
LEONID M. BERESTOV and VADIM V. GORIN Moscow, Izdatel'stvo Mashinostroenie, 1988, 112 p. In Russian. refs

The fundamentals of flight dynamic modeling using in-flight simulators, the principles of base flight vehicle and control system selection, and the use of in-flight simulation for modeling the stability and controllability characteristics of prospective flight vehicles are reviewed. The discussion covers the theory of in-flight simulation, the structure of control systems for in-flight simulators, simulator-flight vehicle similarity criteria, principles of the design of in-flight simulators, and the use of in-flight simulators for pilot training. V.L.

A89-47029#
THE PURSUIT OF INTEGRATED CONTROL - A REALTIME AIRCRAFT SYSTEM DEMONSTRATION
KENNETH D. TILLMAN, TIMOTHY J. IKELER (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL), and RUSSELL A. PURTELL (Northrop Corp., Aircraft Div., Hawthorne, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(AIAA PAPER 89-2701)

Digital flight control and digital engine control hardware were combined with cockpit control hardware and computer simulations of aircraft and engines in order to develop a real-time closed-loop piloted integrated flight and propulsion control system. Integrated control laws have been obtained to provide optimal blending of vectored thrust and aerodynamic control surfaces. MIL-STD-1553B and high speed optic token passing data busses are employed to provide the integrated control communication paths and the simulation feedback data. In piloted tests, the use of pitch vectoring, yaw vectoring, and reversing nozzles as primary control effectors at low air speeds, in combination with the robust control laws and control selector, resulted in greatly enhanced aircraft agility throughout the entire flight envelope. R.R.

A89-47030*# Boeing Co., Seattle, WA.
EXPERIENCES WITH A PREVALIDATION METHODOLOGY FOR DESIGNING INTEGRATED/PROPULSION CONTROL SYSTEM ARCHITECTURES
GERALD C. COHEN, CHARLES W. LEE, MICHAEL J. STRICKLAND (Boeing Co., Boeing Advanced Systems, Seattle, WA), and DANIEL L. PALUMBO (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(Contract NAS1-18099)
(AIAA PAPER 89-2703)

This paper describes a validation methodology and supporting analytical tools developed to provide system designers with a capability of selecting, in the early stages of development, candidate architectures for an integrated airframe/propulsion control system and of predicting their reliability and performance. The results of an application of this methodology to an integrated flight and propulsion control system demonstrated that firm system requirements are being established early in the system life cycle and that an early evaluation exposes missing and conflicting specifications. It is shown that fundamental improvements and refinements can be made early in the concept life cycle when the potential for increased performance is high and the cost and schedule impacts from changes are relatively low. The application of this methodology reduces technical risks associated with integrated system concepts incorporating new technologies. I.S.

A89-47031*# National Aeronautics and Space Administration, Washington, DC.
INTEGRATED CONTROLS PAY-OFF
TERRILL W. PUTNAM and RICHARD S. CHRISTIANSEN (NASA, Washington, DC) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p.
(AIAA PAPER 89-2704)

It is shown that the integration of the propulsion and flight control systems for high performance aircraft can help reduce pilot workload while simultaneously increasing overall aircraft performance. Results of the Highly Integrated Digital Electronic Control (HiDEC) flight research program are presented to demonstrate the emerging payoffs of controls integration. Ways in which the performance of fighter aircraft can be improved through the use of propulsion for primary aircraft control are discussed. Research being conducted by NASA with the F-18 High Angle-of Attack Research Vehicle is described. K.K.

A89-47032#
THE EVOLUTION - IFPC TO VMS
R. E. MATTES and W. A. YONKE (McDonnell Aircraft Co., Saint Louis, MO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p.
(AIAA PAPER 89-2705)

The gains demonstrated in the Highly Integrated Digital Engine Control Program are summarized. Gains expected from the extension of this vehicle management system functional integration philosophy to the utility systems are predicted. Integrated flight/propulsion control has revealed major benefits in engine performance which can be obtained through integrated control. K.K.

A89-47166*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTEGRATED FLIGHT/PROPULSION CONTROL STUDY FOR STOVL APPLICATIONS
JAMES R. MIHALOEW (NASA, Lewis Research Center, Cleveland, OH) and CARL WEISS (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and

ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2908)

The STOVL Integrated Flight Propulsion Controls (IFPC) Program, initiated by NASA Lewis and NASA Ames to develop the necessary technologies for integrating the flight and propulsion controls of a future STOVL aircraft, is described. A major element of the STOVL IFPC Program is the STOVL Controls Integration Program (SCIP), which focuses on the development of an integrated flight propulsion control for the advanced vectored thrust STOVL concept. The SCIP has progressed to the point of generating top level control requirements. K.K.

N89-25141# Technische Hochschule, Aachen (Germany, F.R.).
FLIGHT-MECHANICAL INVESTIGATIONS OF THE LATERAL MOTION OF CONFIGURATIONS WITH WINGLETS [FLUGMECHANISCHE UNTERSUCHUNGEN ZUR SEITENBEWEGUNG VON KONFIGURATIONEN MIT WINGLETS]
A. DIEKMANN and A. JOSTEN *In its* Vortex Flows in Flying Technique p 339-371 1988 In GERMAN
Avail: NTIS HC A17/MF A01

The effect of an aerodynamically optimized winglet with trailing edge flap, on the flight characteristics was investigated, using the Rallye Morane aircraft. The static forces and moments, as well as the effect of the winglet on roll damping were determined in wind tunnel tests. The dynamic behavior and winglet action during spinning were determined during flight tests. The calculation of the dynamic behavior of the aircraft with tip strips or winglets is based on the measured static force and moment coefficients as well as on the estimated dynamic derivatives. The effect of the winglet on the coupling between longitudinal and lateral motion was calculated. Nonlinear effects for large angles of attack and sideslip angles were taken into account. ESA

N89-25189*# Purdue Univ., West Lafayette, IN.
AEROSERVOELASTIC TAILORING FOR LATERAL CONTROL ENHANCEMENT
TERRENCE A. WEISSHAAR and NAM CHANGHO *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 803-814 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

The need for effective aileron power for aircraft lateral control and turning maneuvers dates back to the Wright Brothers and their wing warping concept for active stabilization of their aircraft. Early researchers in Great Britain, Japan, Germany and the United States explored ways to increase the effectiveness of control aileron to generate a roll moment. The basic problem of aileron effectiveness and the interrelationship between structural distortion and the loads applied by the control surface is illustrated. A rigid wing/aileron surface will develop the capability to generate increased roll rates as airspeed increases. A flexible surface will become less effective as airspeed increases because of the twisting distortion created by the aft-mounted control surface. This tendency is further worsened by bending distortion of an aft swept wing. This study focuses its attention on the ability of a combined effort between structural redesign of a wing and sizing and placement of a control surface to create specified roll performance with a minimum hinge moment. This design optimization problem indicates the advantages of simultaneous consideration of structural design and control design. Author

N89-25191*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLUTTER SUPPRESSION USING EIGENSPACE FREEDOMS TO MEET REQUIREMENTS
WILLIAM M. ADAMS, JR., ROBERT E. FENNELL, and DAVID M. CHRISTHILF (Planning Research Corp., Hampton, VA.) *In its* Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 837-859 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 01/3

A constrained optimization methodology has been developed which allows specific use of eigensystem freedoms to meet design requirements. A subset of the available eigenvector freedoms was employed. The eigenvector freedoms associated with a particular closed-loop eigenvalue are coefficients of basis vectors which span the subspace in which that closed-loop vector must lie. Design requirements are included as a vector of inequality constraints. The procedure was successfully applied to develop an unscheduled controller which stabilizes symmetric flutter of an aeroelastic vehicle to a dynamic pressure 44 percent above the open-loop flutter point. The design process proceeded from full-state feedback to the inclusion of a full-order observer to the selection of an eighth-order controller which preserved the full-state sensitivity characteristics. Only a subset of the design freedoms was utilized (i.e., assuming full-state feedback only four out of 26 eigenvectors were used, and no variations were made in the closed-loop eigenvalues). Utilization of additional eigensystem freedoms could further improve the controller. Author

N89-25193*# Planning Research Corp., Hampton, VA.
DIGITAL ROBUST CONTROL LAW SYNTHESIS USING CONSTRAINED OPTIMIZATION
VIVEKANANDA MUKHOPADHYAY *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 879-895 Apr. 1989
(Contract NAS1-8000)
Avail: NTIS HC A22/MF A01 CSCL 01/3

Development of digital robust control laws for active control of high performance flexible aircraft and large space structures is a research area of significant practical importance. The flexible system is typically modeled by a large order state space system of equations in order to accurately represent the dynamics. The active control law must satisy multiple conflicting design requirements and maintain certain stability margins, yet should be simple enough to be implementable on an onboard digital computer. Described here is an application of a generic digital control law synthesis procedure for such a system, using optimal control theory and constrained optimization technique. A linear quadratic Gaussian type cost function is minimized by updating the free parameters of the digital control law, while trying to satisfy a set of constraints on the design loads, responses and stability margins. Analytical expressions for the gradients of the cost function and the constraints with respect to the control law design variables are used to facilitate rapid numerical convergence. These gradients can be used for sensitivity study and may be integrated into a simultaneous structure and control optimization scheme. Author

N89-25195*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
CONTROL SURFACE SPANWISE PLACEMENT IN ACTIVE FLUTTER SUPPRESSION SYSTEMS
E. NISSIM and J. J. BURKEN *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 919-934 Apr. 1989 Prepared in cooperation with Technion-Israel Inst. of Technology, Haifa
Avail: NTIS HC A22/MF A01 CSCL 01/3

All flutter suppression systems require sensors to detect the movement of the lifting surface and to activate a control surface according to a synthesized control law. Most of the work performed to date relates to the development of control laws based on predetermined locations of sensors and control surfaces. These locations of sensors and control surfaces are determined either arbitrarily, or by means of a trial and error procedure. The aerodynamic energy concept indicates that the sensors should be located within the activated strip. Furthermore, the best chordwise location of a sensor activating a T.E. control surface is around the 65 percent chord location. The best chordwise location for a sensor activating a L.E. surface is shown to lie upstream of the wing (around 20 percent upstream of the leading edge), or alternatively, two sensors located along the same chord should be used. Author

N89-25239*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN ANALYTICAL SENSITIVITY METHOD FOR USE IN INTEGRATED AEROSERVOELASTIC AIRCRAFT DESIGN
MICHAEL G. GILBERT May 1989 12 p Presented at the European Forum on Aeroelasticity and Structural Dynamics, Aachen, Fed. Republic of Germany, 17-19 Apr. 1989
(NASA-TM-101583; NAS 1.15:101583) Avail: NTIS HC A03/MF A01 CSCL 01/3

Interdisciplinary analysis capabilities have been developed for aeroservoelastic aircraft and large flexible spacecraft, but the requisite integrated design methods are only beginning to be developed. One integrated design method which has received attention is based on hierarchal problem decompositions, optimization, and design sensitivity analyses. This paper highlights a design sensitivity analysis method for Linear Quadratic Gaussian (LQG) optimal control laws, enabling the use of LQG techniques in the hierarchal design methodology. The LQG sensitivity analysis method calculates the change in the optimal control law and resulting controlled system responses due to changes in fixed design integration parameters using analytical sensitivity equations. Numerical results of a LQG design sensitivity analysis for a realistic aeroservoelastic aircraft example are presented. In this example, the sensitivity of the optimal control law and aircraft response for various parameters such as wing bending natural frequency is determined. The sensitivity results computed from the analytical expressions are used to estimate changes in response resulting from changes in the parameters. Comparisons of the estimates with exact calculated responses show they are reasonably accurate for + or - 15 percent changes in the parameters. Evaluation of the analytical expressions is computationally faster than equivalent finite difference calculations. Author

N89-26009*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTEGRATED FLIGHT/PROPULSION CONTROL SYSTEM DESIGN BASED ON A CENTRALIZED APPROACH
SANJAY GARG, DUANE L. MATTERN (Sverdrup Technology, Inc., Cleveland, OH.), and RANDY E. BULLARD 1989 41 p Presented at the Guidance, Navigation and Control Conference, Boston, MA, 14-16 Aug. 1989; sponsored by the AIAA
(NASA-TM-102137; E-4860; NAS 1.15:102137; AIAA-89-3520) Avail: NTIS HC A03/MF A01 CSCL 01/3

An integrated flight/propulsion control system design is presented for the piloted longitudinal landing task with a modern, statically unstable, fighter aircraft. A centralized compensator based on the Linear Quadratic Gaussian/Loop Transfer Recovery methodology is first obtained to satisfy the feedback loop performance and robustness specificiations. This high-order centralized compensator is then partitioned into airframe and engine sub-controllers based on modal controllability/observability for the compensator modes. The order of the sub-controllers is then reduced using internally-balanced realization techniques and the sub-controllers are simplified by neglecting the insignificant feedbacks. These sub-controllers have the advantage that they can be implemented as separate controllers on the airframe and the engine while still retaining the important performance and stability characteristics of the full-order centralized compensator. Command prefilters are then designed for the closed-loop system with the simplified sub-controllers to obtain the desired system response to airframe and engine command inputs, and the overall system performance evaluation results are presented. Author

N89-26010*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLUTTER SUPPRESSION CONTROL LAW SYNTHESIS FOR THE ACTIVE FLEXIBLE WING MODEL
VIVEK MUKHOPADHYAY (Planning Research Corp., Hampton, VA.), BOYD PERRY, III, and THOMAS E. NOLL May 1989 9 p Presented at the European Forum on Aeroelasticity and Structural Dynamics, Aachen, Fed. Republic of Germany, 17-19 Apr. 1989
(NASA-TM-101584; NAS 1.15:101584) Avail: NTIS HC A02/MF A01 CSCL 01/3

The Active Flexible Wing Project is a collaborative effort between the NASA Langley Research Center and Rockwell International. The objectives are the validation of methodologies associated with mathematical modeling, flutter suppression control law development and digital implementation of the control system for application to flexible aircraft. A flutter suppression control law synthesis for this project is described. The state-space mathematical model used for the synthesis included ten flexible modes, four control surface modes and rational function approximation of the doublet-lattice unsteady aerodynamics. The design steps involved developing the full-order optimal control laws, reducing the order of the control law, and optimizing the reduced-order control law in both the continuous and the discrete domains to minimize stochastic response. System robustness was improved using singular value constraints. An 8th order robust control law was designed to increase the symmetric flutter dynamic pressure by 100 percent. Preliminary results are provided and experiences gained are discussed. Author

N89-26011*# Boeing Commercial Airplane Co., Seattle, WA.
DESCENT STRATEGY COMPARISONS FOR TNAV-EQUIPPED AIRCRAFT UNDER AIRPLANE-PREFERRED OPERATING CONDITIONS Final Report
K. H. IZUMI Washington Aug. 1989 41 p
(Contract NAS1-18027)
(NASA-CR-4248; NAS 1.26:4248) Avail: NTIS HC A03/MF A01 CSCL 01/3

Three 4-D descent strategies were evaluated which were employed by TNAV-equipped aircraft in an advanced metering air traffic control environment. The Flow Management Evaluation Model (FMEM) was used to assess performance using three criteria when traffic enters the simulation under preferred cruise operating conditions (altitude and speed): throughput, fuel usage, and conflict probability. In comparison to an evaluation previously performed under NASA contract, the current analysis indicates that the optimal descent strategy is preferred over the clean-idle and constant descent angle (CFPA) strategies when all three criteria are considered. Author

N89-26012# Virginia Polytechnic Inst. and State Univ., Blacksburg. Interdisciplinary Center for Applied Mathematics.
STATE SPACE MODELS FOR AEROELASTIC AND VISCOELASTIC SYSTEMS Technical Report, 1 Jan. - 31 Dec. 1988
T. L. HERDMAN 15 Feb. 1989 5 p
(Contract *AF-AFOSR-0074-88; AF PROJ. 2304*)
(AD-A207092; AFOSR-89-0380TR) Avail: NTIS HC A02/MF A01 CSCL 01/1

Dynamic modeling of various aeroelastic control systems require at some point in the derivation of the model an application of Soehngen's inversion formula for finite Hilbert transforms to obtain a desired representation for the solution of the airfoil equation. Conditions on initial data to guarantee well-posedness of the resulting model equations must be matched with those needed to justify the validity of the inversion formula. It is shown that this compatibility can be achieved by assuming that the circulation history belongs to a weighted L2 space. The resulting state space formulation provides a suitable setting for control design for the aeroelastic system. GRA

N89-26013*# Systems Technology, Inc., Hawthorne, CA.
ADVANCED PILOTED AIRCRAFT FLIGHT CONTROL SYSTEM DESIGN METHODOLOGY. VOLUME 1: KNOWLEDGE BASE Final Report
DUANE T. MCRUER and THOMAS T. MYERS Oct. 1988 285 p
(Contract NAS1-17987)
(NASA-CR-181726-VOL-1; NAS 1.26:181726-VOL-1; STI-TR-1228-1) Avail: NTIS HC A13/MF A01 CSCL 01/3

The development of a comprehensive and electric methodology for conceptual and preliminary design of flight control systems is presented and illustrated. The methodology is focused on the design stages starting with the layout of system requirements and

ending when some viable competing system architectures (feedback control structures) are defined. The approach is centered on the human pilot and the aircraft as both the sources of, and the keys to the solution of, many flight control problems. The methodology relies heavily on computational procedures which are highly interactive with the design engineer. To maximize effectiveness, these techniques, as selected and modified to be used together in the methodology, form a cadre of computational tools specifically tailored for integrated flight control system preliminary design purposes. While theory and associated computational means are an important aspect of the design methodology, the lore, knowledge and experience elements, which guide and govern applications are critical features. This material is presented as summary tables, outlines, recipes, empirical data, lists, etc., which encapsulate a great deal of expert knowledge. Much of this is presented in topical knowledge summaries which are attached as Supplements. The composite of the supplements and the main body elements constitutes a first cut at a a Mark 1 Knowledge Base for manned-aircraft flight control. Author

N89-26014*# Systems Technology, Inc., Hawthorne, CA.
ADVANCED PILOTED AIRCRAFT FLIGHT CONTROL SYSTEM DESIGN METHODOLOGY. VOLUME 2: THE FCX FLIGHT CONTROL DESIGN EXPERT SYSTEM Final Report
THOMAS T. MYERS and DUANE T. MCRUER Oct. 1988 190 p
(Contract NAS1-17987)
(NASA-CR-181726-VOL-2; NAS 1.26:181726-VOL-2; STI-TR-1228-1) Avail: NTIS HC A09/MF A01 CSCL 01/3

The development of a comprehensive and electric methodology for conceptual and preliminary design of flight control systems is presented and illustrated. The methodology is focused on the design states starting with the layout of system requirements and ending when some viable competing system architectures (feedback control structures) are defined. The approach is centered on the human pilot and the aircraft as both the sources of, and the keys to the solution of, many flight control problems. The methodology relies heavily on computational procedures which are highly interactive with the design engineer. To maximize effectiveness, these techniques, as selected and modified to be used together in the methodology, form a cadre of computational tools specifically tailored for integrated flight control system preliminary design purposes. The FCX expert system as presently developed is only a limited prototype capable of supporting basic lateral-directional FCS design activities related to the design example used. FCX presently supports design of only one FCS architecture (yaw damper plus roll damper) and the rules are largely focused on Class IV (highly maneuverable) aircraft. Despite this limited scope, the major elements which appear necessary for application of knowledge-based software concepts to flight control design were assembled and thus FCX represents a prototype which can be tested, critiqued and evolved in an ongoing process of development. Author

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RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A89-43890
IN THE DRINK
IAN DORMER Flight International (ISSN 0015-3710), vol. 135, May 20, 1989, p. 87-90.

The increasing use of twin-engined airliners for over-water operations has renewed interest in the scale model testing of their emergency water-landing, or 'ditching' characteristics. The U.S. FAA and the U.K. CAA require the ditching ability of all aircraft weighing more than 5669 kg to be established either by model testing or by analysis and extrapolation, in a way that gives due consideration to the effects of inlets, control surfaces, projecting structures, and any other factor likely to affect the hydrodynamic characteristics of the aircraft. Airframe energy-absorption characteristics must also be considered. Helicopter ditching-and-flotation characteristics are also expected to become increasingly important. O.C.

A89-45036
FRENCH AEROSPACE RESEARCH IN THE INTERNATIONAL CONTEXT [LA RECHERCHE AEROSPATIALE FRANCAISE DANS LE CONTEXTE INTERNATIONAL]
JEAN CARPENTIER (ONERA, Chatillon-sous-Bagneux, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 23-27. In French.

The French contribution to the fields of aerodynamics, solid mechanics, advanced materials, aerodynamic structures, and optoelectonics is reviewed. The multidisciplinary approach employed by ONERA is illustrated by the validation of A320 flow calculations via experimental tests performed in the S1 wind tunnel. In the field of propulsion research, numerical simulation results of the unsteady viscous three-dimensional flow in a gas turbine engine are validated using experimental data obtained by laser velocimetry and CARS. Experimental acoustic and thermal data for Ariane 5 are obtained using a reduced-scale model. R.R.

A89-45047
ECONOMIC ASPECTS OF SIMULATION IN AIR TRANSPORTATION [ASPECTS ECONOMIQUES DE LA SIMULATION DANS LE DOMAINE DU TRANSPORT AERIEN]
JEAN PINET (Academie Nationale de l'Air et de l'Espace, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 123-127. In French.

Economic aspects of the application of flight simulators to flight training are considered. The flight hour/simulator hour cost price ratio for the A300 is 10 and for the Concord is 15. The aircraft price/FFS phase II simulator price ratio is found to be 6 for A300, to be 5 for A310, to be 3 for the A320, and to be 1 for the ATR42. It is noted that Airbus-type phase II simulators cost between 12 and 15 million dollars. The recent imposition of stricter safety standards (particularly for take-offs and landings) and the ability of flight simulators to adequately simulate complicated situations (that can easily be repeated) have made it more economical to use fewer flight training hours and more simulator training hours. R.R.

A89-45130
CONCEPT FOR AN AIRCRAFT MULTI-COMPONENT THRUST MEASUREMENT FACILITY
RONALD M. DAVINO and ALLAN W. F. STANLEY (USAF, Flight Test Center, Edwards AFB, CA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. II-2.1 to II-2.13. *refs*

The configuration and capabilities of a multicomponent thrust measurement facility for full-scale tactical aircraft are presented. The thrust measurement capabilities along the axial, vertical, and lateral axes are discussed, along with the required accuracies. The ground effect can be evaluated by varying the aircraft height in the test facility. Means of managing exhaust gas flows, and of measuring the velocity, pressure, temperature, and acoustic fields of the test aircraft, are assessed. It is noted that the present facility will provide a decreased risk to the test vehicle and will decrease the number of required test hours. R.R.

A89-45248* Vigyan Research Associates, Inc., Hampton, VA.
A HIGH SPEED DATA ACQUISITION SYSTEM FOR THE ANALYSIS OF VELOCITY, DENSITY, AND TOTAL TEMPERATURE FLUCTUATIONS AT TRANSONIC SPEEDS
STEVEN J. CLUKEY (Vigyan Research Associates, Inc., Hampton, VA), GREGORY S. JONES (NASA, Langley Research Center, Hampton, VA), and P. CALVIN STAINBACK (Complere, Inc.,

Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p. refs
(SAE PAPER 881451)

The use of a high-speed Dynamic Data Acquisition System (DDAS) to measure simultaneously velocity, density, and total temperature fluctuations is described. The DDAS is used to automate the acquisition of hot-wire calibration data. The data acquisition, data handling, and data reporting techiques used by DDAS are described. Sample data are used to compare results obtained with the DDAS with those obtained from the FM tape and post-test digitization method. C.D.

A89-45249* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A NEW LOOK AT WIND TUNNEL FLOW QUALITY FOR TRANSONIC FLOWS
GREGORY S. JONES (NASA, Langley Research Center, Hampton, VA) and P. CALVIN STAINBACK (Complere, Inc., Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 22 p. refs
(SAE PAPER 881452)

The implementation of several transonic hot wire anemometry techniques for obtaining fluctuating data related to wind tunnel flow quality has been evaluated. An overview of the theoretical considerations, calibration techniques, and related assumptions are discussed for the data presented from the LaRC 8' Transonic Pressure Tunnel. The impact of incorrect assumptions related to hot wire sensitivities are highlighted. Velocity, density, total temperature, and mass flow results from three-element, two-element, and single-element probes are presented in rms and spectral formats. Based on these comparisons, great caution should be used when relying on flow quality information obtained utilizing hot wire techniques other than the three-element technique. Author

A89-46258#
THE RESEARCH OF 2-D FLEXIBLE WALL SELF-CORRECTING WIND TUNNEL
PEICHU ZUO, JIAJU HE, HUAXING LI, and MEN XU (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, no. 2, 1989, p. 208-214. In Chinese, with abstract in English. refs

The results of studies on a two-dimensional flexible wall self-correcting wind tunnel are presented. The parameter choice for this wind tunnel is discussed as well as the iterative test method. Recommendations are made with regard to areas of further research. K.K.

A89-46696#
GUST GENERATION IN A WIND-TUNNEL AND ESTIMATION OF THE MODEL
HIROBUMI OHTA, TAKAFUMI MONJI, ATSUSHI FUJIMORI, and ATSUSHI HATTORI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 424, 1989, p. 247-252. In Japanese, with abstract in English. refs

Three types of gust generators are tested in a wind-tunnel to examine their characteristics. The generators which were investigated are the flag method, turbulent-flow-glid method and their combined method. The gust velocities generated by these methods are measured using a hot wire anemometer of X type, and the characteristics of the power spectra are examined for several parameters such as wind velocity, the size and thickness of a flag. To estimate a gust model for controller designs, discrete models based on an ARMA process are first identified by the AIC method. A continuous model with a lower dimension is then derived by selecting the coefficients of a rational function. These selections are based on the quasi-Newton method which minimizes the square sum of errors at some discrete frequencies. It is found that the gust generators considered here can furnish one with a convenient mean for wind-tunnel experiments. In particular, the estimated gust model may be expected to provide a simple mathematical model for designing controllers. Author

A89-46755#
AN EXPERIMENTAL TECHNIQUE FOR THE MEASUREMENT OF MASS FLOW OF SCRAMJET INLETS TESTED IN HYPERSONIC PULSE FACILITIES
D. M. VAN WIE, G. P. CORPENING, L. A. MATTES, D. A. CARPENTER (Johns Hopkins University, Laurel, MD), S. MOLDER (Ryerson Polytechnical Institute, Toronto, Canada) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 30 p. refs
(AIAA PAPER 89-2331)

An experimental technique for the measurement of inlet mass flow in hypersonic pulse facilities has been investigated. The technique utilizes the rate of pressure rise in a plenum attached to the aft end of an inlet to infer the mass flow into the plenum. The technique has been investigated in two experiments. In the first test, an inlet was simulated using the exhaust from a calibrated sonic nozzle, and pulse flow conditions were generated using a Ludwieg tube. In this test series, the feasibility of the technique was demonstrated. The accuracy of the technique was estimated to be + or - 5 percent with the potential to increase the accuracy to + or - 2 percent. In the second experiment, a Busemann inlet was tested in the Ryerson/University of Toronto Mach 8.3 gun tunnel. The plenum filling technique operated as designed in this test series, although an estimate of the accuracy of the technique could not be obtained due to uncertainties in the tunnel operating conditions. Author

A89-46849*# Virginia Univ., Charlottesville.
INITIAL SUPERSONIC COMBUSTION FACILITY MEASUREMENTS
ROLAND H. KRAUSS, R. BRADFORD WHITEHURST, III, JOHN D. ABITT, III, CORIN SEGAL, and JAMES C. MCDANIEL (Virginia, University, Charlottesville) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p. refs
(Contract NGT-50142; NAG1-795)
(AIAA PAPER 89-2462)

A combustion test tunnel designed for continuous operation to 2000 K was assembled. Flow quality of a Mach 2 nozzle for use with this tunnel was examined using an array of impact probes. The performance of gas shields used to protect optical windows was examined using both shadowgraphs and planar laser induced iodine fluorescence. High speed videography was used to aid in design of pressure relief panels related to hydrogen combustion testing safety. Author

A89-46905*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NEW HYPERSONIC FACILITY CAPABILITY AT NASA LEWIS RESEARCH CENTER
JEFFREY HAAS, ROGER CHAMBERLIN, and JOHN H. DICUS (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. Previously announced in STAR as N89-22617.
(AIAA PAPER 89-2534)

Four facility activities are underway at NASA Lewis Research Center to develop new hypersonic propulsion test capability. Two of these efforts consist of upgrades to existing operational facilities. The other two activities will reactivate facilities that have been in a standby condition for over 15 years. These four activities are discussed and the new test facilities NASA Lewis will have in place to support evolving high speed research programs are described. Author

A89-46908#
FREE-JET TEST CAPABILITY FOR THE AEROPROPULSION SYSTEMS TEST FACILITY
D. A. DUESTERHAUS (USAF, Directorate of Propulsion Test, Arnold AFB, TN) and P. V. MAYWALD (Sverdrup Technology, Inc., Arnold AFB, TN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11

p. refs
(AIAA PAPER 89-2537)

The Arnold Engineering Development Center (AEDC) is installing into the Aeropropulsion Systems Test Facility (ASTF) a free-jet test capability for ground determination in a simulated flight environment of turbine engine and aircraft inlet compatibility utilizing full-scale inlets and engines as test articles. The details of the design, installation, and projected testing capability are described for a 57-sq ft supersonic nozzle and a 77-sq ft subsonic nozzle. Support systems for mechanically pitching and yawing the free-jet nozzles are also reported, as well as the test cell hardware for capturing the free-jet nozzle flow. The plans for demonstrating the free-jet capability prior to its initial operational date are explained. Author

A89-47020#
TURBINE AERODYNAMIC PERFORMANCE MEASUREMENTS IN SHORT DURATION FACILITIES
G. R. GUENETTE, A. H. EPSTEIN, and E. ITO (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 14 p. refs
(Contract F33615-87-C-2729)
(AIAA PAPER 89-2690)

Short duration, blowdown-type turbomachinery test facilities offer the potential for very low cost, high accuracy testing of axial flow turbines and have been used extensively to generate heat transfer data. This paper addresses the use of these facilities for turbine aerodynamic performance testing for research and development in place of conventional rigs. Differences between the quasi-isothermal testing of short duration rigs and adiabatic testing in steady state rigs are explored and shown to be of the order of 1 percent in turbine adiabatic efficiency. Procedures for minimizing this difference during testing and/or correcting for the difference during post-test data analysis are discussed. The errors associated with this correction are shown to be below those from other sources in the turbine measurement processes. Accuracy requirements for pressure, temperature, torque, and heat transfer instrumentation in short duration rigs are presented along with examples of current practice. It is shown that no new instrumentation development is required for these facilities, so that overall they represent little technical risk. Author

N89-25240# National Aeronautical Lab., Bangalore (India). Structures Div.
ON THE STRESS PROBLEM OF THE PEBBLE BED HEAT EXCHANGER IN A HYPERSONIC WIND TUNNEL
M. N. BAPURAO and ASHOK KAMATH Jul. 1987 78 p
(NAL-TM-ST-8705) Avail: NTIS HC A05/MF A01

The stress problem associated with the pebble bed heat exchanger in the hypersonic wind tunnel at IISc, Bongalore, is investigated. The investigation is carried out in two stages: the first stage deals with the problem encountered during the preheating of pebble bed, while in the second stage pressure loading arising from tunnel blowdowns is considered. The heat transfer and the associated thermal stress problems of stage one and also the problem of pressure loading in the presence of temperature occurring in stage two are analyzed using the finite element method with the aid of the NASTRAN and ASKA software packages. The results obtained indicate the presence of stress concentration in the disc-flange region at the entry section and in the ellipsoidal cap near the exit section of the pebble bed heat exchanger. The significance of finite element results presented with the aid of the FEMVIEW interactive graphic processor is discussed in detail. Author

N89-25241# Federal Aviation Administration, Washington, DC. Office of Airport Planning and Programming.
REPORT TO CONGRESS: TECHNICAL FEASIBILITY OF JOINT USE AT SCOTT AFB, SELFRIDGE AGB AND EL TORO MCAS
LAURENCE KIERNAN May 1988 46 p
(AD-A194597; APP-88-5; DOT/FAA/PP-88/5) Avail: NTIS HC A03/MF A01 CSCL 01/5

The technical feasibility of joint civil/military use of Scott Air Force Base (AFB), Selfridge Air Guard Base (AGB), and El Toro Marine Corps Air Station (MCAS) was investigated. Considered were the airfield, terminal, access issues, and any previous studies conducted by Federal, State, regional, or local authorities that evaluated the short and long term importance of using these facilities to alleviate the shortage of civil airport and air space capacity. Author

N89-25242* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
WARM FOG DISSIPATION USING LARGE VOLUME WATER SPRAYS Patent
VERNON W. KELLER, inventor (to NASA) 1 Nov. 1988 10 p Filed 23 Jul. 1984 Supersedes N84-32398 (22-22, p 3538)
(NASA-CASE-MFS-25962-1; US-PATENT-4,781,326; US-PATENT-APPL-SN-633180; US-PATENT-CLASS-239-2.1; US-PATENT-CLASS-239-14.1) Avail: U.S. Patent and Trademark Office CSCL 14/2

To accomplish the removal of warm fog about an area such as an airport runway, a plurality of nozzles along a line adjacent the area propelled water jets through the fog to heights of approximately twenty-five meters. Each water jet breaks up forming a water drop size distribution that falls through the fog overtaking, colliding, and coalescing with individual fog droplets and thereby removes the fog. A water retrieval system is used to collect the water and return it to reservoirs for pumping it to the nozzles once again.
Official Gazette of the U.S. Patent and Trademark Office

N89-25243# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Hauptabteilung Windkanaele.
PRESSURE MEASUREMENT TECHNIQUE OF WT-WK Status Report, 1988
RUEDIGER SIEBERT Sep. 1988 49 p In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-1145)
(DFVLR-MITT-88-11; ISSN-0176-7739; ESA-TT-1145; ETN-89-94643) Avail: NTIS HC A03/MF A01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Federal Republic of Germany, 19.50 deutsche marks

Information for users of the wind tunnels of DFVLR (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt) in Braunschweig, Gottingen, and Koln is presented. The principal arrangement, details, and status of the pressure measurement technique are described. For quick information, the data of all available pressure transducers and pressure measurement systems are presented in tables. ESA

N89-26015# National Aerospace Lab., Tokyo (Japan).
THE SCHLIEREN OBSERVATION SYSTEM INSTALLED IN THE NAL TWO-DIMENSIONAL HIGH-REYNOLDS NUMBER TRANSONIC WIND TUNNEL AND ATTEMPTS TO IMPROVE IT
YASUO OGUNI, MAMORU SATO, HIROSHI KANDA, SEIZO SAKAKIBARA, and HITOSHI MIWA Mar. 1988 23 p
(NAL-TR-964; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

For years attempts were made to improve the resolution of a colored Schlieren system used in the NAL2DHi-Re transonic wind tunnel. Experience was gained as to the relative advantages between the two colored Schlieren systems: the prism method and the color-filter method. The change of color is continuous for change of fluid density gradient with the former method while discontinuous with the latter. However, the latter method is less susceptible to disturbances due to density fluctuations in the plenum chamber through which the rays travel before being recorded, and is more appropriate when displaying qualitative pictures of the flow field. Firstly an attempt was made to cope with the plenum chamber noises by using a system with a cylindrical channel to isolate the ray paths from the disturbing plenum environment. Secondly to get better resolution for quantifying density gradients, a filter with a fine array of colors was successfully tried; the array consists of 47 stripes, each containing seven colors alternately from red to purple. The density gradients along the

model surface were estimated from the Schlieren record, and were favorably compared with those obtained from the surface pressure distribution data. While it was observed that more improvement of the resolution is needed for accurate determination of the density field, the results so far show the merit of further exploring the procedure for deriving a density gradient field from two Schlieren records by using filters with the stripes of colors perpendicular to each other. Author

N89-26018# Army Armament Research and Development Command, Dover, NJ. Development and Engineering Center.
AIRCRAFT JET ENGINE EXHAUST BLAST EFFECTS ON PAR-56 RUNWAY THRESHOLD LAMP FIXTURES Final Report
JACOB K. STRUCK and ANTHONY J. BARILE (Federal Aviation Administration, Atlantic City, NJ.) Jun. 1989 79 p
(Contract DTFA03-84-A-40020)
(DOT/FAA/CT-89/4) Avail: NTIS HC A05/MF A01

The effects of jet engine exhaust blast on PAR-56 lamps located at the runway threshold were measured. Sensors were placed on and near the lamp assemblies which measured blast velocity and temperature, bulb face temperature, lamp fixture acceleration and sound pressure level. These sensors were coupled to a computer controlled instrumentation system housed in a van located near the threshold of runway 13 at La Guardia Airport. Data were acquired during the engine runup and takeoff roll of some 162 aircraft during the measurement phase. The data were recorded on digital magnetic tape and video tape to form a permanent record of the raw data. The data were later plotted and analyzed, both manually and using a computer in order to extract the worst case environmental parameters encountered during the measurement phase. A prediction algorithm was developed to allow prediction of key environmental effects on the PAR-56 lamps caused by new aircraft or aircraft not measured. The algorithm was developed by correlating the acquired data against the manufacturers' published jet exhaust blast velocity and temperature contours. A protective shroud was devised and installed on one of the instrumented lamp assemblies during the last portion of data collection. The data suggest a beneficial reduction of the hostile jet blast effects measured on the shrouded lamp versus the unshrouded lamp. Author

N89-26019# Army Engineer Waterways Experiment Station, Vicksburg, MS. Geotechnical Lab.
DESIGN CRITERIA FOR AGGREGATE-SURFACED ROADS AND AIRFIELDS Final Report, 1986 - 1988
YU T. CHOU Apr. 1989 113 p
(Contract DA PROJ. 4A1-62719-AT-40)
(AD-A207059; WES/TR/GL-89-5) Avail: NTIS HC A06/MF A01 CSCL 01/5

Failure criteria for aggregate-surfaced pavements subject to vehicular and aircraft loadings are developed. The criteria determine the required thickness making use of the layered elastic design procedure. A literature study was conducted to determine existing design procedures that might be applicable. Types of distresses in aggregate pavements were identified. Those basic parameters that influence performance were defined. Efforts were made to compare the existing design procedures using hypothetical design conditions, and the differences between the procedures were discussed. The technique of reliability analysis was applied on the design procedures. It was found that the reliabilities of some procedures were very low. Field tests on subgrade soils covered with high strength aggregates are recommended. The tests are necessary for the verification of developed failure criteria. GRA

N89-26020# Army Engineer Waterways Experiment Station, Vicksburg, MS. Geotechnical Lab.
EVALUATION OF NONDESTRUCTIVE TEST EQUIPMENT FOR AIRFIELD PAVEMENTS. PHASE 1: CALIBRATION TEST RESULTS AND FIELD DATA COLLECTION Final Report, Feb. 1986 - Jun. 1988
ROSS A. BENTSEN, ALBERT J. BUSH, III, and J. A. HARRISON Jan. 1989 331 p Sponsored in part by Department of the Air Force, Tyndall AFB, FL and Department of the Navy, Alexandria, VA
(Contract DTFA01-87-Z-02015)
(AD-A207159; WES/TR/GL-89-3; ESL-TR-88-52; DOT/FAA/DS-88/03) Avail: NTIS HC A15/MF A01 CSCL 14/2

This study evaluates seven nondestructive testing devices for use on airfield pavements. Four falling weight deflectometers and three vibrators were evaluated for accuracy, repeatability, and reliability. Deflection data were collected on 12 pavements consisting of thick and thin asphalt concrete, portland cement concrete, and composite (asphalt concrete over portland cement concrete) pavements over fine and coarse grain subgrades. This report describes the test program, presents results of accuracy and repeatability tests, and presents the deflection data collected on the 12 pavements. GRA

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ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A89-43869
THE 'NERVE CENTER' OF ESA - TASKS AND PROCEDURES OF THE ESOC IN DARMSTADT [DAS 'NERVENZENTRUM' DER ESA - AUFGABEN UND ARBEITSWEISEN DES ESOC IN DARMSTADT]
REIMAR LUEST (ESA, Paris, France) Astronautik (ISSN 0004-6221), vol. 26, Jan.-Mar. 1989, p. 5-7. In German.

The design and activities of the European Space Operations Center (ESOC) in Darmstadt (FRG) are reviewed. Topics addressed include the ESOC organizational structure, the role of the ESOC in ESA operations, activities from launch preparation to the mission proper, the ESOC approach to space-flight control, telemetry and telecommand procedures, satellite monitoring, and man-machine interfaces. Diagrams and photographs are provided. T.K.

A89-43892
CIVIL SATELLITE NAVIGATION AND LOCATION SYSTEMS
W. F. BLANCHARD Journal of Navigation (ISSN 0373-4633), vol. 42, May 1989, p. 202-222. refs

The use of satellites for civil navigation and location, including satellites not necessarily launched for that purpose, is reviewed. In particular, attention is given to differences between civil and military satellites; civil use of military systems and the associated commercial considerations and regulatory issues; the use of communication satellites; and radiodetermination satellite service based on geostationary satellites. The discussion also covers integration with ground-based radio-navigation systems; existing radio-navigation satellite systems; and the Starfix, Geostar/Locstar, Starfind, Navsat, and Rexstar systems. V.L.

A89-46016#
THE ATR/RJ ENGINE PERFORMANCE AT CONSTANT DYNAMIC PRESSURE AND THE CONSIDERATION OF TRANSITION CONDITION
SHAOQING WANG (The 31st Research Laboratory, People's Republic of China) and QING HUA (The 606th Research Institute, People's Republic of China) Journal of Propulsion Technology (ISSN 1001-4055), June 1989, p. 20-24. In Chinese, with abstract in English.

The ATR/RJ combined engine performance at constant dynamic pressure is analyzed. Based on the data, the transition condition is considered and calculated. Also, the static temperature, static pressure in combustor, airflow rate, and thrust under the

condition of various dynamic pressure are compared. All the performance parameters presented in the paper are useful for the design of the air-turborocket/ramjet combined engine. Author

A89-47005*# Oklahoma Univ., Norman.
INTEGRATION OF SCRAMJETS WITH WAVERIDER CONFIGURATIONS
M. L. RASMUSSEN (Oklahoma, University, Norman) and C. E. SOARES AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(Contract NAG1-886)
(AIAA PAPER 89-2675)

This paper presents a parametric study of a scramjet propulsion system integrated into a waverider lifting-body configuration. The analysis explores the effect of inlet geometry, internal cross-section-area distribution of the combustor section, the distribution of the heat release of the reacting mixture, the heat transfer, and the friction on the performance of the propulsion system. The Mach number, temperature, and pressure distributions within the scramjet model are studied parametrically, and the effects on the thrust are obtained. The results provide insight on the design concepts and problems that might arise for a given internal-flow configuration. Author

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A89-44103#
DEVELOPMENT AND APPLICATION OF A SURROGATE DISTILLATE FUEL
C. P. WOOD, V. G. MCDONELL, R. A. SMITH, and G. S. SAMUELSEN (California, University, Irvine) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, July-Aug. 1989, p. 399-405. refs
(Contract F08635-83-C-0052; N00014-83-C-9151)

A surrogate fuel comprised of 14 pure hydrocarbons is formulated based on the distillation curve and compound class composition of a petroleum-derived JP-4. The goal is to establish a fuel of controlled composition for modeling, and for the study of fuel property and chemical composition effects in the combustion of JP-4 fuels. Spatially resolved interferometric measurements of droplet size and droplet velocity are obtained and compared for both the petroleum and surrogate JP-4 in a nonreacting spray chamber. Measurements are also obtained for a high aromatic JP-5 of purposefully disparate properties. The performance of these three fuels is then compared in a swirl-stabilized, spray-atomized model laboratory combustor where in-flame measurements of velocity and temperature are acquired and compared. The nonreacting measurements of atomization quality establish that the atomization characteristics of the petroleum and surrogate JP-4 are identical, whereas the atomization performance of the JP-5 is significantly different. Under reacting conditions, substantial differences between the JP-4 and JP-5 are observed in both the velocity and thermal fields, whereas the surrogate, in contrast, yields an identical velocity and thermal field to that of the petroleum JP-4. Author

A89-44400
FIBER METAL ACOUSTIC MATERIAL FOR GAS TURBINE EXHAUST ENVIRONMENTS
MICHAEL S. BEATON (Brunswick Corp., Technetics Div., DeLand, FL) Journal of Materials Engineering (ISSN 0931-7058), vol. 11, June 1989, p. 149-157. refs

FELTMETAL fiber metal acoustic materials function as broad band acoustic absorbers. Their acoustic energy absorbance occurs through viscous flow losses as sound waves pass through the tortuous pore structure of the material. Exhaust gas noise attenuation requirements are reviewed. Their selection process for higher performance materials is discussed. A new FELTMETAL fiber metal acoustic material has been designed for use in gas turbine auxiliary power unit exhaust environments without supplemental cooling. The physical and acoustic properties of mesh supported fiber metal acoustic medium FM 827 are discussed. Exposure testing was conducted under conditions which simulated auxiliary power unit operation. Weight gain and tensile strength data as a function of time of exposure at 650 C (1202 F) are reported. Fabrication of components with fiber metal acoustic materials is easily accomplished using standard roll forming and gas tungsten arc welding practices. Author

A89-44577
A STUDY OF AL-LI ALLOYS USING SMALL ANGLE NEUTRON SCATTERING
B. C. PIKE, S. MESSOLORAS, and R. J. STEWART (Reading, University, England) Scripta Metallurgica (ISSN 0036-9748), vol. 23, June 1989, p. 983-988. Research supported by SERC. refs

The present study follows the growth of the delta-prime precipitates in Al-Li alloys as a function of aging time for bulk samples at various temperatures; attention is given to the results obtained with small-angle neutron scattering for the effects of small additions of Cu or Zr on precipitation in samples of two binary alloy, a ternary Al-Li-Zr alloy, and two commercial alloys with different Cu contents. All the precipitate sizes determined for the different aging times and temperatures are parameterized on a single linear plot for all alloys studied. On the basis of the growth of the delta-prime precipitates, the energy of fusion and the interfacial tension are determined. O.C.

A89-45330
HOT DUCTILITY RESPONSE OF AL-MG AND AL-MG-LI ALLOYS
J. P. BALAGUER (Raytheon Co., Microwave Tube Div., Waltham, MA; Rensselaer Polytechnic Institute, Troy, NY) and D. W. WALSH (California State Polytechnic University, San Luis Obispo) Welding Journal, Research Supplement (ISSN 0043-2296), vol. 68, July 1989, p. 253-s to 261-s. Research supported by ASM International. refs

The effect of Li addition on the heat-affected zone (HAZ) hot-cracking susceptibility of aluminum alloys was investigated by comparing the hot-ductility behavior of a commercial Al-4Mg alloy (alloy 5083) with that of an Al-4Mg-2Li alloy. Hot-ductility profiles for the two alloys were developed for two thermal cycles designed to simulate the weld HAZ. The results of on-heating and on-cooling tests were compared on the basis of the strength ratio and the ductility ratio between the two, as a function of homologous strain temperature. Also compared were the results of micrography and SEM fractography of the two alloys tested on heating and on cooling. It was found that the HAZ cracking susceptibility of Al-4Mg-2li alloy was similar to that of Al-4Mg alloy. I.S.

A89-45554#
EFFECTS OF FUEL CHEMICAL PROPERTIES ON EXHAUST SMOKE FROM GAS TURBINE COMBUSTOR
RUSHAN JIN (Beijing University of Aeronautics and Astronautics, People's Republic of China) and A. H. LEFEBVRE (Purdue University, West Lafayette, IN) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 121-126, 194. In Chinese, with abstract in English. refs

The state-of-the-art of the study on soot formation and exhaust smoke from gas turbine combustor has been reviewed with stress on the effects of fuel chemical properties. Based on a great amount of experimental data obtained on a variety of gas turbine combustors, the best correlation parameter representing the fuel effect has been determined as SP exp -0.92(100 - N) exp-0.4, where SP is smoke point, and N is the naphthalene content (in percentage) of the fuel. Author

A89-45927
SPACE AGE METALS TECHNOLOGY; PROCEEDINGS OF THE SECOND INTERNATIONAL SAMPE METALS AND METALS PROCESSING CONFERENCE, DAYTON, OH, AUG. 2-4, 1988
F. H. FROES, ED. (USAF, Materials Laboratory, Wright-Patterson AFB, OH) and RAY A. CULL, ED. Conference sponsored by SAMPE. Covina, CA, Society for the Advancement of Material and Process Engineering (International SAMPE Metals and Metals Processing Conference Series. Volume 2), 1988, 542 p. For individual items see A89-45928 to A89-45959.

The present conference discusses advancements in Ti alloy casting methods, NiAl-based alloys for high temperature applications, electron-beam cold hearth melting of metals, Al-Li alloys for fighter aircraft applications, mechanically-alloyed high-modulus/elevated temperature Al-Ti alloys, the stress-induced hot corrosion of Rene 90, the high temperature oxidation behavior of Ti3Al alloys, and Ti requirements for current and future military gas turbine engines. Also discussed are the fatigue behavior of P/M Ti-6Al-4V, hydrogen in advanced aerospace materials, beryllides for very high temperature service, rapidly solidified P/M Al-Fe-Ce alloys, advanced Mg alloys for aerospace applications, adaptive gas tungsten arc-welding, development trends in electrodeposition, the fractography of titanium aluminide metal-matrix composites, and ingot-metallurgy metal-matrix composites. O.C.

A89-45929
MICROSTRUCTURE-PROPERTY RELATIONSHIPS IN ADVANCED NICKEL BASE SUPERALLOY AIRFOIL CASTINGS
ALAN D. CETEL and DAVID N. DUHL (United Technologies Corp., Pratt and Whitney Group, Hartford, CT) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 37-48. refs

The present assessment of the current understanding of microstructure-property relationships in both polycrystalline and single-crystal superalloys gives attention to the behavior of advanced, high-strength single-crystal turbine airfoil casting alloys containing high volume fractions of the ordered intermetallic N13Al gamma-prime phase. Heat treatment after casting can strongly influence the size and distribution of the gamma-prime strengthening particles, which in turn affect creep and tensile strength characteristics. Such secondary microstructural features as shrinkage porosity and carbides also significantly affect fatigue life. O.C.

A89-45931
CONTINUAL OPPORTUNITIES FOR SUPERALLOY DEVELOPMENT
KEH-MINN CHANG (GE Corporate Research and Development Center, Schenectady, NY) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 76-90. refs

Two recent developments in the field of gas turbine superalloys, a crack growth-resistant alloy and a weldable casting alloy, are judged to be indicative of remaining horizons for further superalloy advancements. The path to crack growth resistance for P/M superalloys is heat-treatment above their precipitate solvus, to yield a large recrystallized grain structure. Based on the criterion of precipitation reaction, the novel weldable casting alloy Rene 220C has been demonstrated in gas turbine engine hardware trials to offer an at least 50 C advantage in peak service temperature over the 718 superalloy. O.C.

A89-45937
ALUMINUM-LITHIUM ALLOYS FOR FIGHTER AIRCRAFT APPLICATIONS
V. M. VASEY-GLANDON, E. A. WALKER-HECKMAN, and K. K. SANKARAN (McDonnell Aircraft Co., Saint Louis, MO) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 166-176. refs

Proprietary Al-Li alloy development efforts aimed at aircraft primary structure applications have led to the successful fabrication and testing of upper aft wing skins for an F-15 fighter. In the wake of such efforts, it has emerged that significant differences exist in response to commonly employed forming and processing operations between Al-Li alloys and conventional Al alloys. The applicability of Al-Li alloys is enhanced by their superplastic formability; they have also been found to be more corrosion-resistant than conventional alloys. The segregation of Al-Li scrap from that of conventional alloys is, however, necessary prior to recycling. O.C.

A89-45944
TITANIUM REQUIREMENTS FOR CURRENT AND FUTURE MILITARY GAS TURBINE ENGINES
E. S. HURON and J. A. MILLER (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 271-285. refs

The substitution of titanium for nickel in gas turbine engine components would result in significant weight savings. Currently the use of titanium is limited by the possibility of catastrophic titanium fires and by elevated temperature properties, including creep and damage tolerance. With careful design, the fire problem can be controlled, but mechanical properties must be improved. In this paper, some of the key current and projected requirements for titanium are outlined, and compared with the results of recent alloy developments and future alloy design philosophy. Author

A89-45948
A REVIEW OF BERYLLIDES FOR VERY HIGH TEMPERATURE SERVICE
J. M. MARDER and A. J. STONEHOUSE (Brush Welman, Inc., Elmore, OH) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 357-367. refs

With the renewed emphasis on very high operating temperatures of aircraft and engine structural materials, the potential application of beryllide intermetallic compounds is undergoing serious evaluation. The beryllides, as a group, present a unique combination of high temperature strength and low density, which may be translatable into significant improvements in high speed aircraft performance. The objective of this paper is to review the current state of beryllide technology. Binary intermetallic compounds of beryllium are fabricated, under laboratory conditions, as powder metallurgy products. The typical fabrication processes used for these materials are reviewed with an emphasis upon the characteristics of the consolidated compounds, including density, microstructure, high temperature strength and oxidation resistance. Directions for future development are suggested. Author

A89-47149#
COMBUSTION BEHAVIOR OF BORON-BASED BAMO/NMMO FUEL-RICH SOLID PROPELLANTS
WEN-HSIN HSIEH, ARIE PERETZ, KENNETH K. KUO (Pennsylvania State University, University Park), and I-TE HUANG AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. refs
(Contract N00014-86-K-0468)
(AIAA PAPER 89-2884)

Combustion characteristics of boron/poly (BAMO/NMMO) fuel-rich solid propellants have been studied due to their potential application to solid-fuel ramjets (SFRJ). For the same boron content, BAMO/NMMO copolymer-based fuels are superior to conventional HTPB fuels due to their vigorous pyrolysis characteristic for dispersing boron particles into the main reaction

zone. However, their specific impulses are generally lower than that of HTPB, in spite of high positive heats of formation. Formation of hexagonal crystalline boron nitride (BN) has been found in the combustion of this family of propellants studied. Favorable conditions for the formation of BN have been identified. BN also has a significant effect on the theoretical performance for high equivalence ratio conditions. The burning rate was found to depend strongly upon pressure and nonmonotonically on boron content. An 'energy sink' hypothesis is proposed to explain this observation. Fine-wire thermocouple measurements support this hypothesis.
Author

A89-47213
MECHANICAL PROPERTIES OF HIGH-TEMPERATURE BERYLLIUM INTERMETALLIC COMPOUNDS
R. L. FLEISCHER and R. J. ZABALA (GE Corporate Research and Development Center, Schenectady, NY) Metallurgical Transactions A - Physical Metallurgy and Materials Science (ISSN 0360-2133), vol. 20A, July 1989, p. 1279-1282. refs
(Contract F33615-86-C-5055)

For such high-temperature mechanical uses as high thrust/weight advanced gas turbine engine hot section components, beryllium intermetallic compounds possess high elastic stiffness, low specific gravity, and relatively high melting temperatures. Their strength and tendency toward brittleness has been evaluated by conducting microhardness tests to 1150 or 1300 C, examining the specimens' indentations for cracks at each temperature. Results are presented for the beryllium intermetallics Be17Nb2, Be12Ti, Be13Zr, and highly anisotropic Be12Nb; performance comparisons are made with high-performance nonberyllium intermetallics. O.C.

N89-26110# IIT Research Inst., Bartlesville, OK. National Inst. for Petroleum and Energy Research.
COMPARISONS BETWEEN UNLEADED AUTOMOBILE GASOLINE AND AVIATION GASOLINE ON VALVE SEAT RECESSION IN LIGHT AIRCRAFT ENGINES Final Report
JERRY R. ALLSUP May 1989 19 p
(Contract DTFA03-88-A-00016)
(NIPER-409; DOT/FAA/CT-TN89/33) Avail: NTIS HC A03/MF A01

Testing was conducted to determine the potential for excessive valve seat recession in light aircraft engines using unleaded automobile gasoline (autogas) fuel. Two I0320 Lycoming engines were operated on a test stand for a 150 hr duration; one engine used 100LL aviation gasoline (avgas) and the other used unleaded premium autogas. New original equipment manufacture (OEM) valve seats (hardness Rockwell HRB 40) were installed at the beginning of the test and recession was measured at 16 hr intervals. The air-fuel mixture was precisely controlled by monitoring exhaust gas composition. Results show valve seat recession using unleaded autogas fuel was not significantly different from 100LL avgas.
Author

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A89-43840
OPTICAL RESEARCH NEEDED TO SUPPORT THE TESTING OF HYPERSONIC VEHICLE STRUCTURES
GENE E. MADDUX (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Annual Hostile Environments and High Temperature Measurements Conference, 5th, Costa Mesa, CA, Mar. 22, 23, 1988, Proceedings. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1-3.

The nature of high-temperature structural measurement requirements is discussed. While attention is focused on airframe structural applications, the discussion is valid for the propulsion area as well. The requirements are outlined by considering the following areas: large-scale structures, structural components, and small specimens. K.K.

A89-43843
EMBEDDED TEMPERATURE MEASUREMENTS IN A CARBON-CARBON WING LEADING EDGE HOT STRUCTURE
F. J. SZAFRANSKI (General Dynamics Corp., Convair Div., San Diego, CA) IN: Annual Hostile Environments and High Temperature Measurements Conference, 5th, Costa Mesa, CA, Mar. 22, 23, 1988, Proceedings. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 12-26. refs

Technology development efforts related to the measurement of subsurface temperatures in a two-dimensional carbon-carbon wing leading edge test sample are described. The feasibility of using microminiature fine-wire temperature probes for making subsurface in situ temperature measurements in a carbon-carbon hot structure is demonstrated. The detection of thermal gradients and the accurate measurement of in situ temperature in the carbon-carbon test article along with the airfoil X (fore-aft) and Y (lateral) axes is successfully demonstrated. K.K.

A89-43844
APPARENT STRAIN CHARACTERISTICS OF STRAIN GAUGES UNDER HIGH TEMPERATURE ENVIRONMENT
H. AONO, T. CHIKATA, and R. SATO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) IN: Annual Hostile Environments and High Temperature Measurements Conference, 5th, Costa Mesa, CA, Mar. 22, 23, 1988, Proceedings. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 27-30.

Results of an experimental study on the behavior of a high-temperature strain gage are used to develop a method for estimating the apparent strain with allowance for scatter. The histogram of the apparent strain which was obtained exerimentally for a titanium specimen at 100 C is presented. A scatter factor of + or - 0.23 was suggested for use in the theoretical formula proposed by Bapu Rao, et al. K.K.

A89-43876
THE LINKS IN THE CHAIN - THE INMARSAT SYSTEM
JOHN WILLIAMSON (International Maritime Satellite Organization, London, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, June 1989, p. 267-276.

The components of the Inmarsat system are examined. The locations and status of the various Inmarsat spacecraft are listed and the characteristics of the spacecraft are discussed. The Standard-A, Standard-C, land-mobile, and aeronautical terminals of the Inmarsat system and the functions of the coast earth stations, the network coordination stations for the different ocean regions, and the operation control center are described. In addition, consideration is given to the telex and telephony processes, and the process of obtaining approval to operate a ship earth station.
R.B.

A89-44635
RECENT DEVELOPMENTS IN CALCULATION METHODS FOR TURBOMACHINES [DEVELOPPEMENTS RECENTS DES METHODES DE CALCULS DANS LES TURBOMACHINES]
CH. HIRSCH (Brussel, Vrije Universiteit; Bruxelles, Universite Libre, Brussels, Belgium) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 5-10. In French. refs

A quasi-three-dimensional approach to the modeling of multistage turbomachines is presented which is based on the superposition of two-dimensional flows. Recent developments in these methods include a more precise and rigorous definition of the averaged parameters, the introduction of contributions due to the nonaxisymmetric and unsteady flow components, and the

introduction of secondary flow effects (such as turbulent diffusion) on the radial mixing. Meridianal flow models which take into account the coupling effects of the wall boundary layers are also discussed. R.R.

A89-44636
PRESENT STATE OF THE THEORY OF SECONDARY FLOWS AND EXPERIMENTAL VERIFICATIONS [ETAT ACTUEL DE LA THEORIE DES ECOULEMENTS SECONDAIRES ET VERIFICATIONS EXPERIMENTALES]
I. TREBINJAC, F. LEBOEUF, A. VOUILLARMET (Lyon, Ecole Centrale, Ecully, France), and G. BOIS (Metraflu, Ecully, France) Revue Francaise de Mecanique (ISSN 0373-6601), no. 4, 1988, p. 35-46. In French. refs

Secondary flow theories based on coherent models of the averaged flow allow the three-dimensional effects encountered in industrial flows to be simulated. Secondary flow models for turbomachines include the effects of flow injection on the walls of the motor hub and housing, along with the effects of static pressure on the mean flow. It is suggested that the pressure losses near the walls, the three-dimensional transport of the secondary vorticity, and the clearance between the blade tip and the compressor housing are not adequately modeled using present techniques. R.R.

A89-44663
CRACK SHAPE IDENTIFICATION AS AN INVERSE BOUNDARY VALUE PROBLEM [RISSFORMIDENTIFIKATION ALS INVERSES RANDWERTPROBLEM]
DIRK F. HARTMANN (Hannover, Universitaet, Hanover, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Vienna, Austria, Apr. 5-9, 1988) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 69, no. 4, 1989, p. T 166, T 167. In German.

Rotor damage frequently involves transverse cracks in the shaft. This paper presents a nondestructive way to determine the shape of such cracks. The resulting predictions are shown to be in good agreement with observation. C.D.

A89-45136*
EXPERTVISION - A VIDEO-BASED NON-CONTACT SYSTEM FOR MOTION MEASUREMENT
JAMES S. WALTON (Motion Analysis Corp., Santa Rosa, CA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. IV-1.1 to IV-1.6. Research supported by NASA. refs

A system known as ExpertVision for obtaining noncontact kinematic measurements using standard video signals is described. In the system, a video processor extracts edge information from video images using a proprietary thresholding technique. Images can be examined in real time at up to 200 fields/s, and as many as four synchronized inputs can be treated simultaneously by buffering the edge coordinates for each view in dedicated RAM memory. Mechanical applications for ExpertVision include the study of simple impacts, ballistics, wing flutter, the kinematics of helicopter rotor blades, and fluid and gas flow problems. R.R.

A89-45137
LOW COST EQUIPMENT FOR FLIGHT TEST FILM AND VIDEO EVALUATION
V. M. STORCH and F. J. ENZINGER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. IV-2.1 to IV-2.6.

A low-cost method for the precise measurement of lateral movements of aircraft and missiles is discussed in which video images are processed by a computer. In the method, the filmed object is compared with a computer simulated picture, and various procedures for bringing the computed picture into coincidence with the real picture are discussed. The present method is shown to be capable of performing such flight-test photo-evaluation tasks as flight path determination, calibration of side-slip and angle of attack, and terrain following control. R.R.

A89-45142
THE MEASUREMENT OF LINEAR AND ANGULAR DISPLACEMENTS IN PROTOTYPE AIRCRAFT - INSTRUMENTATION, CALIBRATION AND OPERATIONAL ACCURACY
SAM STORM VAN LEEUWEN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. V-3.1 to V-3.10. refs

The design and development of angular displacement transducers for flight test instrumentation systems are considered. Calibration tools, developed to meet the accuracy requirements, allowed in situ calibration with short turn around times. The design of the control surface deflection measurement channels for the Fokker 100 prototype aircraft is discussed in detail. It is demonstrated that a bellows coupling provides accurate results, and that the levers and push-pull rod drive mechanisms perform well. The results suggest that a complex mechanical drive mechanism reduces the system accuracy. R.R.

A89-45144
RESEARCH AND APPLICATION OF A NEW KIND OF MEASUREMENT TECHNOLOGY OF TAKE-OFF AND LANDING PERFORMANCE
YANG CHUNBAO (Harbin Aircraft Factory, People's Republic of China) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug. 14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. VI-2.1 to VI-2.5.

A video-based take-off and landing performance measurement system has been developed to aid in certification of the Y-12 aircraft. The system has high accuracy and is adaptable to computer analysis. Employing dual channel audio inputs, and the video system is capable of coordinating such synchronous signals as IRIG B time code and voice with flight data obtained using an airborne data acquisition system. Applications of the system include searching for the best take-off and landing flight path, the establishment of helicopter hovering capacity, and fly-over noise evaluation. R.R.

A89-45177#
REINFORCING SOLUTIONS FOR A PANEL CUT-OUT
R. VISINESCU (Institutul National pentru Creatie Stiintifica si Tehnica, Bucharest, Rumania) Revue Roumaine des Sciences Techniques, Serie de Mecanique Appliquee (ISSN 0035-4074), vol. 34, Jan.-Feb. 1989, p. 33-41.

Reinforcing solutions are presented for the cut-out of the skin and two stringers in an aircraft structure such as a wing or fuselage. It is assumed that the perturbation functions form a self-balanced system of forces which will minimize the strain energy of an imposed area of structure. The Cauchy problem for the Euler-type differential equations system, representing the condition required to minimize the strain energy, is solved. R.B.

A89-45188#
STUDY OF FLOW AND HEAT TRANSFER IN ROTATING CAVITIES
J. GUIDEZ, M. IZARD, P. J. MICHARD, and J. PERRUCHINI (ONERA, Chatillon-sous-Bagneux, France) ONERA, TP no. 1989-33, 1989, 24 p. Research sponsored by DRET, SNECMA, and Turbomeca. refs
(ONERA, TP NO. 1989-33)

Two experimental rigs contructed at ONERA to study flow and heat transfer in rotating cavities are described. The MERCI test rig is used to study the influence of rotation on the heat transfer coefficient inside a channel rotating in an orthogonal mode. The thermal analysis was performed with thermocouples located on

the rotating channel and IR pyrometry at high spatial and temporal resolutions. The CRETE test rig was used to study the flow between two disks which represent the turbine disks. K.K.

A89-45191#
INFRARED AND MILLIMETER WAVE ACQUISITION SYSTEM [STATION DE MESURES MILLIMETRIQUE ET INFRAROUGE]
B. VAIZAN (ONERA, Chatillon-sous-Bagneux, France) (Colloque International sur le Radar, Paris, France, Apr. 24-28, 1989) ONERA, TP no. 1989-36, 1989, 5 p. In French.
(ONERA, TP NO. 1989-36)

The purpose of this paper is, at first, to describe a system devoted to signatures acquisition at 35 GHz and 94 GHz and in two infrared bands around 3 and 10 microns, simultaneously. This system, installed aboard a helicopter in a side-looking position, collects data on clutters; producing maps of the observed areas. In the following, various application studies are mentioned: among them, a multispectral signatures analysis of various extended targets which may be applied to navigation updating, and also performance studies of dual-mode sensors using different kinds of fusion techniques. Author

A89-45208
ISOPARAMETRIC SHEAR SPRING ELEMENT APPLIED TO CRACK PATCHING AND INSTABILITY
R. C. CHU and T. C. KO (Aeronautical Industry Development Center, Taichung, Republic of China) Theoretical and Applied Fracture Mechanics (ISSN 0167-8442), vol. 11, May 1989, p. 93-102. refs

The effect of an adhesive-bonded rectangular patch on the stress and energy states of a center-cracked panel is investigated analytically, applying an FEM approach based on a novel isoparametric shear-spring element. The formulation of the element and the construction of the FEM model are explained, and numerical results for aircraft-type panels reinforced with unidirectional BFRP laminate patches are presented in extensive tables and graphs. The distance l between the points of local and global maxima of the minimum strain-energy density function is identified as a critical parameter affecting panel stability; it is shown that, if the patch thickness is increased sufficiently to contain l within the patch, failure can be kept localized. T.K.

A89-45210
FATIGUE FAILURE INITIATION ANALYSIS OF WING/FUSELAGE BOLT ASSEMBLY
G. C. SIH and C. K. CHAO (Lehigh University, Bethlehem, PA) Theoretical and Applied Fracture Mechanics (ISSN 0167-8442), vol. 11, May 1989, p. 109-120. refs

This work is concerned with predicting the fatigue failure initiation of a wing/fuselage bolt assembly. Accounted for in the analysis are both the influence of energy dissipation and damage accumulation as the structure is subjected to repeated cyclic loading. Results involving the location and number of cycles to initiate a fatigue crack of 0.01 inches are obtained. They agree both qualitatively and quantitatively with the experimental findings. Also discussed is the influence of pretorque in the bolt, which tends to decrease the number of cycles to fatigue-crack initiation. Fatigue life may be extended by altering the load path so as to decrease the accumulation of energy near the site of failure initiation. Author

A89-45351* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTERNATIONAL CONFERENCE ON NUMERICAL METHODS IN FLUID DYNAMICS, 11TH, WILLIAMSBURG, VA, JUNE 27-JULY 1, 1988, PROCEEDINGS
D. L. DWOYER, ED., M. Y. HUSSAINI, ED., and R. G. VOIGT, ED. (NASA, Langley Research Center; Institute for Computer Applications in Science and Engineering, Hampton, VA) Conference sponsored by NASA. Berlin and New York, Springer-Verlag (Lecture Notes in Physics. Volume 323), 1989, 634 p. For individual items see A89-45352 to A89-45434.

Recent advances in computational fluid dynamics (CFD) are discussed in reviews and reports. Topics addressed include CFD models in plasma dynamics, parallel computation for simulation studies, CFD for hypersonic airbreathing aircraft, multigrid methods for the steady incompressible Navier-Stokes equations, upwind differencing techniques, TV stable schemes for shock-interacting flows, Euler models of hypersonic vortex flows, parallel multilevel adaptive methods, and vortex methods for slightly viscous three-dimensional flows. Consideration is given to the accuracy of node-based solutions on irregular meshes, multigrid calculations for cascades, a finite-volume-element method for planar cavity flow, parallel heterogeneous mesh refinement for advection-diffusion equations, the convergence of the spectral-viscosity mehtod for nonlinear conservation laws, and numerical simulations of Taylor vortices in a spherical gap. T.K.

A89-45352* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATIONAL FLUID DYNAMICS - A PERSONAL VIEW
M. Y. HUSSAINI (NASA, Langley Research Center; Institute for Computer Applications in Science and Engineering, Hampton, VA) IN: International Conference on Numerical Methods in Fluid Dynamics, 11th, Williamsburg, VA, June 27-July 1, 1988, Proceedings. Berlin and New York, Springer-Verlag, 1989, p. 3-12. refs

This paper provides a personal view of computational fluid dynamics. The main theme is divided into two categories - one dealing with algorithms and engineering applications and the other with scientific investigations. The former category may be termed computational aerodynamics, with the objective of providing reliable aerodynamic or engineering predictions. The latter category is essentially basic research, where the algorithmic tools are used to unravel and elucidate fluid-dynamic phenomena hard to obtain in a laboratory. A critique of the numerical solution techniques for both compressible and incompressible flows is included. The discussion on scientific investigations deals in particular with transition and turbulence. Author

A89-45453
THE INSTABILITY AND ACOUSTIC WAVE MODES OF SUPERSONIC MIXING LAYERS INSIDE A RECTANGULAR CHANNEL
CHRISTOPHER K. W. TAM and FANG Q. HU (Florida State University, Tallahassee) Journal of Fluid Mechanics (ISSN 0022-1120), vol. 203, June 1989, p. 51-76. refs
(Contract N00014-87-J-1130)

A thin unconfined two-dimensional shear layer in a rectangular channel is considered, and the coupling between the motion of the shear layer and the acoustic modes of the channel is shown to produce new two-dimensional instability waves. An analysis of the normal modes of a supersonic shear layer inside a rectangular channel indicates that, in addition to the unstable waves, there are basically two other families of neutral acoustic waves. The new instabiity waves are the dominant instabilities of a confined mixing layer at high supersonic convective Mach numbers, and they are relevant to the study of the supersonic mixing and combustion process inside a ramjet engine combustion chamber. R.R.

A89-45535* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE SPATIALLY NON-UNIFORM CONVERGENCE OF THE NUMERICAL SOLUTIONS OF FLOWS
ARGYRIS G. PANARAS (NASA, Ames Research Center, Moffett Field, CA) Journal of Computational Physics (ISSN 0021-9991), vol. 82, June 1989, p. 429-453. Previously announced in STAR as N88-11429. refs

The spatial distribution of the numerical disturbances that are generated during the numerical solution of a flow is examined. It is shown that the distribution of the disturbances is not uniform. In regions where the structure of a flow is simple, the magnitudes of the generated disturbances is small and their decay is fast. However, in complex flow regions, as in separation and vortical areas, large magnitude disturbances appear and their decay may

be very slow. The observed nonuniformity of the numerical disturbances makes possible the reduction of the calculation time by application of what may be called the partial-grid calculation technique, in which a major part of the calculation procedure is applied in selective subregions, where the velocity disturbances are large, and not within the whole grid. This technique is expected to prove beneficial in large-scale calculations such as the flow about complete aircraft configurations at high angle of attack. Also, it has been shown that if the Navier-Stokes equations are written in a generalized coordinate system, then in regions in which the grid is fine, such as near solid boundaries, the norms become infinitesimally small, because in these regions the Jacobian has very large values. Thus, the norms, unless they are unscaled by the Jacobians, reflect only the changes that happen at the outer boundaries of the computation domain, where the value of the Jacobian approaches unity, and not in the whole flow field. Author

A89-45552#
APPLICATION OF THE BOUNDARY ELEMENT METHOD TO UNSTEADY HEAT TRANSFER PROBLEMS
JING DING (Northwestern Institute of Architectural Engineering, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 110-114, 193. In Chinese, with abstract in English.

The boundary element method is applied to analyzing temperature field transient distribution on aircraft engine turbine blades. It is possible to calculate the thermal stresses and life span of the blade and to check the blade strength according to the temperature field determined by this method. The temperature distributions on a set of different sections in a turbine blade at several instants have been calculated. Author

A89-45561#
MEASUREMENT OF THREE-DIMENSIONAL FLOW IN TURBOMACHINERY WITH A SINGLE SLANTED HOT-WIRE
YUCHUN LI and HAOKANG JIANG (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 145-149, 195. In Chinese, with abstract in English. refs

An improvement to measuring three-dimensional mean flow field in turbomachinery with a single slanted hot-wire is presented. The method features high accuracy and broad angular measuring range. In order to obtain the three-dimensional flow field, the single slanted wire is set in several positions around the probe axis. The data are sampled with the help of a high-speed data acquisition system and the phase-locked ensemble averaging technique. Then, the three-dimensional mean flow field is calculated by means of a data processing program previously developed. A periodic three-dimensional flow field at the exit of an axial-flow compressor rotor is successfully measured. A proof calculation against the calibration data shows that the errors in velocity measurement are less than 1 percent of the mean velocity, and the errors in the flow direction are less than 1 degree. Author

A89-45568#
STUDY OF NONLINEAR DUFFING CHARACTERISTICS OF FLEXIBLE ROTOR WITH SFDB
GUANG MENG and ZHONGQING XUE (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 173-178, 197. In Chinese, with abstract in English. refs

Nonlinear characteristics comparable with those of the one-DOF Duffing equation are theoretically and numerically predicted for a flexible rotor-centralized squeeze-film damper bearing. It is established that the number of intersection points of the bone curve with the amplitude-limit curve determine the nonlinear form of system response, and that the amplitude-limit curve is tangential to the amplitude-frequency response curve at the intersection point. While the squeeze-film force will not change the rigid critical speed of the original system, it will deflect the amplitude-frequency response curve; this deflection has the characteristics of a hard spring. O.C.

A89-45570#
EXPERIMENTAL INVESTIGATION OF AEROENGINE HIGH-SPEED ROLLER BEARING
YANGYUAN FENG, JIAXING SHAO, and MINGXUE ZHAN (Shenyang Aeroengine Research Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 4, April 1989, p. 183, 184, 200. In Chinese, with abstract in English.

A research work for developing aircraft engine high-speed roller bearings with 2.5 x 10 to the 6th DN has been completed. At first, a front roller bearing of a turbine rotor on an existing engine was tested to expose its defects as its DN was increased. Then, a new bearing was designed to eliminate these defects, and comparative tests have been carried out. The results show that the new bearing can meet the requirements of the roller bearing working at 2.5 x 10 to the 6th DN, when its design parameter are chosen reasonably. Author

A89-45950
MACHINE VISION FOR CONTROL OF GAS TUNGSTEN ARC WELDING
ROBERT A. ANDERSON (GE Aircraft Engines, Cincinnati, OH) IN: Space age metals technology; Proceedings of the Second International SAMPE Metals and Metals Processing Conference, Dayton, OH, Aug. 2-4, 1988. Covina, CA, Society for the Advancement of Material and Process Engineering, 1988, p. 393-406. refs

A gas tungsten arc welding robot system using machine vision control to weld aircraft engine components is described. The equipment, capabilities, and operational theory of the system are discussed. Both vision controlled robot motion for weld joint tracking and vision-based weld process control are used to overcome typical production conditions such as nonrepeatable joint locations, joint width variations, and part thickness variations. This state of the art robotic system is currently being used to weld aircraft engine hardware in a production environment. Improvements in productivity and quality have been realized. Author

A89-46218
INERTIAL GUIDANCE TEST FACILITY USING THE EARTH ENVIRONMENT
ALLEN DEITCH (General Electric Co., Fairfield, CT) IN: Institute of Environmental Sciences, Annual Technical Meeting, 34th, King of Prussia, PA, May 3-5, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 188-192.

A facility for the calibration and simulated flight testing of high accuracy inertial guidance systems is discussed. The facility is located below ground in the interior of a six-story building and utilizes the motion of the earth and precisely established geodetic references. To establish a highly accurate North reference, a Polaris sighting pier is placed outside of the facility so that Polaris is visible at a vertically angled line of sight into the below-grade test area. The desired precision is obtained by applying a collimator for the transfer of azimuth from a different elevation. The optical window, azimuth survey, alignment mirror, and theodolite are described. The total facility error, based on the root sum squared method is found to be 6 sec, which is satisfactory for a 10-arcsec test facility. R.B.

A89-46221
MECHANICAL STRESSES DURING AIR TRANSPORT AND GROUND OPERATIONS
THOMAS TROST (Swedish Packaging Research Institute, Sweden) IN: Institute of Environmental Sciences, Annual Technical Meeting, 34th, King of Prussia, PA, May 3-5, 1988, Proceedings. Mount Prospect, IL, Institute of Environmental Sciences, 1988, p. 213-217. refs

Data on the mechanical hazards in the air transport environment were obtained with a unit load device on the main deck of a Boeing 747 aircraft. Vertical, transverse, and longitudinal accelerations and vibrations during different flight modes and ground operations were measured for a flight on the route Stockholm-Oslo-New York-Stockholm. The data are analyzed in both time and frequency domains. Consideration is given to the

application of the results for simulating vibration tests and for the design and testing of products and packages to optimize securing equipment and improve loading routines. R.B.

A89-46282#
THE SOLUTION OF 3-D TEMPERATURE DISTRIBUTION IN A CYCLING OIL COOLED AIRCRAFT AC GENERATOR BY *NETWORK TOPOLOGY METHOD*
XINFU ZHUANG and HOAZHI CHEN (Nanjing Aeronautical Institute, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, March 1989, p. A143-A150. In Chinese, with abstract in English. refs

A89-46462
ADINTS - MOVING TOWARD STANDARDIZATION OF AUTOMATIC TEST EQUIPMENT
LINDA M. SYLVESTRE (Kearfott Guidance and Navigation Corp., Little Falls, NJ) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 82-85.

In a move towards standardization of automatic test equipment (ATE), the US Air Force is enforcing utilization of modular ATE (MATE) guides in the development of test systems for both current and future avionics programs. The author discusses the design and production of thirteen automatic depot inertial navigation test systems (ADINTS), using the MATE guides. ADINTS is designed with accessible interfaces, large computer memory, reserved rack space and test table flexibility, all of which make it adaptable to many kinds of units under test. Of particular importance in testing inertial products, a real-time-controlled interface is available. The bus architecture complies with the MIL-STD-1553 A/B requirements. When coupled with the benefits to a depot of standardization, commonality of spare parts, and shorter run times, ADINTS has the potential to provide support to other military services and some commercial users of inertial products both in this country and overseas, as well as the US Air Force. I.E.

A89-46468
MECHANICAL DURABILITY PREDICTION METHODS
RONALD G. LAMBERT (General Electric Co., Utica, NY) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 119-127. refs

Simple closed-form analytical expressions are derived to accurately predict the durability (i.e., failure-free operating period or fatigue life) of avionic equipment structural elements as part of the US Air Force Avionics Integrity Program (AVIP) requirements. These expressions are functions of both the quantity of like-structural elements per assembly and quantity of identical assemblies per system for thermal cycling and random vibration environments. Analytical predictions are compared with empirical results for cantilever beams for solder joints on multilayer assemblies containing leadless chip carriers (LCCs). I.E.

A89-46472
A TOP-DOWN SFP ANALYSIS OF A COMPLEX SYSTEM
OWEN R. GREEN (Boeing Aerospace, Mountain View, CA) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 154-156.

The single-failure points (SFPs) in a system can be found by either bottom-up or top-down analysis, since each SFP must cause a significant system-level failure effect. For a large complex system, top-down analysis can be more efficient. The authors present, as an example, a high-pressure air heater and its pressure controller, which are part of a hypersonic wind tunnel. The failure effect of concern is heater overpressurization. At least one failure in the pressure controller and one or more in the application safety features would be required for overpressure to occur. It is therefore concluded that there are not SFPs for heater overpressurization in this wind tunnel. I.E.

A89-46474
A COROLLARY TO - DUANE'S POSTULATE ON RELIABILITY GROWTH
DANIEL G. FRANK (Litton Industries, Guidance and Control Systems Div., Woodland Hills, CA) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 167-170.

Results are presented of an investigation into reliability characteristics demonstrated by selected avionic equipments over the major portion of their expected service life. It was found that avionics equipment items of various types demonstrate remarkably similar trends of a gradual decline in reliability during prolonged service. The data provide a basis for modification on Duane's (1964) learning curve approach by extending its applicability to project a reliability profile over an equipment's planned service life. The revised equations are then used to predict changes in equipment reliability and availability, thus providing a capability to more accurately estimate life-cycle support resource requirements and costs. I.E.

A89-46478
A PERFORMANCE MEASURE FOR A VHSIC AVIONIC SYSTEM - MISSION DEPENDENT AVAILABILITY
SEUNG C. CHAY (Westinghouse Research and Development Center, Pittsburgh, PA) and JOSEPH G. HENDERSON (Westinghouse Electric Corp., Hunt Valley, MD) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 191-196. refs

A VHSIC (very-high-speed integrated circuit) avionic system is designed to carry out multiple missions, and the determination of whether the system is in the operable state or in the failed state depends on what particular mission the system is to perform at any given moment. Moreover, a VHSIC system contains an important feature, which allows extensive built-in-test capabilities with LRM (line replaceable module) modularity, which in turn gives a reconfiguration capability. For this type of system, the conventional reliability measures are not adequate. The authors introduce a performance and reliability measure, which they call Åmission-dependent availability,' to be used for a VHSIC type of system. The measure is used to determine the logistics requirements and also to carry out tradeoff studies involving redundancies, built-in-test capabilities, maintenance actions, and the extent of reconfiguration capability. I.E.

A89-46480
R&M THROUGH AVIONICS/ELECTRONICS INTEGRITY PROGRAM
WILBUR W. BHAGAT (USAF, Wright-Patterson AFB, OH) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 216-220. refs

The author addresses the importance of designing reliability and maintainability (R&M) into electronic equipment in the early stages of its development. He describes an approach called the Avionics/Electronics Integrity Program (AVIP), which emphasizes early attention to design criteria and analysis, and dictates a process which strikes a balance between analysis and test. He outlines some of the problems and limitatons that have been observed using the traditional reliability approach (MIL-STD-785 process) and discusses how the AVIP approach will overcome these problems and limitations. AVIP retains and incorporates the proven and useful elements of the traditional reliability approach, such as failure modes; effects and criticality analysis (FMECA); failure reporting analysis and corrective action system (FRACAS); and environmental stress screening (ESS). I.E.

A89-46483
A NONTRADITIONAL APPROACH TO RELIABILITY
WILSON D. YATES, III (McDonnell Aircraft Co., Saint Louis, MO) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA,

Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 239-241.

The author suggests tha 85 percent of the reliability factors that influence the customer's cost of ownership are established prior to full-scale development; therefore, reliability needs to be considered before that point. To that end, the author has prototyped an expert system which recommends a prioritized list of design alternatives to improve the reliability of the system under study. When faced with a design problem, the designer can use the expert system to derive a thorough list of preassessed design alternatives. I.E.

A89-46493
SPAREL - A MODEL FOR RELIABILITY AND SPARING IN THE WORLD OF REDUNDANCIES
ARNE NORDIN and FRITZ F. MAIER (Ericsson Radar Electronics, AB, Stockholm, Sweden) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 313-320. refs

A description is given of a state-of-the-art computerized model which is developed to handle reliability and sparing problems for systems with complex redundancies. The model is used in the daily work when doing different kinds of system reliability analysis. The main applications of SPAREL are discussed. A detailed model description including equipment and maintenance support modeling is given. The mathematical assumptions and the calculation methods are examined. Some program facilities are mentioned, and some examples are presented for a fictitious sample case. SPAREL is a very useful tool since it considers availability, redundancies with complex structures and logistic support as an entity. I.E.

A89-46503* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TESTING OF RELIABILITY - ANALYSIS TOOLS
KELLY J. HAYHURST (NASA, Langley Research Center, Hampton, VA) IN: Annual Reliability and Maintainability Symposium, Atlanta, GA, Jan. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 487-490. refs

An outline is presented of issues raised in verifying the accuracy of reliability analysis tools. State-of-the-art reliability analysis tools implement various decomposition, aggregation, and estimation techniques to compute the reliability of a diversity of complex fault-tolerant computer systems. However, no formal methodology has been formulated for validating the reliability estimates produced by these tools. The author presents three states of testing that can be performed on most reliability analysis tools to effectively increase confidence in a tool. These testing stages were applied to the SURE (semi-Markov Unreliability Range Evaluator) reliability analysis tool, and the results of the testing are discussed. I.E.

A89-46697*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CERAMIC BEARINGS FOR USE IN GAS TURBINE ENGINES
E. V. ZARETSKY (NASA, Lewis Research Center, Cleveland, OH) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 111, Jan. 1989, p. 146-154; Discussion, p.154, 155; Author's Closure, p. 156, 157. Previously announced in STAR as N88-18007. refs

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

A89-46748#
A MODEL FOR AIRBLAST ATOMIZATION
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(AIAA PAPER 89-2321)

The objective of fuel injection modeling activities is generally to give support to the atomizer design effort to achieve improved spray quality. in gas turbine combustors, enhanced atomization is essential for satisfactory performance, since droplet sizes can have direct impact on almost all key aspects of combustion. A model that includes the integration of the submodels of air flow, fuel injection and atomization, and droplets turbulent dispersion has been formulated. The model was applied to an airblast atomizer that incorporated a short prefilming device. The predictions were validated against two-component phase Doppler interferometry data of that atomizer. The results of the present investigation demonstrate the capability of the developed model to predict satisfactorily the air flow field and spray characteristics. They indicate the need for detailed measurements in the near field of atomizer in order to quantitatively verify the modeling of the initial atomization processes in this region. Author

A89-46750#
SPRAY PATTERNATION AT HIGH PRESSURE
J. M. COHEN and T. J. ROSFJORD (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. refs
(Contract F33615-85-C-2515)
(AIAA PAPER 89-2323)

The spatial distribution of the fuel spray created by a gas turbine fuel injector has been measured at high pressure and temperature. A patternation system for measuring fuel spray mass flux distributions at high power conditions has been designed and operated. The facility has been designed to simulate the environment inside a gas turbine combustor as closely as possible. Results for a full scale gas turbine fuel injector have been obtained at high levels of pressure, temperature and liquid flowrate and compared with visual observations. Author

A89-46778#
COMPUTATIONAL FLUID DYNAMICS USING CATIA CREATED GEOMETRY
JEANNE E. GENGLER (Boeing Commercial Airplanes, Seattle, WA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 5 p.
(AIAA PAPER 89-2368)

A method has been developed to link the geometry definition residing on a CAD/CAM system with a computational fluid dynamics (CFD) tool needed to evaluate aerodynamic designs and requiring the memory capacity of a supercomputer. Requirements for surfaces suitable for CFD analysis are discussed. Techniques for developing surfaces and verifying their smoothness are compared, showing the capability of the CAD/CAM system. The utilization of a CAD/CAM system to create a computational mesh is explained, and the mesh interaction with the geometry and input file preparation for the CFD analysis is discussed. C.D.

A89-46841*# Textron Lycoming, Stratford, CT.
THREE-DIMENSIONAL MULTIGRID NAVIER-STOKES COMPUTATIONS FOR TURBOMACHINERY APPLICATIONS
S. V. SUBRAMANIAN (Textron, Inc., Textron Lycoming, Stratford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 10 p. Research supported by the Textron Lycoming Independent Research and Development Program and NASA. refs
(AIAA PAPER 89-2453)

The fully three-dimensional, time-dependent compressible Navier-Stokes equations in cylindrical coordinates are presently used, in conjunction with the multistage Runge-Kutta numerical integration scheme for solution of the governing flow equations,

to simulate complex flowfields within turbomechanical components whose pertinent effects encompass those of viscosity, compressibility, blade rotation, and tip clearance. Computed results are presented for selected cascades, emphasizing the code's capabilities in the accurate prediction of such features as airfoil loadings, exit flow angles, shocks, and secondary flows. Computations for several test cases have been performed on a Cray-YMP, using nearly 90,000 grid points. O.C.

A89-46846#
A CONCENTRATION PROBE FOR THE STUDY OF MIXING IN SUPERSONIC SHEAR FLOWS
W. F. NG, F. T. KWOK, and T. A. NINNEMANN (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p. Research supported by Johns Hopkins University and United Technologies Corp. refs
(AIAA PAPER 89-2459)

An aspirating hot-film probe is developed to measure local mean gas composition in supersonic flows. The probe consists of a constant temperature hot-film sensor operating in a channel with a choked exit. Thus, the flow over the hot film is influenced only by total temperature, total pressure, and gas concentration. The probe has a spatial resolution of 0.011 inches. It is easily calibrated and shows acceptable sensitivity to flow angularity. The probe is applied in the study of a supersonic air/helium mixing layer in the VPI&SU 23 cm x 23 cm Supersonic Wind Tunnel. Data are presented in raw form and after reduction to concentration and mean flow quantities. Author

A89-46858#
ADVANTAGES OF CERAMIC, SOLID LUBRICATED BEARINGS FOR SMALL GAS TURBINE ENGINES
J. T. EXLEY and J. LAW (Teledyne CAE, Toledo, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p.
(AIAA PAPER 89-2472)

The engine and system benefits development from solid lubricated, ceramic bearings are numerous. These benefits include simpler mechanical subsystems, enhanced survivability and mission completion probability, greater engine design/configurational freedom, increased 'wooden round' storage capability, reduced weight, increased engine performance and reduced engine life cycle cost. Ceramic, solid lubricated bearings were demonstrated in various projects involving rig and engine testing for unmanned air vehicle applications. Bearing design features are discussed for future engine benefits. Author

A89-46928*# Virginia Univ., Charlottesville.
QUANTITATIVE CHARACTERIZATION OF A NONREACTING, SUPERSONIC COMBUSTOR FLOWFIELD USING UNIFIED, LASER-INDUCED IODINE FLUORESCENCE
D. G. FLETCHER and J. C. MCDANIEL (Virginia, University, Charlottesville) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 34 p. refs
(Contract NAG1-373)
(AIAA PAPER 89-2565)

A calibrated, nonintrusive optical technique, laser-induced iodine fluorescence (LIIF) was used to quantify the steady, compressible flowfield of a nonreacting, supersonic combustor. The combustor was configured with single and staged, transverse-air injection into a supersonic-air freestream behind a rearward-facing step. Pressure, temperature, two-velocity components, and injectant mole fraction were measured with high spatial resolution in the three-dimensional flowfields. These experimental results provide a benchmark set of data for validation of computational fluid dynamic (CFD) codes being developed to model supersonic combustor flowfields. Author

A89-46943#
LIGHT WEIGHT GAS TURBINE ENGINE FUEL PUMPING TECHNOLOGY
JOHN M. KASSEL (Sundstrand Corp., Aerospace Fluid Systems Div., Rockford, IL) and JIM BIRDSALL (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 5 p.
(AIAA PAPER 89-2587)

The paper discusses the use of a single high speed centrifugal fuel pump as the only pump in a gas turbine engine fuel system. The characteristics and requirements of the high speed centrifugal fuel pump system are compared with a more traditional fuel pump system. The application of composite technology to the high speed centrifugal pump concept is also reviewed. Author

A89-47025*# Toledo Univ., OH.
AEROELASTIC ANALYSIS OF PROP FAN BLADES WITH A SEMIEMPIRICAL DYNAMIC STALL MODEL
T. S. R. REDDY (Toledo, University, OH) and ORAL MEHMED (NASA, Lewis Research Center, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 20 p. refs
(AIAA PAPER 89-2695)

The time-history response of a propfan wind-tunnel model with dynamic stall was studied analytically. The response obtained from the analysis was compared with available experimental data. The governing equations of motion were formulated in terms of blade normal modes calculated using the COSMIC-NASTRAN computer code. The response analysis considered the blade plunging and pitching motions. The lift, drag, and moment coefficients for angles of attack below the static stall angle were obtained from a quasi-steady theory. For angles above static stall angles, a semiempirical dynamic stall model based on a correction to the angle of attack was used to obtain lift, drag, and moment coefficients. Using these coefficients, the aerodynamic forces were calculated at a selected number of strips, and integrated to obtain the total generalized forces. The combined momentum-blade element theory was used to calculate the induced velocity. The semiempirical stall model predicted a limit cycle oscillation near the setting angle at which large vibratory stresses were observed in an experiment. The predicted mode and frequency of oscillation also agreed with those measured in the experiment near this setting angle. The results also correlated well with the other published data that used a semiempirical dynamic stall model based on a synthesized procedure. Author

A89-47083#
REVIEW OF PASSIVE SHEAR-FLOW CONTROL RESEARCH FOR IMPROVED SUBSONIC AND SUPERSONIC COMBUSTION
K. C. SCHADOW and E. GUTMARK (U.S. Navy, Naval Weapons Center, China Lake, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 17 p. refs
(AIAA PAPER 89-2786)

Shear-flow investigations have been conducted in the high-Re, turbulent initial-condition combustion regime representative of flow configurations encountered in ramjets and in supersonic plumes. Large-scale vortical structures were identified and characterized in both nonreacting and combustion-reaction experimental conditions; attention was given to these structures' role in mixing, and their breakup into fine-scale turbulence. Shear-flow/combustion control was obtained by actively enlisting duct acoustics and passively employing noncircular flow cross-sections. The investigations were extended to supersonic shear flows, yielding improved mixing for supersonic combustion. O.C.

A89-47104#
TECHNOLOGY DEVELOPMENT REQUIRED BY PROPFAN POWER REDUCTION GEARBOXES
L. BATTEZZATO and R. PIAS (Fiat Aviazione S.p.A., Turin, Italy) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 6 p.
(AIAA PAPER 89-2818)

The design requirements for the propfan transmission are discussed, with respect to the power-turbine and the fan speed ranges required for advanced aircraft, and the weight, reliability,

maintenance, safety, and quietness aspects. Particular attention is given to the mechanical characteristics of the materials and the configuration of the planet gear and carrier and the ring gear. The design of the oil system is also considered. I.S.

A89-47163#
TIME DEPENDENT PROBABILISTIC FAILURE OF COATED COMPONENTS
BRICE N. CASSENTI (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 11 p. refs
(AIAA PAPER 89-2900)

A probabilistic time dependent failure model has been developed for the failure of materials. The model is an extension of a previously developed theory for static probabilistic failure that includes fatigue and creep rupture failure. The model has been applied to coatings and ceramic matrix composites. It has been shown to accurately predict the segment size in coatings and the statistical failure locations in brittle tensile specimens. Many of the features of the model can be illustrated using one-dimensional (i.e., through thickness) analyses of layered materials. Such analyses have direct applications to coated components. The model has been incorporated in a computer program that processes output from a finite element model, and hence allows the application in structural analyses in any number of dimensions, with arbitrary loading. Author

A89-47168#
OPTICAL FIBER SENSOR DEVELOPMENT FOR TURBINE APPLICATIONS
JAMES R. DUNPHY and GERALD MELTZ (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p.
(Contract F33615-80-C-2044; F33615-83-C-2330)
(AIAA PAPER 89-2914)

A twin-core optical fiber sensor is being developed for application to turbine engine diagnostics. It promises advantages of small, nonintrusive dimensions, inherent immunity to EMI, high temperature durability, and the capability to perform static strain and temperature measurements simultaneously. This paper summarizes the sensor concept, nonrotating risk reduction experiments, and rotating demonstration tests. During these experiments, the optical fiber sensors were attached to modified F100 turbine disks and operated in extreme conditions with temperatures higher than 1200 F, strains approaching 3000 microstrain, and spin rates greater than 7000 rpm. Author

A89-47172#
THREE DIMENSIONAL FINITE ELEMENT STRESS PREDICTIONS OF SPUR GEARS COMPARED TO GEAR FATIGUE RIG MEASUREMENTS
MARTIN OZKUL (Pratt and Whitney Canada, Mississauga) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2918)

A three dimensional finite element analysis technique has been developed for evaluating the gear tooth contact and fillet bending stresses. The method is based on an isoparametric formulation using 20-noded solid elements and the sub-structure approach to minimize computer core usage. The analysis has been applied to a test case of LCR spur gears specifically designed for pitting endurance testing on a gear fatigue rig. The analysis results are compared with strain gauge results obtained from gear fatigue rig to determine allowables for gear tooth stressing. They are finally compared to the tooth stresses obtained using a gear teeth dynamic model for further substantiation. Author

A89-47173*# Akron Univ., OH.
TRANSMISSION OVERHAUL AND REPLACEMENT PREDICTIONS USING WEIBULL AND RENEWAL THEORY
M. SAVAGE (Akron, University, OH) and D. G. LEWICKI (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 9 p. Previously announced in STAR as N89-22925. refs
(AIAA PAPER 89-2919)

A method to estimate the frequency of transmission overhauls is presented. This method is based on the two-parameter Weibull statistical distribution for component life. A second method is presented to estimate the number of replacement components needed to support the transmission overhaul pattern. The second method is based on renewal theory. Confidence statistics are applied with both methods to improve the statistical estimate of sample behavior. A transmission example is also presented to illustrate the use of the methods. Transmission overhaul frequency and component replacement calculations are included in the example. Author

A89-47181#
BRAYTON CYCLE ENGINES WITH RECIPROCATING WORK COMPONENTS
R. DECHER (Washington, University, Seattle) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 8 p. refs
(AIAA PAPER 89-2933)

This paper is a description of a family of novel engine concepts which utilize displacement work components in the Brayton cycle. The performance characteristics of these engines are described in detail in the cited references and summarized here. The implications of these characteristics on configuration possibilities are discussed. It is shown that low cost, steady flow engines with their high potential for low emissions are practical for small to medium power output. Author

A89-47189*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
IMPROVED PLASMA TORCH FOR IGNITION AND FLAME HOLDING IN SUPERSONIC COMBUSTION
W. F. O'BRIEN, R. J. ROBY (Virginia Polytechnic Institute and State University, Blacksburg), and S. D. STOUFFER AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 12 p. Research supported by NASA. refs
(AIAA PAPER 89-2945)

A plasma torch system designed for ignition and flame-holding in supersonic combustion studies has been modified, in order to decrease electrode wear and increase stability, through the incorporation of a flow swirler in the gas inlet that adds vortex-stabilization to the arc. The torch body was redesigned in order to achieve superior alignment of the electrodes; the electrode gap was made continuously adjustable, thereby allowing fine tuning during torch operation. Table operation of the improved torch has been demonstrated in pure nitrogen, eliminating the requirement of argon gas for arc stabilization. O.C.

A89-47250* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SELECTION OF ROLLING-ELEMENT BEARING STEELS FOR LONG-LIFE APPLICATIONS
ERWIN V. ZARETSKY (NASA, Lewis Research Center, Cleveland, OH) IN: ASTM International Symposium on the Effect of Steel Manufacturing Processes on the Quality of Bearing Steels, Phoenix, AZ, Nov. 4-6, 1986, Proceedings. Philadelphia, PA, American Society for Testing and Materials, 1989, p. 5-43. Previously announced in STAR as N87-11993. refs

Nearly four decades of research in bearing steel metallurgy and processing have resulted in improvements in bearing life by a factor of 100 over that obtained in the early 1940s. For critical applications such as aircraft, these improvements have resulted in longer lived, more reliable commercial aircraft engines. Material factors such as hardness, retained austenite, grain size and carbide size, number, and area can influence rolling-element fatigue life. Bearing steel processing such as double vacuum melting can have a greater effect on bearing life than material chemistry. The selection and specification of a bearing steel is dependent on the integration of all these considerations into the bearing design and

application. The paper reviews rolling-element fatigue data and analysis which can enable the engineer or metallurgist to select a rolling-element bearing steel for critical applications where long life is required. Author

N89-25164*# LTV Aerospace and Defense Co., Dallas, TX. Military Aircraft Div.
THE DESIGNER OF THE 90'S: A LIVE DEMONSTRATION
TOMMY L. GREEN, BASIL M. JORDAN, JR., and TIMOTHY L. OGLESBY *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 373-385 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 13/2

A survey of design tools to be used by the aircraft designer is given. Structural reliability, maintainability, cost and predictability, and acoustics expert systems are discussed, as well as scheduling, drawing, engineering systems, sizing functions, and standard parts and materials data bases. R.J.F.

N89-25166*# Lockheed Aeronautical Systems Co., Burbank, CA.
COMPOSITE SIZING AND PLY ORIENTATION FOR STIFFNESS REQUIREMENTS USING A LARGE FINITE ELEMENT STRUCTURAL MODEL
N. A. RADOVCICH and D. P. GENTILE *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 403-429 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 20/11

A NASTRAN bulk dataset preprocessor was developed to facilitate the integration of filamentary composite laminate properties into composite structural resizing for stiffness requirements. The NASCOMP system generates delta stiffness and delta mass matrices for input to the flutter derivative program. The flutter baseline analysis, derivative calculations, and stiffness and mass matrix updates are controlled by engineer defined processes under an operating system called CBUS. A multi-layered design variable grid system permits high fidelity resizing without excessive computer cost. The NASCOMP system uses ply layup drawings for basic input. The aeroelastic resizing for stiffness capability was used during an actual design exercise. Author

N89-25174*# Northrop Corp., Hawthorne, CA. Aircraft Div.
ASTROS: A MULTIDISCIPLINARY AUTOMATED STRUCTURAL DESIGN TOOL
D. J. NEILL *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 529-543 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 20/11

ASTROS (Automated Structural Optimization System) is a finite-element-based multidisciplinary structural optimization procedure developed under Air Force sponsorship to perform automated preliminary structural design. The design task is the determination of the structural sizes that provide an optimal structure while satisfying numerous constraints from many disciplines. In addition to its automated design features, ASTROS provides a general transient and frequency response capability, as well as a special feature to perform a transient analysis of a vehicle subjected to a nuclear blast. The motivation for the development of a single multidisciplinary design tool is that such a tool can provide improved structural designs in less time than is currently needed. The role of such a tool is even more apparent as modern materials come into widespread use. Balancing conflicting requirements for the structure's strength and stiffness while exploiting the benefits of material anistropy is perhaps an impossible task without assistance from an automated design tool. Finally, the use of a single tool can bring the design task into better focus among design team members, thereby improving their insight into the overall task. Author

N89-25177*# General Dynamics Corp., Fort Worth, TX.
RECENT EXPERIENCES USING FINITE-ELEMENT-BASED STRUCTURAL OPTIMIZATION
B. K. PAUL, J. C. MCCONNELL, and MIKE H. LOVE *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 581-599 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 20/11

Structural optimization has been available to the structural analysis community as a tool for many years. The popular use of displacement method finite-element techniques to analyze linearly elastic structures has resulted in an ability to calculate the weight and constraint gradients inexpensively for numerical optimization of structures. Here, recent experiences in the investigation and use of structural optimization are discussed. In particular, experience with the commercially available ADS/NASOPT code is addressed. An overview of the ADS/NASOPT procedure and how it was implemented is given. Two example problems are also discussed. Author

N89-25187*# Worcester Polytechnic Inst., MA. Dept. of Mechanical Engineering.
TREATMENT OF BODY FORCES IN BOUNDARY ELEMENT DESIGN SENSITIVITY ANALYSIS
SUNIL SAIGAL, JAMES H. KANE, R. AITHAL, and JIZU CHENG *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 759-776 Apr. 1989
(Contract NSF MSM-87-0742)
Avail: NTIS HC A22/MF A01 CSCL 20/11

The inclusion of body forces has received a good deal of attention in boundary element research. The consideration of such forces is essential in the desgin of high performance components such as fan and turbine disks in a gas turbine engine. Due to their critical performance requirements, optimal shapes are often desired for these components. The boundary element method (BEM) offers the possibility of being an efficient method for such iterative analysis as shape optimization. The implicit-differentiation of the boundary integral equations is performed to obtain the sensitivity equations. The body forces are accounted for by either the particular integrals for uniform body forces or by a surface integration for non-uniform body forces. The corresponding sensitivity equations for both these cases are presented. The validity of present formulations is established through a close agreement with exact analytical results. Author

N89-25196*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
AN APPROXIMATION FUNCTION FOR FREQUENCY CONSTRAINED STRUCTURAL OPTIMIZATION
R. A. CANFIELD *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 937-953 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 20/11

The purpose is to examine a function for approximating natural frequency constraints during structural optimization. The nonlinearity of frequencies has posed a barrier to constructing approximations for frequency constraints of high enough quality to facilitate efficient solutions. A new function to represent frequency constraints, called the Rayleigh Quotient Approximation (RQA), is presented. Its ability to represent the actual frequency constraint results in stable convergence with effectively no move limits. The objective of the optimization problem is to minimize structural weight subject to some minimum (or maximum) allowable frequency and perhaps subject to other constraints such as stress, displacement, and gage size, as well. A reason for constraining natural frequencies during design might be to avoid potential resonant frequencies due to machinery or actuators on the structure. Another reason might be to satisy requirements of an aircraft or spacecraft's control law. Whatever the structure supports may be sensitive to a frequency band that must be avoided. Any of these situations or others may require the designer to insure the satisfaction of frequency constraints. A further motivation for considering accurate approximations of natural frequencies is that they are fundamental to dynamic response constraints. Author

N89-25197*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
STRUCTURAL OPTIMIZATION OF FRAMED STRUCTURES USING GENERALIZED OPTIMALITY CRITERIA
R. M. KOLONAY, VIPPERLA B. VENKAYYA, V. A. TISCHLER, and R. A. CANFIELD *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 955-969 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 20/11

The application of a generalized optimality criteria to framed structures is presented. The optimality conditions, Lagrangian multipliers, resizing algorithm, and scaling procedures are all represented as a function of the objective and constraint functions along with their respective gradients. The optimization of two plane frames under multiple loading conditions subject to stress, displacement, generalized stiffness, and side constraints is presented. These results are compared to those found by optimizing the frames using a nonlinear mathematical programming technique. Author

N89-25231*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
RECENT DEVELOPMENTS IN LARGE-SCALE STRUCTURAL OPTIMIZATION
VIPPERLA B. VENKAYYA *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1521-1540 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 20/11

A brief discussion is given of mathematical optimization and the motivation for the development of more recent numerical search procedures. A review of recent developments and issues in multidisciplinary optimization is also presented. These developments are discussed in the context of the preliminary design of aircraft structures. A capability description of programs FASTOP, TSO, STARS, LAGRANGE, ELFINI and ASTROS is included. Author

N89-25358# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Structures and Materials Dept.
MATERIALS AND STRUCTURES FOR 2000 AND BEYOND: AN ATTEMPTED FORECAST
CARL-JOCHEN WINTER and MARTIN MAILAENDER Feb. 1989 86 p In GERMAN; ENGLISH summary
(DFVLR-MITT-89-02; ISSN-0176-7739; ETN-89-94648) Avail: NTIS HC A05/MFA01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Federal Republic of Germany, 51 deutsche marks

Developments in aerospace materials and structures, and research needed to meet the challenges imposed by these developments were discussed. ESA

N89-25432*# Connecticut Univ., Storrs. Dept. of Mechanical Engineering and Physics.
X-RAY BASED EXTENSOMETRY Final Report, 15 Dec. 1987 - 15 Dec. 1988
E. H. JORDAN and D. M. PEASE Dec. 1988 26 p
(Contract NAG3-854)
(NASA-CR-185058; NAS 1.26:185058) Avail: NTIS HC A03/MF A01 CSCL 14/2

A totally new method of extensometry using an X-ray beam was proposed. The intent of the method is to provide a non-contacting technique that is immune to problems associated with density variations in gaseous environments that plague optical methods. X-rays are virtually unrefractable even by solids. The new method utilizes X-ray induced X-ray fluorescence or X-ray induced optical fluorescence of targets that have melting temperatures of over 3000 F. Many different variations of the basic approaches are possible. In the year completed, preliminary experiments were completed which strongly suggest that the method is feasible. The X-ray induced optical fluorescence method appears to be limited to temperatures below roughly 1600 F because of the overwhelming thermal optical radiation. The X-ray induced X-ray fluorescence scheme appears feasible up to very high temperatures. In this system there will be an unknown tradeoff between frequency response, cost, and accuracy. The exact tradeoff can only be estimated. It appears that for thermomechanical tests with cycle times on the order of minutes a very reasonable system may be feasible. The intended applications involve very high temperatures in both materials testing and monitoring component testing. Gas turbine engines, rocket engines, and hypersonic vehicles (NASP) all involve measurement needs that could partially be met by the proposed technology. Author

N89-25443*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AUTOMATED THERMAL MAPPING TECHNIQUES USING CHROMATIC IMAGE ANALYSIS
GREGORY M. BUCK Apr. 1989 17 p
(NASA-TM-101554; NAS 1.15:101554) Avail: NTIS HC A03/MF A01 CSCL 14/2

Thermal imaging techniques are introduced using a chromatic image analysis system and temperature sensitive coatings. These techniques are used for thermal mapping and surface heat transfer measurements on aerothermodynamic test models in hypersonic wind tunnels. Measurements are made on complex vehicle configurations in a timely manner and at minimal expense. The image analysis system uses separate wavelength filtered images to analyze surface spectral intensity data. The system was initially developed for quantitative surface temperature mapping using two-color thermographic phosphors but was found useful in interpreting phase change paint and liquid crystal data as well. Author

N89-25464*# Bently Rotor Dynamics Research Corp., Minden, NV.
INFLUENCE OF RUBBING ON ROTOR DYNAMICS, PART 2 Final Report
AGNES MUSZYNSKA, DONALD E. BENTLY, WESLEY D. FRANKLIN, ROBERT D. HAYASHIDA, LORI M. KINGSLEY, and ARTHUR E. CURRY Mar. 1989 202 p
(Contract NAS8-36719)
(NASA-CR-183649-PT-2; NAS 1.26:183649-PT-2) Avail: NTIS HC A10/MF A01 CSCL 13/9

Rotor dynamic behavior depends considerably on how much the specific physical phenomena accompanying rotor rubbing against the stator is involved. The experimental results of rotor-to-stator rubbing contact are analyzed. The computer code is described for obtaining numerical calculations of rotor-to-stator rubbing system dynamic responses. Computer generated results are provided. The reduced dynamic data from High Pressure Fuel Turbo Pump (HPFTP) hot fire test are given. The results provide some significant conclusions. Information is provided on the electronic instrumentation used in the experimental testing. B.G.

N89-25479*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLAP-LAG STABILITY DATA FOR A SMALL-SCALE ISOLATED HINGELESS ROTOR IN FORWARD FLIGHT
MICHAEL J. MCNULTY Apr. 1989 121 p
(NASA-TM-102189; A-89124; NAS 1.15:102189; USAAVSCOM-TR-89-A-003) Avail: NTIS HC A06/MF A01 CSCL 20/11

An isolated, hingeless rotor with discrete flap and lead-lag flexures and relatively rigid blades was tested in the Aeroflightdynamics Directorate's 7- by 10-Foot Wind Tunnel. The lead-lag stability of a structurally simple rotor configuration in forward flight was determined. The model tested had no cyclic pitch control, and was therefore operated untrimmed at several collective pitch angles, at shaft angles from 0 deg to -20 deg, and at advance ratios as high as 0.55. Two inplane natural frequencies, 0.61/rev and 0.72/rev, were tested for configuration both with and without structural flap lag coupling. Concomitant hover testing of the model was also conducted. Representative plots of the frequency and damping data are presented to show general trends, and complete tabular data and model properties

information are included for use in detailed correlation exercises. The most prominent feature of the forward flight data is an abrupt increase in damping with advance ratio at certain high-speed, high shaft-angle conditions, with high flapping loads. The hover data are consistent with previous experimental and theoretical results for hingeless rotors without kinematic couplings. Overall, the data quality is very good and the data are expected to be useful in the development and validation of rotor aeroelastic stability analyses. Author

N89-25480*# Boeing Helicopter Co., Philadelphia, PA.
PLAN, FORMULATE, DISCUSS AND CORRELATE A NASTRAN FINITE ELEMENT VIBRATIONS MODEL OF THE BOEING MODEL 360 HELICOPTER AIRFRAME
R. GABEL, P. F. LANG, L. A. SMITH, and D. A. REED Apr. 1989 296 p
(Contract NAS1-17497)
(NASA-CR-181787; NAS 1.26:181787) Avail: NTIS HC A13/MF A01 CSCL 20/11

Boeing Helicopter, together with other United States helicopter manufacturers, participated in a finite element applications program to emplace in the United States a superior capability to utilize finite element analysis models in support of helicopter airframe design. The activities relating to planning and creating a finite element vibrations model of the Boeing Model 36-0 composite airframe are summarized, along with the subsequent analytical correlation with ground shake test data. Author

N89-26120# Electroimpact, Inc., Seattle, WA.
ELECTROMAGNETIC EMISSIONS FROM A MODULAR LOW VOLTAGE ELECTRO-IMPULSE DE-ICING SYSTEM Final Report
PETER ZIEVE, BRENT HUFFER, and JAMES NG Mar. 1989 44 p
(DOT/FAA/CT-88/31) Avail: NTIS HC A03/MF A01

An important consideration in the certification of electro-impulse deicing (EIDI) systems for aircraft ice protection is electromagnetic interference (EMI). When the capacitor bank in an EIDI system discharges, a large pulse of current travels down a transmission line to the coil. Subsequent radiation by the transmission line and the coil produces EMI. The low voltage electro-impulse deicing system (LVEIDI) is unique in that the capacitor bank is mounted adjacent to the coil thereby eliminating most of the cables. Electromagnetic emissions from this system would then be primarily from the coil. The performed tests investigate the EMI environment inside and outside of both a composite and an aluminum wing. Due to the absence of the shielding effect of aluminum, the problem of electromagnetic emissions is particularly severe when the wing is constructed of composite materials. Measurements of the radiated electric field indicate that emissions from the aluminum wing were well within the standards. Some tests with the composite wing were within standards while others were not. It was found that the composite wing could be brought back into compliance through the addition of thin metallic shielding. Conducted emissions on the LVEIDI power feed cable were brought within standards with the addition of a line filter. An unshielded connection cable for a compass flux valve was run through the wing just behind the LVEIDI module. Discharge of the capacitor bank had no discernible effect on operation of the compass flux valve. No problems were observed in other tests of the wing internal environment. Author

N89-26121# Federal Aviation Administration, Atlantic City, NJ.
FUNCTIONAL REQUIREMENTS OF THE COMMUNICATIONS INTERFACE DRIVER (CID)
JEFFREY LIVINGS, JAMES DAVIS, CHARLES DUDAS, and MARK SCHOENTHAL Jun. 1989 23 p
(Contract T-1007-A)
(DOT/FAA/CT-TN87/41-REV) Avail: NTIS HC A03/MF A01

The functional requirements that the Communications Interface Driver (CID) was built to and tested against are listed. The CID is a test tool whose purpose is to supply and receive a capacity level of communications messages to and from the air traffic control (ATC) ports of the Mode S sensor. A requirements document was necessary since there were no specifications given for the CID in the Mode S specifications. Note that this document lists the functional requirements for the CID and is not a detailed specification. Author

N89-26123# Federal Aviation Administration, Atlantic City, NJ. Technical Center.
COMMUNICATIONS INTERFACE DRIVER (CID) SYSTEM USER'S MANUAL
TOM BRATTON, CHARLES DUDAS, MARK SCHOENTHAL, JIM DAVIS, ANDREW LEONE, and JEFFREY LIVINGS Jun. 1989 71 p
(DOT/FAA/CT-TN89/36) Avail: NTIS HC A04/MF A01

This user's manual for the Communications Interface Driver (CID) systems is used to describe the operating procedures of the CID. The CID system is a test tool intended to supply or receive a capacity level of communications messages to and from the air traffic control (ATC) and non-ATC ports of the Mode Select (Mode S) sensor. The primary intent of the CID user's manual is to guide the user through the operating procedures of the X.25 communications diagnostic (COMMDIAG) and Time-of-Year (TOY) diagnostic programs, the scenario generator and CID initialization (CIDINIT) data base off-line support programs, the CID real-time program and the scenario list (SCLIST) and extraction list (EXLIST) data analysis programs. The manual also includes the procedures to boot the CID system and to handle the required cabling and baud rate switch setup. Author

N89-26127# Federal Aviation Administration, Atlantic City, NJ. Technical Center.
MODE S PERFORMANCE TEST PLAN
CHARLES BAXTER Jul. 1989 67 p
(DOT/FAA/CT-TN89/24) Avail: NTIS HC A04/MF A01

The Mode S Performance Tests to be conducted by t he Federal Aviation Administration Technical Center is described. The Mode S Performance Tests will provide a performance baseline and site-adaptation optimization effort for each Mode S configuration (terminal, en route, and multi-sensor). System level accuracy and resolution tests will be conducted using live test aircraft and precision trackers. These tests have not been previously accomplished due to the lack of multiple sensors and precision trackers at the contractor's facility. A stress test effort will also be conducted to characterize the performance of the Mode S sensor beyond its specified requirements. This plan addresses the National Airspace System requirements and test objective as outlined in the Mode S Master Test Plan. This plan also identifies the organizational responsibilities, resources, coordination efforts, and success criteria necessary to develop a set of test procedures to accomplish the above tests. Author

N89-26133# Federal Aviation Administration, Atlantic City, NJ.
SATELLITE LOW RATE VOICE DEMONSTRATION TEST PLAN Test Plan Jan. 1988 - Mar. 1989
JOAN GRELIS Dec. 1988 18 p
(AD-A206710; DOT/FAA/CT-TN88/39) Avail: NTIS HC A03/MF A01 CSCL 25/4

This test plan describes the design of the demonstration of a low data rate voice Codec communications link via satellite. The demonstration will include the use of 4.8 kbps voice Codec equipment interfaced with a mobile satellite (MSAT) communications terminal installed in the Federal Aviation Administration's (FAA's) B- 727 (N-40) aircraft and similar equipment at the COMSAT ground earth station in Southbury, Connecticut. This configuration, used in conjunction with INMARSAT satellite capability, completes an aircraft-to-satellite-to-ground facility circuit that provides a communications quality voice link between the pilot and the ground. In addition to a demonstration, techniques will be developed for evaluating voice Codecs for air traffic control (ATC) applications. Controllers from the FAA will be used in the evaluation. A Codec Test Bed Facility will be developed to conduct stress testing in a

laboratory controlled environment. This project will allow critical evaluation of digital voice satellite communications technology in a simulated ATC environment. GRA

N89-26168# National Aerospace Lab., Tokyo (Japan).
MECHANISMS OF ENDWALL LEAKAGE FLOWS AND THE ASSOCIATED LOSSES IN A LINEAR TURBINE ROTOR CASCADE WITH BLADE TIP-CLEARANCE
ATSUMASA YAMAMOTO and KATSUYOSHI KABA Jun. 1988 23 p
(NAL-TR-985T; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

The mechanisms of three-dimensional flows and of the associated losses occurring in the tip endwall region of a linear turbine cascade with tip-clearance are discussed. The clearance gap sizes and the cascade incidences were chosen as the most important variables affecting the mechanisms. Flows close to the endwall and inside the clearance were surveyed in great detail using a micro five-hole Pitot tube of 0.6 mm head size. The results gave very detailed information on the mechanisms, such as leakage flow vectors and pressure distributions throughout the clearance. Interaction of leakage flow with the endwall flow and their associated separation lines, effects of gap size and inlet flow angle on loss generation, and skewness of the three-dimensional endwall flows are also discussed. Author

N89-26172*# Cornell Univ., Ithaca, NY. School of Mechanical and Aerospace Engineering.
MULTIGRID CALCULATION OF THREE-DIMENSIONAL TURBOMACHINERY FLOWS Final Report, 1 Sep. 1985 - 30 Jan. 1989
DAVID A. CAUGHEY Jun. 1989 28 p Sponsored by NSF; IBM and Corporate Research Inst.
(Contract NAG3-645)
(NASA-CR-185332; NAS 1.26:185332; FDA-89-07) Avail: NTIS HC A03/MF A01 CSCL 20/4

Research was performed in the general area of computational aerodynamics, with particular emphasis on the development of efficient techniques for the solution of the Euler and Navier-Stokes equations for transonic flows through the complex blade passages associated with turbomachines. In particular, multigrid methods were developed, using both explicit and implicit time-stepping schemes as smoothing algorithms. The specific accomplishments of the research have included: (1) the development of an explicit multigrid method to solve the Euler equations for three-dimensional turbomachinery flows based upon the multigrid implementation of Jameson's explicit Runge-Kutta scheme (Jameson 1983); (2) the development of an implicit multigrid scheme for the three-dimensional Euler equations based upon lower-upper factorization; (3) the development of a multigrid scheme using a diagonalized alternating direction implicit (ADI) algorithm; (4) the extension of the diagonalized ADI multigrid method to solve the Euler equations of inviscid flow for three-dimensional turbomachinery flows; and also (5) the extension of the diagonalized ADI multigrid scheme to solve the Reynolds-averaged Navier-Stokes equations for two-dimensional turbomachinery flows. K.C.D.

N89-26174*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CFD IN THE CONTEXT OF IHPTET: THE INTEGRATED HIGH PERFORMANCE TURBINE TECHNOLOGY PROGRAM
ROBERT J. SIMONEAU and DALE A. HUDSON (Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.) 1989 17 p Presented at the 25th Joint Propulsion Conference, Monterey, CA, 10-12 Jul. 1989; cosponsored by the AIAA, ASME, SAE, and ASEE
(NASA-TM-102132; E-4868; NAS 1.15:102132; AIAA-89-2904) Avail: NTIS HC A03/MF A01 CSCL 20/4

The Integrated High Performance Turbine Engine Technology (IHPTET) Program is an integrated DOD/NASA technology program designed to double the performance capability of today's most advanced military turbine engines as we enter the twenty-first century. Computational Fluid Dynamics (CFD) is expected to play an important role in the design/analysis of specific configurations within this complex machine. In order to do this, a plan is being developed to ensure the timely impact of CFD on IHPTET. The developing philosphy of CFD in the context of IHPTET is discussed. The key elements in the developing plan and specific examples of state-of-the-art CFD efforts which are IHPTET turbine engine relevant are discussed. Author

N89-26176*# High Technology Corp., Hampton, VA.
HOMAR: A COMPUTER CODE FOR GENERATING HOMOTOPIC GRIDS USING ALGEBRAIC RELATIONS: USER'S MANUAL
ANUTOSH MOITRA Washington NASA Jul. 1989 79 p
(Contract NAS1-18240)
(NASA-CR-4243; NAS 1.26:4243) Avail: NTIS HC A05/MF A01 CSCL 20/4

A computer code for fast automatic generation of quasi-three-dimensional grid systems for aerospace configurations is described. The code employs a homotopic method to algebraically generate two-dimensional grids in cross-sectional planes, which are stacked to produce a three-dimensional grid system. Implementation of the algebraic equivalents of the homotopic relations for generating body geometries and grids are explained. Procedures for controlling grid orthogonality and distortion are described. Test cases with description and specification of inputs are presented in detail. The FORTRAN computer program and notes on implementation and use are included. Author

N89-26196# Manchester Univ. (England). Dept. of Engineering.
A PRELIMINARY INVESTIGATION INTO EULER METHODS FOR APPLICATION TO MULTI-ELEMENT AEROFOILS FOR HIGH LIFT Ph.D. Thesis
MICHAEL L. BARBER Nov. 1987 116 p
(AERO-REPT-8710; ETN-89-94950) Avail: NTIS HC A06/MF A01

The full potential equation is solved for flow past a circular cylinder and the results obtained are compared with the benchmark solution of Rayleigh and Janzen. Euler's equations of motion are derived in a Cartesian coordinate system. A general form of the equations for orthogonal curvilinear coordinate systems is also given. The equations in Cartesian coordinates are discretized. The main methods are those or Lax, MacCormack, and Hall. The first order finite difference technique and first and second order cell-vertex integral method are applied to the problem of a 10 percent symmetric thin airfoil in subsonic freestream. The results are compared to those or the linearized model. A flow solution over a circular cylinder is treated. The Euler equations are developed in inverted cylindrical polar coordinates. The inverse conformal mapping is used to map the exterior region of the circle onto the internal region. A subsonic freestream flow is considered for a leading quarter of the circle using the second order finite difference technique and the second order cell-vertex method. Results are compared with those obtained using the full-potential model. For a half-circle, results for a slightly supercritical freestream are given. ESA

N89-26207*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A LONG-RANGE LASER VELOCIMETER FOR THE NATIONAL FULL-SCALE AERODYNAMICS COMPLEX: NEW DEVELOPMENTS AND EXPERIMENTAL APPLICATION
MICHAEL S. REINATH Jun. 1989 44 p Presented at the 13th International Congress on Instrumentation in Aerospace Facilities, Gottingen, Fed. Republic of Germany, 18-21 Sep. 1989
(NASA-TM-101081; A-89070; NAS 1.15:101081) Avail: NTIS HC A03/MF A01 CSCL 14/2

A long-range laser velocimeter (LV) developed for remote operation from within the flow fields of the large wind tunnels of the National Full-Scale Aerodynamics Complex is described. Emphasis is placed on recent improvements in optical hardware as well as recent additions to data acquisition and processing techniques. The system has been upgraded from a dual-beam,

single-color LV with focal range to 10 m, to a dual-beam, two-color LV with focal range to 20 m. At the new extended measurement range (between 10 and 20 m), signals are photon-resolved, and a photon correlation technique is applied to acquire and process the LV signals. This technique permits recovery of the velocity probability distributions at a particular measurement location from which the mean components of velocity and the corresponding normal stress components of turbulence are obtained. The method used for data reduction is outlined in detail, and a discussion of measurement accuracy is made. To study the performance of the LV and verify the measurement accuracy, laboratory measurements were made in the flow field of a 10 cm-diameter, 30-m/sec axisymmetric jet. A discussion of the requirements and techniques used to seed the flow is made, and boundary-layer surveys of mean velocity and turbulence intensity of the streamwise component and the component normal to the surface are presented. Author

N89-26240 Department of the Air Force, Washington, DC.
SUPERCONDUCTING ROTOR COOLING SYSTEM Patent
PHILLIP W. ECKELS, inventor (to Air Force) 18 Oct. 1988 4 p Filed 13 Oct. 1987
(AD-D014020; US-PATENT-4,779,017; US-PATENT-APPL-SN-107197; US-PATENT-CLASS-310-52)
Avail: US Patent and Trademark Office CSCL 13/1

A superconducting rotor cooling system for an electrical generator includes a free vortex type pump which is located within and forms an integral part of the rotor assembly. The free vortex pump takes advantage of the centrifugal force of rotation of the cooling fluid to help the rotor winding compartment to remain in a superfluid helium state. Improved cooling results from combined natural convection (which occurs in a conventional rotor) and the superfluid heat transport (which occurs at the velocity of sound). GRA

N89-26259*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPUTATIONAL STRUCTURAL MECHANICS FOR ENGINE STRUCTURES
C. C. CHAMIS 1989 12 p Presented at the 30th Structures, Structural Dynamics and Materials (SDM) Conference, Mobile, AL, 3-5 Apr. 1989; cosponsored by the AIAA, ASME, ASCE, AHS, and ACS
(NASA-TM-102119; E-4898; NAS 1.15:102119) Avail: NTIS HC A03/MF A01 CSCL 20/11

The computational structural mechanics (CSM) program at Lewis encompasses: (1) fundamental aspects for formulating and solving structural mechanics problems, and (2) development of integrated software systems to computationally simulate the performance/durability/life of engine structures. It is structured to mainly supplement, complement, and whenever possible replace, costly experimental efforts which are unavoidable during engineering research and development programs. Specific objectives include: investigate unique advantages of parallel and multiprocesses for: reformulating/solving structural mechanics and formulating/solving multidisciplinary mechanics and develop integrated structural system computational simulators for: predicting structural performances, evaluating newly developed methods, and for identifying and prioritizing improved/missing methods needed. Herein the CSM program is summarized with emphasis on the Engine Structures Computational Simulator (ESCS). Typical results obtained using ESCS are described to illustrate its versatility. Author

N89-26267# Northrop Corp., Hawthorne, CA. Aircraft Div.
AUTOMATED STRUCTURAL OPTIMIZATION SYSTEM (ASTROS): USER TRAINING WORKSHOP Final Report, Jul. 1983 - Jun. 1988
E. H. JOHNSON, D. J. NEILL, D. L. HERENDEEN, and R. A. CANFIELD (Department of the Air Force, Wright-Patterson AFB, OH.) Mar. 1989 427 p
(Contract F33615-83-C-3232)
(AD-A207090; AFWAL-TR-88-3101) Avail: NTIS HC A19/MF A01 CSCL 12/5

The ASTROS (Automated Structural Optimization System) procedure provides multidisciplinary analysis and design capability for aerospace structures. The engineering analysis capabilities in the system include structural analysis (static and dynamic), aeroelastic analysis (static and dynamic) and automated design. A specifically designed data base and executive system were implemented to maximize the system's efficiency, flexibility, and maintainability. The charts used in the ASTROS User Training Workshop, conducted by the Air Force and Northrop are presented in this report. GRA

N89-26273*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LANGLEY ROTORCRAFT STRUCTURAL DYNAMICS PROGRAM: BACKGROUND, STATUS, ACCOMPLISHMENTS, PLANS
RAYMOND G. KVATERNIK Jun. 1989 22 p
(NASA-TM-101618; NAS 1.15:101618) Avail: NTIS HC A03/MF A01 CSCL 20/11

Excessive vibration is the most common technical problem to arise as a show stopper in the development of a new rotorcraft. Vibration predictions have not been relied on by the industry during design because of deficiencies in finite element dynamic analyses. A rotorcraft structural dynamics program aimed at meeting the industry's long-term needs in this key technical area was implemented at Langley in 1984. The subject program is a cooperative effort involving NASA, the Army, academia, and the helicopter industry in a series of generic research activities directed at establishing the critical elements of the technology base needed for development of a superior finite element dynamics design analysis capability in the U.S. helicopter industry. An executive overview of the background, status, accomplishments, and future direction of this program is presented. Author

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GEOSCIENCES

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

A89-44016
LOW-TEMPERATURE PERFORMANCE OF A POWER-PACK FOR A 2-WATT ELT
FRASER WALSH and RADEK FUKSA (Energy Conversion Corp., Somerville, MA) IN: International Power Sources Symposium, 33rd, Cherry Hill, NJ, June 13-16, 1988, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 633-638.

The performance characteristics of two power packs for an airborne emergency locator transmitter (ELT) are described. One of these power packs is based on the use of 12 C-size alkaline cells; the other, on the use of four Li/SOCl2 cells. The performance under load of the two power packs was tested as a function of operating temperature. In these tests, the ELT with power pack was held in a cold chamber at the desired temperature for 24 h or longer prior to turning on the ELT; at this point, the load voltage across both the continuous drain and the pulse load circuits was monitored. It was found that, at temperatures lower than -10 C, only the Li/SOCl2-based power pack was capable of meeting both the desired discharge lifetime and power output requirements. I.S.

A89-45131
'FLIGHT TESTING' A MULTI-MEGAWATT WIND TURBINE
M. G. REES (Boeing Aerospace, Seattle, WA) IN: Society of Flight Test Engineers, Annual Symposium, 19th, Arlington, TX, Aug.

14-18, 1988, Proceedings. Lancaster, CA, Society of Flight Test Engineers, 1988, p. II-3.1 to II-3.10. refs

The field test program for the Mod-5b, a 3.2 megawatt horizontal axis wind turbine, is described. The test results showed the structural stresses to be significantly below the allowable fatigue-related values. The variable speed generator employed is characterized by improved energy capture, reduced power swings at rated power, and reduced structural loads with respect to a previous synchronous generator. A good fit is found between the control law assumptions and experimental results for aerodynamic torque. Design, assembly, and equipment reliability problems are identified. R.R.

A89-46775#
NOISE ISSUES - AN FAA PERSPECTIVE ON TRANSPORT NOISE
NICHOLAS P. KRULL (FAA, Office of Environment and Energy, Washington, DC) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2362)

The history of noise regulation in the United States is traced and the current status of noise regulations is presented for several types of aircraft and propulsion systems. Consideration is given to helicopters, tiltrotors, conventional turbojet and turbofan powered transports, advanced turboprop or unducted fan powered transports, and high-speed civil transports. Some international developments which may influence the U.S. aviation industry and U.S. noise regulations are addresed as well. It is believed that, in time, Stage 2 aircraft will be eliminated, either through local access restrictions or by Federal regulations. K.K.

N89-25530# Lawrence Livermore National Lab., CA.
PREVENTING DEPLETION OF STRATOSPHERIC OZONE: IMPLICATIONS ON FUTURE AIRCRAFT EMISSIONS
DOUGLAS E. KINNISON and DONALD J. WUEBBLES Apr. 1989 17 p Presented at the 82nd Air and Waste Management Association Annual Meeting and Exhibition, Anaheim, CA, 25-30 Jun. 1989
(Contract W-7405-ENG-48)
(DE89-009964; UCRL-99926; CONF-890692-4) Avail: NTIS HC A03/MF A01

There is much renewed interest in the development of faster aircraft for intercontinental passenger flights. Such aircraft would likely spend a large fraction of their flight time in the stratosphere, at altitudes as high as 35 km. It is important, in order to present the problems with the proposed supersonic-transport that occurred in the early 1970's, that the aircraft industry work together with the atmospheric science community to insure that future aircraft emissions will not deplete stratospheric ozone. In this study, we have used our two-dimensional model of the troposphere and stratosphere to examine the sensitivity of stratospheric ozone to such emissions. Initial results indicate, for commercial fleets as large as proposed for the origina! SST and depending on the odd-nitrogen emissions per engine, that substantial decreases in stratospheric ozone could result. The decrease in ozone is sensitive to the altitude and latitude in the emissions. Effects on ozone, for the same emission rate, tend to be larger as altitude increases, until a maximum effect is reached near 30 km. DOE

N89-26294# Federal Aviation Administration, Atlantic City, NJ.
ANALYSIS OF HELICOPTER ENVIRONMENTAL DATA: INDIANAPOLIS DOWNTOWN HELIPORT, WALL STREET HELIPORT. VOLUME 1: SUMMARY Technical Note for Period Ending May 1988
ROSANNE M. WEISS, JOHN G. MORROW, DONALD GALLAGHER, MARK DIMEO, and SCOTT ERLICHMAN Oct. 1988 61 p
(AD-A206708; DOT/FAA/CT-TN87/54-VOL-1) Avail: NTIS HC A04/MF A01 CSCL 01/5

During the summer of 1987 heliport environmental data were collected at the Indianapolis Downtown Heliport and at New York's Wall Street Heliport. The purpose of this data collection activity was to obtain measures of rotorwash in the heliport environment due to maneuvering helicopters, and to obtain pilot perceptions and observations concerning maneuvering and parking separation criteria. Ten wind vector transmitters were situated at various locations around the helicopter in order to gather information to describe the rotorwash induced wind speed and direction changes. Pilot interviews were also conducted at these heliports. Volume 1 of this report documents the results of this activity. It describes the data collection and analysis methodology and addresses technical as well as operational issues. It provides graphical descriptions of the heliport environment and of wind speed changes due to rotorwash from maneuvering helicopters, along with analysis of pilot responses. The results of this study will be considered in future modifications of the Federal Aviation Administration Heliport Design Advisory Circular 150/390-2. GRA

N89-26323# Massachusetts Inst. of Tech., Lexington. Lincoln Lab.
SELECTED WIND SHEAR EVENTS OBSERVED DURING THE 1987 EVALUATION OF ENHANCEMENTS TO THE FAA (FEDERAL AVIATION ADMINISTRATION) LOW LEVEL WIND SHEAR ALERT SYSTEM AT STAPLETON INTERNATIONAL AIRPORT
MICHAEL F. DONOVAN and MARILYN M. WOLFSON 15 Feb. 1989 118 p
(Contract DTFA01-80-Y-10546; F19628-85-C-0002)
(AD-A206711; ATC-158; DOT/FAA/PS-88/9) Avail: NTIS HC A06/MF A01 CSCL 04/2

The FAA Technical Center (FAATC) conducted a test of the enhancements to the FAA Low Level Wind Shear Alert System (LLWAS) at Denver Stapleton International Airport from 3 Aug. to 4 Sep. 1987. Upon completion of the test, the performance of the LLWAS during selected microburst and gust front test cases was investigated in detail. Additional sources of true wind shear information were sought to help evaluate the performance of the LLWAS. In support of these efforts, Lincoln Laboratory supplied complete data sets, including single Doppler radar data from the Lincoln network of 30 automatic weather stations in the vicinity of Stapleton, and LLWAS data to the FAATC. This report summarizes salient features for a number of FAATC selected wind shear events which occurred during the evaluation of the enhanced LLWAS, and documents the data that Lincoln Laboratory has provided to the FAA as part of its project responsibilities. GRA

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MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A89-44423
IN SEARCH OF EFFECTIVE DIVERSITY - A SIX-LANGUAGE STUDY OF FAULT-TOLERANT FLIGHT CONTROL SOFTWARE
ALGIRDAS AVIZIENIS, MICHAEL R. LYU, and WERNER SCHUTZ (California, University, Los Angeles) IN: FTCS-18; International Symposium on Fault-Tolerant Computing, 18th, Tokyo, Japan, June 27-30, 1988, Digest of Papers. Washington, DC, Computer Society Press, 1988, p. 15-22. Research supported by Honeywell, Inc. and California Microelectronics Innovation and Computer Research Opportunities Program. refs

The techniques used in the design of multiversion flight-control software are investigated experimentally. Software for the computer-controlled landing of commercial transport aircraft was developed in six computer languages (C, PASCAL, Ada, Modula-2, PROLOG, and T) by independent, isolated teams of programmers, with three formal reviews and careful error reporting incorporated into the design process. The resulting programs were subjected to unit, integration, acceptance, and flight-simulation tests and

evaluated in detail. Recommendations are given to maximize the potential for diversity in the software design process while assuring the identification and elimination of duplicate faults. T.K.

A89-45293#
EXPERT SYSTEMS' ROLE BROADENS
DAVID M. SMITH (Lockheed Aeronautical Systems Co., Burbank, CA) Aerospace America (ISSN 0740-722X), vol. 27, July 1989, p. 26-28.

Expert-system technologies are under development for such aerospace applications as the scheduling of complex, resource-limited processes, composite materials' fabrication, and the intelligent, real-time-interactive assistance of flight crews in high-stress/high-workload situations. All such real-time cooperative expert systems involve (1) the capture of expertise from multiple sources; (2) the creation of an adequate interface between the user and the system; and (3) the creation of a suitable interface between the system and the process or vehicle to be managed. The most challenging of these system-definition tasks has been found to be the first, since contributions from specialists in many fields must be integrated. O.C.

A89-46144
CONTROL AND DYNAMIC SYSTEMS. VOLUME 29 - ADVANCES IN ALGORITHMS AND COMPUTATIONAL TECHNIQUES IN DYNAMIC SYSTEMS CONTROL. PART 2
C. T. LEONDES, ED. (California, University, Los Angeles) San Diego, CA, Academic Press, Inc., 1988, 324 p. For individual items see A89-46145 to A89-46148.

Recent advances in the theory of numerical control for dynamical systems are discussed in reviews and reports contributed by leading experts. Topics examined include the numerical reliability of Kalman-filter schemes, algorithms for system fault detection through modeling and estimation techniques, computer architectures set up to generate higher-performance controllers, and angle-only-tracking filtering. Consideration is given to gradient-projection methods for systems-optimization problems; optimal control, estimation, and compensation of linear discrete-time systems with stochastic parameters; an algorithm for the approximation of multivariable linear systems; and algorithms for discrete-time adaptive control of rapidly time-varying systems. T.K.

A89-46147* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ARRANGING COMPUTER ARCHITECTURES TO CREATE HIGHER-PERFORMANCE CONTROLLERS
STEPHEN A. JACKLIN (NASA, Ames Research Center, Moffett Field, CA) IN: Control and dynamic systems. Volume 29. Part 2. San Diego, CA, Academic Press, Inc., 1988, p. 67-99. refs

Techniques for integrating microprocessors, array processors, and other intelligent devices in control systems are reviewed, with an emphasis on the (re)arrangement of components to form distributed or parallel processing systems. Consideration is given to the selection of the host microprocessor, increasing the power and/or memory capacity of the host, multitasking software for the host, array processors to reduce computation time, the allocation of real-time and non-real-time events to different computer subsystems, intelligent devices to share the computational burden for real-time events, and intelligent interfaces to increase communication speeds. The case of a helicopter vibration-suppression and stabilization controller is analyzed as an example, and significant improvements in computation and throughput rates are demonstrated. T.K.

A89-46150
GAIN TRANSFER - AN ALGORITHM FOR DECENTRALIZED HIERARCHICAL ESTIMATION
WILLIAM T. GARDNER (Hughes Aircraft Co., Los Angeles, CA) IN: Control and dynamic systems. Volume 30. Part 3. San Diego, CA, Academic Press, Inc., 1989, p. 19-64. refs

The development of the gain transfer algorithm for application to a decentralized hierarchical estimator is studied. This technique permits the reconstruction of global covariance information from local observation data without significant loss of accuracy. The data computation is significantly reduced in comparison to methods requiring the inversion of potentially large matrices. K.K.

A89-46244
LOCAL ANALYTICAL METHODS FOR DIGITAL SIMULATION OF DYNAMICAL CONTROL SYSTEM
JING-GAO FEI (Beijing Institute of Computer Applications and Simulation Technology, People's Republic of China) Science in China, Series A - Mathematics, Physics, Astronomy and Technological Sciences (ISSN 0253-5831), vol. 32, March 1989, p. 361-373.

Local analytical methods for digital simulation of the dynamical control system are presented to overcome the difficulties due to the stiffness, the oscillation with high frequency, and the discontinuity. The idea of computation of the analog computer is introduced into the computation of digital simulation, the system is decomposed into some subsystems, each of which can run independently, and, with the approximated input information, the local analytical expressions for the solutions of these subsystems are constructed. Finally, a simple analysis about the accuracy estimate and the stability of the algorithms is given. The computational results show that the CPU time expended on the digital simulation of a flying control system is only 1/20 of that needed by the traditional numerical methods. Author

A89-46551
METHODS FOR THE MATHEMATICAL MODELING OF FLIGHT VEHICLE ENGINES [METODY MATEMATICHESKOGO MODELIROVANIIA DVIGATELEI LETATEL'NYKH APPARATOV]
ROSTISLAV K. CHUIAN Moscow, Izdatel'stvo Mashinostroenie, 1988, 288 p. In Russian. refs

Methods for modeling and optimizing flight vehicle engines and their components using state-of-the-art digital and analog computers are reviewed. In particular, attention is given to the classification of mathematical models, hierarchical principles of the development of mathematical models, statistical testing of models, and digital and analog models of flight vehicle engines. The discussion also covers engine identification models and methods and optimal design of flight vehicle engines. V.L.

N89-25162*# Georgia Inst. of Tech., Atlanta.
TRUSS: AN INTELLIGENT DESIGN SYSTEM FOR AIRCRAFT WINGS
PRESTON R. BATES and DANIEL P. SCHRAGE *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 1 p 333-355 Apr. 1989
Avail: NTIS HC A23/MF A01 CSCL 09/2

Competitive leadership in the international marketplace, superiority in national defense, excellence in productivity, and safety of both private and public systems are all national defense goals which are dependent on superior engineering design. In recent years, it has become more evident that early design decisions are critical, and when only based on performance often result in products which are too expensive, hard to manufacture, or unsupportable. Better use of computer-aided design tools and information-based technologies is required to produce better quality United States products. A program is outlined here to explore the use of knowledge based expert systems coupled with numerical optimization, database management techniques, and designer interface methods in a networked design environment to improve and assess design changes due to changing emphasis or requirements. The initial structural design of a tiltrotor aircraft wing is used as a representative example to demonstrate the approach being followed. Author

N89-25179*# Northrop Corp., Hawthorne, CA. Aircraft Div.
ROBUST COMPUTER-AIDED SYNTHESIS AND OPTIMIZATION OF LINEAR MULTIVARIABLE CONTROL SYSTEMS WITH VARYING PLANT DYNAMICS VIA AUTOCON
C. P. LEFKOWITZ, J. A. TEKAWY, P. K. PUJARA, and M. G.

SAFONOV (University of Southern California, Los Angeles.) *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 621-638 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 09/2

AUTOCON is an automated computer-aided design tool for the synthesis and optimization of linear multivariable control systems based upon user-defined control parameter optimization. Violations in stability and performance requirements are computed from constraints on Single Input/Single Output (SISO) open- and closed-loop transfer function frequency responses, and from constraints on the singular-value frequency responses of Multiple Input/Multiple Output (MIMO) transfer functions, for all critical plant variations. Optimum nonlinear programming algorithms are used in the search for local constrained solutions in which violations in stability and performance are caused either to vanish or be minimized for a proper selection of the control parameters. Classical control system stability and performance design can, in this way, be combined with modern multivariable robustness methods to offer general frequency response loop-shaping via a computer-aided design tool. Complete Nichols, Nyquist, Bode, singular-value Bode magnitude and transient response plots are produced, including user-defined boundary responses. AUTOCON is used to synthesize and optimize the lateral/directional flight control system for a typical high-performance aircraft. Author

N89-25180*# McDonnell-Douglas Helicopter Co., Mesa, AZ.
COMPUTERIZED DESIGN SYNTHESIS (CDS), A DATABASE-DRIVEN MULTIDISCIPLINARY DESIGN TOOL
D. M. ANDERSON and A. O. BOLUKBASI *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 2 p 639-650 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 09/2

The Computerized Design Synthesis (CDS) system under development at McDonnell Douglas Helicopter Company (MDHC) is targeted to make revolutionary improvements in both response time and resource efficiency in the conceptual and preliminary design of rotorcraft systems. It makes the accumulated design database and supporting technology analysis results readily available to designers and analysts of technology, systems, and production, and makes powerful design synthesis software available in a user friendly format. Author

N89-25220*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
THE ROLE OF OPTIMIZATION IN THE NEXT GENERATION OF COMPUTER-BASED DESIGN TOOLS
J. EDWARD ROGAN *In* NASA. Langley Research Center, Recent Advances in Multidisciplinary Analysis and Optimization, Part 3 p 1335-1357 Apr. 1989
Avail: NTIS HC A22/MF A01 CSCL 09/2

There is a close relationship between design optimization and the emerging new generation of computer-based tools for engineering design. With some notable exceptions, the development of these new tools has not taken full advantage of recent advances in numerical design optimization theory and practice. Recent work in the field of design process architecture has included an assessment of the impact of next-generation computer-based design tools on the design process. These results are summarized, and insights into the role of optimization in a design process based on these next-generation tools are presented. An example problem has been worked out to illustrate the application of this technique. The example problem - layout of an aircraft main landing gear - is one that is simple enough to be solved by many other techniques. Although the mathematical relationships describing the objective function and constraints for the landing gear layout problem can be written explicitly and are quite straightforward, an approximation technique has been used in the solution of this problem that can just as easily be applied to integrate supportability or producibility assessments using theory of measurement techniques into the design decision-making process. Author

N89-26606*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
APPLICATIONS OF FUZZY SETS TO RULE-BASED EXPERT SYSTEM DEVELOPMENT
ROBERT N. LEA *In* NASA. Goddard Space Flight Center, The 1989 Goddard Conference on Space Applications of Artificial Intelligence p 385-388 Apr. 1989
Avail: NTIS HC A17/MF A01 CSCL 12/1

Problems of implementing rule-based expert systems using fuzzy sets are considered. A fuzzy logic software development shell is used that allows inclusion of both crisp and fuzzy rules in decision making and process control problems. Results are given that compare this type of expert system to a human expert in some specific applications. Advantages and disadvantages of such systems are discussed. Author

N89-26610*# Massachusetts Inst. of Tech., Cambridge. Lab. for Information and Decision Systems.
NONLINEAR AND ADAPTIVE CONTROL Final Report, 1 Jun. 1984 - 31 Jan. 1989
MICHAEL ATHANS Jul. 1989 24 p
(Contract NAG2-297)
(NASA-CR-180088; NAS 1.26:180088; LIDS-FR-1891; MIT-OSP-95178) Avail: NTIS HC A03/MF A01 CSCL 09/2

The primary thrust of the research was to conduct fundamental research in the theories and methodologies for designing complex high-performance multivariable feedback control systems; and to conduct feasibiltiy studies in application areas of interest to NASA sponsors that point out advantages and shortcomings of available control system design methodologies. Author

N89-26623*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED STRUCTURE/CONTROL LAW DESIGN BY MULTILEVEL OPTIMIZATION
MICHAEL G. GILBERT and DAVID K. SCHMIDT Jun. 1989 12 p Presented at the AIAA Guidance, Navigation and Control Conference, Boston, MA, 14-16 Aug. 1989
(NASA-TM-101623; NAS 1.15:101623) Avail: NTIS HC A03/MF A01 CSCL 09/2

A new approach to integrated structure/control law design based on multilevel optimization is presented. This new approach is applicable to aircraft and spacecraft and allows for the independent design of the structure and control law. Integration of the designs is achieved through use of an upper level coordination problem formulation within the multilevel optimization framework. The method requires the use of structure and control law design sensitivity information. A general multilevel structure/control law design problem formulation is given, and the use of Linear Quadratic Gaussian (LQG) control law design and design sensitivity methods within the formulation is illustrated. Results of three simple integrated structure/control law design examples are presented. These results show the capability of structure and control law design tradeoffs to improve controlled system performance within the multilevel approach. 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.

A89-46772*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPERSONIC JET NOISE AND THE HIGH SPEED CIVIL TRANSPORT
JOHN M. SEINER (NASA, Langley Research Center, Hampton, VA) and EUGENE A. KREJSA (NASA, Lewis Research Center,

Cleveland, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 24 p. refs (AIAA PAPER 89-2358)

An evaluation is made of the comparative advantages of prospective SST engine noise-suppression systems, with a view to their effectiveness in meeting the federally-mandated community noise standards of FAR 36 Stage III. A noise-suppression system must be capable of removing at least 4 EPNdB of noise percent thrust loss at takeoff. While none of the suppressors presently discussed is capable of meeting this goal, the inverted velocity profile/annular convergent-divergent plug/acoustically-treated ejector suppressor combination of configurational elements appears to represent the most efficient noise-control apparatus. Noncircular cross-section nozzle geometries also furnish a general noise reduction advantage over circular ones. O.C.

N89-25140# Technische Hochschule, Aachen (Germany, F.R.).
STRUCTURAL LOADING AND NOISE DISTURBANCE OF HELICOPTERS [STRUKTURBEANSPRUCHUNG UND LAERMBELAESTIGUNG BEIN HUBSCHRAUBER]
R. MUELLER *In its* Vortex Flows in Flying Technique p 313-337 1988 In GERMAN
Avail: NTIS HC A17/MF A01

Test experiments were performed and calculation methods were developed to study the structural loading of helicopter rotor blades and the resulting noise emission which can strongly reduce operational conditions of a helicopter. An optimized winglet was constructed which reduced rotor blade loading and rotor noise emission by changing position and structure of the wing tip vortices. The use of such winglets is especially advantageous in case of fast descent. In fast forward flight the flow at the winglet can become a problem due to the high angles of attack at the winglet; however, no separation phenomena at the winglet were observed. ESA

N89-25673*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIRFOIL SELF-NOISE AND PREDICTION
THOMAS F. BROOKS, D. STUART POPE (PRC Kentron, Inc., Hampton, VA.), and MICHAEL A. MARCOLINI Jul. 1989 145 p
(NASA-RP-1218; L-16528; NAS 1.61:1218) Avail: NTIS HC A07/MF A01 CSCL 20/1

A prediction method is developed for the self-generated noise of an airfoil blade encountering smooth flow. The prediction methods for the individual self-noise mechanisms are semiempirical and are based on previous theoretical studies and data obtained from tests of two- and three-dimensional airfoil blade sections. The self-noise mechanisms are due to specific boundary-layer phenomena, that is, the boundary-layer turbulence passing the trailing edge, separated-boundary-layer and stalled flow over an airfoil, vortex shedding due to laminar boundary layer instabilities, vortex shedding from blunt trailing edges, and the turbulent vortex flow existing near the tip of lifting blades. The predictions are compared successfully with published data from three self-noise studies of different airfoil shapes. An application of the prediction method is reported for a large scale-model helicopter rotor, and the predictions compared well with experimental broadband noise measurements. A computer code of the method is given. Author

N89-25675*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
IN-FLIGHT MEASUREMENT OF PROPELLER NOISE ON THE FUSELAGE OF AN AIRPLANE
FREDERIC G. PLA (Sverdrup Technology, Inc., Cleveland, OH.), RICHARD RANAUDO, and RICHARD P. WOODWARD Jul. 1989 58 p
(Contract NAS3-24105)
(NASA-TM-102285; E-4952; NAS 1.15:102285) Avail: NTIS HC A04/MF A01 CSCL 20/1

In-flight measurements of propeller noise on the fuselage of an OV-10A aircraft were obtained using a horizontal and a vertical microphone array. A wide range of flight conditions were tested including changes in angle of attack, sideslip angle, power coefficient, helical tip Mach number and advance ratio, and propeller direction of rotation. Results show a dependence of the level and directivity of the tones on the angle of attack and on the sideslip angle with the propeller direction of rotation, which is similar to results obtained in wind tunnel tests with advanced propeller designs. The level of the tones at each microphone increases with increasing angle of attack for inboard-down propeller rotation and decreases for inboard-up rotation. The level also increases with increasing slideslip angle for both propeller directions of rotation. Increasing the power coefficient results in a slight increase in the level of the tones. A strong shock wave is generated by the propeller blades even at relatively low helical tip Mach numbers resulting in high harmonic levels. As the helical tip Mach number and the advance ratio are increased, the level of the higher harmonics increases much faster than the level of the blade passage frequency. Author

N89-25676# Technische Univ., Berlin (Germany, F.R.). Fachgebeit Flugfuehrung und Luftverkehr.
REDUCTION OF AIRCRAFT NOISE IN CIVIL AIR TRANSPORT BY OPTIMIZATION OF FLIGHT TRACKS AND TAKEOFF AND APPROACH PROCEDURES Final Report, 31 Mar. 1988
UWE ROTTMANN Aug. 1988 229 p In GERMAN; ENGLISH summary
(Contract BMUNR-FB-88-105-05-501)
(ILR-MITT-200; ETN-89-94560) Avail: NTIS HC A11/MF A01

Noise optimized design of operational flight procedures for effective noise pollution reduction is analyzed. Power cutback during certain stages of approach and takeoff, extension of distance between sound source and sound receiver, as well as diminution of sound impact time are optimized for specific flight procedures and routings. Five takeoff and three landing procedures are analyzed in acoustic effects. Sound immission is computed by NOISIMSIS (NOISe IMpact SImulation System), a simulation system especially created for this task, under consideration of aircraft type specified sound emission characteristics and performance data as well as different meteorological conditions. The investigations for the example of Frankfurt airport result in formulating a planning guideline with notes and impulses for activities in operational noise abatement. ESA

N89-25697# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Abteilung Lasertechnik.
PROTOTYPE OF A SLANT VISUAL RANGE MEASURING DEVICE
JUERGEN STREICHER, CHRISTIAN WERNER, UWE BERGHAUS, HARALD GATZ, EBERHARD GELBKE, ANDREAS LISIUS, and CHRISTOPH MUENKEL (Impulsphysik G.m.b.H., Hamburg, Germany, F.R.) Aug. 1988 81 p In GERMAN; ENGLISH summary
(DFVLR-FB-88-42; ISSN-0171-1342; ETN-89-94632) Avail: NTIS HC A05/MF A01; DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Fed. Republic of Germany, DM 25.50

A prototype an eye-safe slant visual range measuring device consisting of a modified eye-safe cloud ceilograph is described. The system concept with a fast data system and a complex data handling program is presented. It is intended for airports. ESA

N89-26679*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A NEW CLASS OF RANDOM PROCESSES WITH APPLICATION TO HELICOPTER NOISE Annual Report No. 2
JAY C. HARDIN and A. G. MIAMEE (Hampton Inst., VA.) 1989 25 p
(Contract NAG1-768)
(NASA-CR-185037; NAS 1.26:185037) Avail: NTIS HC A03/MF A01 CSCL 20/1

The concept of dividing random processes into classes (e.g., stationary, locally stationary, periodically correlated, and harmonizable) has long been employed. A new class of random processes is introduced which includes many of these processes as well as other interesting processes which fall into none of the

above classes. Such random processes are denoted as linearly correlated. This class is shown to include the familiar stationary and periodically correlated processes as well as many other, both harmonizable and non-harmonizable, nonstationary processes. When a process is linearly correlated for all t and harmonizable, its two-dimensional power spectral density S(x)(omega 1, omega 2) is shown to take a particularly simple form, being non-zero only on lines such that omega 1 to omega 2 = + or - r(k) where the r(k's) are (not necessarily equally spaced) roots of a characteristic function. The relationship of such processes to the class of stationary processes is examined. In addition, the application of such processes in the analysis of typical helicopter noise signals is described. Author

N89-26683*# United Technologies Research Center, East Hartford, CT.
NOISE PRODUCED BY TURBULENT FLOW INTO A ROTOR: THEORY MANUAL FOR NOISE CALCULATION Final Report
R. K. AMIET Jun. 1989 36 p
(Contract NAS1-17763)
(NASA-CR-181788; NAS 1.26:181788) Avail: NTIS HC A03/MF A01 CSCL 20/1

An analysis is presented for the calculation of noise produced by turbulent flow into a helicopter rotor. The method is based on the analysis of Amiet for the sound produced by an airfoil moving in rectilinear motion through a turbulent flow field. The rectilinear motion results are used in a quasi-steady manner to calculate the instantaneous spectrum of the rotor noise at any given rotor position; the overall spectrum is then found by averaging the instantaneous spectrum over all rotor azimuth angles. Account is taken of the fact that the rotor spends different amounts of retarded time at different rotor positions. Blade to blade correlation is included in the analysis, leading to harmonics of blade passing frequency. The spectrum of the turbulence entering the rotor is calculated by applying rapid distortion theory to an isotropic turbulence spectrum, assuming that the turbulence is stretched as it is pulled into the rotor. The inputs to the program are obtained from the atmospheric turbulence model and mean flow distortion calculation, described in another volume of this set of reports. The analytical basis is provided for a module which was incorporated in NASA's ROTONET helicopter noise prediction program. Author

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SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

A89-45039
AIRBUS INDUSTRIE, LESSONS FROM EXPERIENCE [AIRBUS INDUSTRIE, LECONS D'UNE EXPERIENCE]
ROGER BETEILLE (Airbus Industrie, Blagnac, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 136-137, 1989, p. 60-68. In French.

The Airbus program, a cooperative venture of France, England, Germany, Spain, the Netherlands, and Belgium, is discussed in detail. The problems encountered during the design, fabrication, and marketing of the Airbus aircraft are reviewed. It is emphasized that cooperation among the various countries requires the standardization of computer languages, technical terms, and scientific parameters. R.R.

A89-45175
ANNALS OF AIR AND SPACE LAW. VOLUME 13
NICOLAS MATEESCO MATTE, ED. (McGill University, Montreal, Canada) Montreal, McGill University, 1988, 429 p. In English and French. No individual items are abstracted in this volume.

Papers are presented on the obsolescence of bilateral air transport agreements, air transport deregulation in jurisdictions other than the U.S., the role of the ICAO in the suppression of drug trafficking, and aircraft accidents in Japan. Also considered are legal aspects of space conquest, liability for damage caused in outer space by space refuse, international organizations for space regulation, and key judical decisions related to space law. Other topics include space surveillance for arms control and verification, the extraterritorial application of U.S. antitrust laws, ESA resolutions on participation in the Space Station program, and an international agreement on the establishment of tariffs for intra-European scheduled air services. R.R.

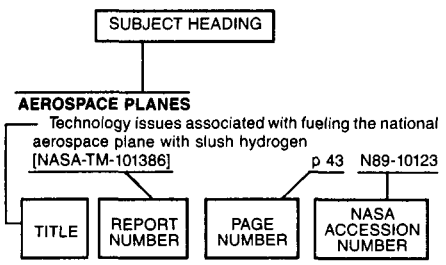
A89-46835#
ECONOMIC ANALYSIS OF A BEAM-POWERED, PERSONALIZED GLOBAL AEROSPACE TRANSPORTATION SYSTEM
GEORGE LIST, LEIK MYRABO (Rennselaer Polytechnic Institute, Troy, NY), and DAVID WALTON AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-13, 1989. 7 p.
(AIAA PAPER 89-2443)

This paper presents an economic analysis of a revolutionary transport technology intended for high-speed world travel. The Apollo lightcraft technology will make possible door-to-door travel half-way around the globe in 45 minutes; an unmanned experimental launch of a laser-boosted demonstration is due within five years. Estimates are presented of vehicle size; ridership; revenues; fleet size; capital, operating and maintenance cost; and expected profitability. On a net present value basis, over a 20-year time span, the system should have costs 20 percent below revenues, implying not only an ability to be economically profitable but, as the reader will probably agree, a potential market penetrability which goes well beyond the conservative assumptions made in the analyses. Author

N89-25764*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
FEDERAL INCENTIVES FOR INDUSTRIAL MODERNIZATION: HISTORICAL REVIEW AND FUTURE OPPORTUNITIES
SANDRA C. COLEMAN and ROBERT G. BATSON (Alabama Univ., Tuscaloosa.) Aug. 1987 37 p Submitted for publication
(NASA-TM-101785; NAS 1.15:101785) Avail: NTIS HC A03/MF A01 CSCL 05/1

Concerns over the aging of the U.S. aerospace industrial base led DOD to introduce first its Technology Modernization (Tech Mod) Program, and more recently the Industrial Modernization Incentive Program (IMIP). These incentives include productivity shared savings rewards, contractor investment protection to allow for amortization of plant and equipment, and subcontractor/vendor participation. The purpose here is to review DOD IMIP and to evaluate whether a similar program is feasible for NASA and other non-DOD agencies. The IMIP methodology is of interest to industrial engineers because it provides a structured, disciplined approach to identifying productivity improvement opportunities and documenting their expected benefit. However, it is shown that more research on predicting and validating cost avoidance is needed. Author

Typical Subject Index Listing



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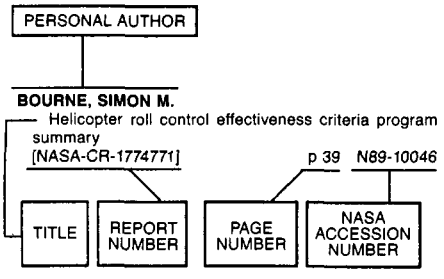

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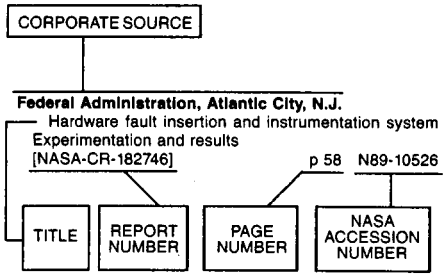

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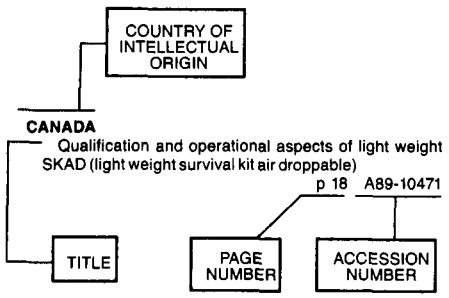

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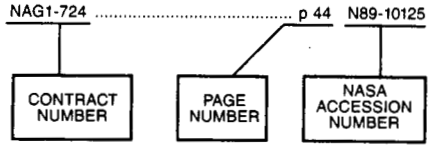

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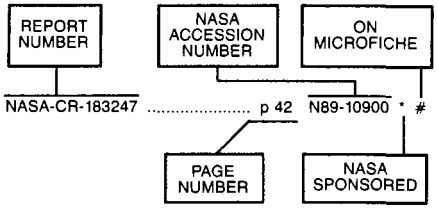

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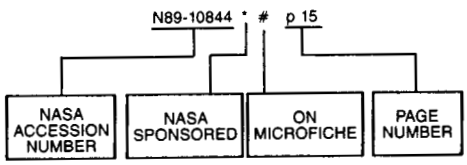

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