NASA SP-7037 (309)
October 1994

P-83

AERONAUTICAL ENGINEERING

(NASA-SP-7037(309)) AERONAUTICAL ENGINEERING: A CONTINUING BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 309) (NASA) 83 p

N95-12894

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A CONTINUING BIBLIOGRAPHY WITH INDEXES

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AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

National Aeronautics and Space Administration
Scientific and Technical Information Program
Washington, DC 1994

This publication was prepared by the NASA Center for AeroSpace Information,
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INTRODUCTION

This issue of *Aeronautical Engineering — A Continuing Bibliography with Indexes* (NASA SP-7037) lists 212 reports, journal articles, and other documents recently announced in the NASA STI Database.

Accession numbers cited in this issue include:

Scientific and Technical Aerospace Reports (STAR) (N-10000 Series)	N94-36231 — N94-37480
Open Literature (A-60000 Series)	A94-61024 — A94-61885

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 publication 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.

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

A cumulative index for 1994 will be published in early 1995.

Information on availability of documents listed, addresses of organizations, and CASI price schedules are located at the back of this issue.

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TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED
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ACCESSION NUMBER → N94-10675*# National Aeronautics and Space Administration. ← CORPORATE SOURCE
Langley Research Center, Hampton, VA.
TITLE → STATIC INTERNAL PERFORMANCE OF A SINGLE EXPANSION RAMP NOZZLE WITH MULTIAXIS THRUST VECTORING CAPABILITY
AUTHORS → FRANCIS J. CAPONE and ALBERTO W. SCHIRMER (George Washington Univ., Hampton, VA.) Washington Jul. 1993 ← PUBLICATION DATE
272 p
CONTRACT NUMBER → (Contract RTOP 505-62-30-01)
REPORT NUMBERS → (NASA-TM-4450; L-17163; NAS 1.15:4450) Avail: CASI HC A12/ MF A03 ← AVAILABILITY AND PRICE CODE

An investigation was conducted at static conditions in order to determine the internal performance characteristics of a multiaxis thrust vectoring single expansion ramp nozzle. Yaw vectoring was achieved by deflecting yaw flaps in the nozzle sidewall into the nozzle exhaust flow. In order to eliminate any physical interference between the variable angle yaw flap deflected into the exhaust flow and the nozzle upper ramp and lower flap which were deflected for pitch vectoring, the downstream corners of both the nozzle ramp and lower flap were cut off to allow for up to 30 deg of yaw vectoring. The effects of nozzle upper ramp and lower flap cutout, yaw flap hinge line location and hinge inclination angle, sidewall containment, geometric pitch vector angle, and geometric yaw vector angle were studied. This investigation was conducted in the static-test facility of the Langley 16-foot Transonic Tunnel at nozzle pressure ratios up to 8.0. Author (revised)

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED

ACCESSION NUMBER → A94-60042* National Aeronautics and Space Administration. ← CORPORATE SOURCE
Lewis Research Center, Cleveland, OH.
TITLE → EXPERIMENTAL INVESTIGATION OF COUNTER-ROTATING PROPFAN FLUTTER AT CRUISE CONDITIONS
AUTHORS → ORAL MEHMED NASA Lewis Research Center, Cleveland, OH and ← AUTHOR'S AFFILIATION
ANATOLE P. KURKOV *Journal of Propulsion and Power* (ISSN ← JOURNAL TITLE
PUBLICATION DATE → 0748-4658) vol. 10, no. 3 May-June 1994 p. 343-347 refs
REPORT NUMBER → (BTN-94-EIX94321333310) Copyright

This article presents wind-tunnel experimental flutter results, at transonic relative flows, for a 0.62-m-diam composite propfan model. A blade row that fluttered was tested alone, and with a stable aft counter-rotating blade row. The major objectives of the experiment were to study the effect of the second blade row on the row in flutter, and to investigate the flutter. Results show that the second row had a small stabilizing effect. Two distinct flutter modes were found within the operating regime of the rotor: both apparently single-degree-of-freedom instabilities, associated respectively with the first and second natural blade modes. For both flutter modes, flutter boundary, frequency, nodal diameter, and blade displacement data are given. The blade displacement data, obtained with an optical method, gives an indication of the flutter mode shape at a span near the blade tip. Author (EI)

AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 309)

October 1994

A B S T R A C T S

01 AERONAUTICS (GENERAL)

A94-61782
ONE-EQUATION TURBULENCE MODEL FOR AERODYNAMIC FLOWS
P. R. SPALART Boeing Commercial Airplane Group, Seattle, WA and S. R. ALLMARAS *Recherche Aerospatiale* (ISSN 0034-1223) no. 1 1994 p. 5-21 refs
(BTN-94-EIX94401367449) Copyright

A transport equation for the turbulent viscosity is assembled using empiricism and arguments of dimensional analysis, Galilean invariance, and selective dependence on the molecular viscosity. It has similarities with the models of Nee and Kovaszany, Secundov et al., and Baldwin and Barth. The equation includes a nonviscous destruction term that depends on the distance of the wall. EI

A94-61783
COMPUTATION OF TRANSONIC FLOWS AROUND A WING-PLUS-FUSELAGE CONFIGURATION TAKING VISCOUS EFFECTS AND A THIN SEPARATED REGION INTO ACCOUNT
V. E. KOVALEV Inst. Hydro-Aeriodynamique Central, Moscow (Russia) and O. V. KARAS *Recherche Aerospatiale* (ISSN 0034-1223) no. 1 1994 p. 23-38 refs
(BTN-94-EIX94401367450) Copyright

An algorithm and a program were developed for computing the transonic flow around a wing-plus-fuselage configuration taking viscous effects into account. They are based on a semi-inverse viscous-inviscid coupling method that also takes the possible existence of a thin separated region into account. The inviscid fluid flow is computed by numerically integrating the complete potential equation expressed in conservative form. EI

A94-61785
MULTIDOMAIN METHOD FOR SEVERAL BODIES IN RELATIVE MOTION
WEN-ZHONG SHEN LIMSI-CNRS, Orsay (France) and S. HUBERSON *Recherche Aerospatiale* (ISSN 0034-1223) no. 1 1994 p. 53-66 refs
(BTN-94-EIX94401367452) Copyright

We present a numerical study of the flow around two airfoils. The first one is oscillating while the second is fixed. A multidomain method is used. An appropriate discretization scheme is used in each subdomain. A finite difference method is used in the near solid walls. A vortex method is used in the rest of the domain. EI

A94-61788
COPING WITH THE DEFENSE CUTBACK
JOHN C. DYER Mitre Corp. Aerospace America (ISSN 0740-722X) vol. 32, no. 1 January 1994 p. 20-25
(BTN-94-EIX94401216109) Copyright

The drop in defense-related employment will be experienced throughout the decade. In their struggle to survive and prosper as markets shrink, aerospace companies are applying and mixing a broad array of strategies. The author analyzes corporate behaviors and strategies of big military enterprises. EI

A94-61855
VORTEX CUTTING BY A BLADE. PART 1: GENERAL THEORY AND A SIMPLE SOLUTION
J. S. MARSHALL Iowa Univ., Iowa City, IA *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1154-1150 refs
(BTN-94-EIX94421374957) Copyright

A simplified theory for long-wave motion of vortex filaments with variable core radius is given, for small values of the ratio epsilon = max(sigma/L) of core radius sigma to axial length scale L, which offers a number of advantages for numerical computations of the vortex response. An analytical solution of this theory is then obtained for the axial flow within a straight vortex filament following cutting of the vortex by a flat blade at an angle of attack alpha. EI

A94-61856
FLUCTUATING WALL PRESSURES NEAR SEPARATION IN HIGHLY SWEPT TURBULENT INTERACTIONS
J. D. SCHMISSEUR Wright-Patterson Air Force Base, Dayton, OH *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1151-1157 refs
(BTN-94-EIX94421374958) Copyright

Fluctuating wall pressures have been measured in Mach 5 interactions generated by sharp, unswept fins at angles of attack of 16 to 28 deg. The results show that rms pressure distributions, like the mean, can be collapsed in conical coordinates. The wall pressure signal near separation is intermittent and is qualitatively similar to that measured in unswept interactions and other swept flows. EI

A94-61865* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
LOW-DIMENSIONAL DESCRIPTION OF THE DYNAMICS IN SEPARATED FLOW PAST THICK AIRFOILS
ANIL E. DEANE NASA. Goddard Space Flight Center, Greenbelt, MD and CATHERINE MAVRIPLIS *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1222-1227 refs
(BTN-94-EIX94421374967) Copyright

Results are presented for the numerical simulation of unsteady viscous incompressible flow past thick airfoils. Specifically, flow past a NACA 4424 at an angle of attack of 2.5 deg and Reynolds numbers in the range of 1700-4000 has been simulated using the spectral element method. At these conditions the flow is separated and an unsteady wake is formed. Application of the method of empirical eigenfunctions reveals the structures of the most energetic components of the flow. Author (revised by EI)

A94-61868
SWIRL CONTROL IN AN S-DUCT AT HIGH ANGLE OF ATTACK
P. F. WENG Shanghai Jiao Tong Univ., Shanghai (China) and R. W. GUO *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1321-1322 refs

(BTN-94-EIX94421374970) Copyright

The problem of angular swirl flow in an S-shaped inlet without guide vanes has come to the fore in the past several years. Many possible modifications of the inlet geometry have been used in the reduction of swirl. This paper describes an improvement of a severely distorted swirl flow in an S-shaped duct at very high angle of attack using a variable lip technique. Author (revised by EI)

A94-61877

EQUIVALENT PLATE STRUCTURAL MODELING FOR WING SHAPE OPTIMIZATION INCLUDING TRANSVERSE SHEAR

ELI LIVNE Univ. of Washington, Seattle, WA *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1278-1288 refs

(BTN-94-EIX94421374979) Copyright

A new technique for structural modeling of airplane wings is presented taking transverse shear effects into account. The kinematic assumptions of first-order shear deformation plate theory in combination with numerical analysis, where simple polynomials are used to define geometry, construction, displacement approximations, lead to analytical expressions for elements of the stiffness and mass matrices and load vector. EI

N94-36648*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

PRELIMINARY ANALYSIS FOR A MACH 8 CROSSFLOW TRANSITION EXPERIMENT ON THE PEGASUS (R) SPACE BOOSTER

LESLIE GONG, W. LANCE RICHARDS, RICHARD C. MONAGHAN, and ROBERT D. QUINN Nov. 1993 23 p Presented at the Society for Experimenal Mechanics, Structural Testing Technology at High Temperature 2 Conference, Ojai, CA, 8-10 Nov. 1993

(Contract RTOP 505-70-91)

(NASA-TM-104272; H-1954; NAS 1.15:104272) Avail: CASI HC A03/MF A01

A boundary-layer transition is proposed for a future flight mission of the air-launched Pegasus space booster. The flight experiment requires attaching a glove assembly to the wing of the first-stage booster. The glove design consists of a spring and hook attachment system which allows for thermal growth of a steel 4130 skin. The results from one- and two-dimensional thermal analyses of the initial design are presented. Results obtained from the thermal analysis using turbulent flow conditions showed a maximum temperature of approximately 305 C and a chordwise temperature gradient of less than 8.9 C/cm for the critical areas in the upper glove skin. The temperatures obtained from these thermal analyses are well within the required temperature limits of the glove. Author (revised)

N94-37332*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

TRENDS: A FLIGHT TEST RELATIONAL DATABASE USER'S GUIDE AND REFERENCE MANUAL

M. J. BONDI, W. S. BJORKMAN, and J. L. CROSS Jun. 1994 286 p See also N90-25149

(Contract RTOP 505-59-36)

(NASA-TM-108806; A-94042; NAS 1.15:108806) Avail: CASI HC A13/MF A03

This report is designed to be a user's guide and reference manual for users intending to access rotocraft test data via TRENDS, the relational database system which was developed as a tool for the aeronautical engineer with no programming background. This report has been written to assist novice and experienced TRENDS users. TRENDS is a complete system for retrieving, searching, and analyzing both numerical and narrative data, and for displaying time history and statistical data in graphical and numerical formats. This manual provides a 'guided tour' and a 'user's guide' for the new and intermediate-skilled users. Examples for the use of each menu item within TRENDS is provided in the Menu Reference section of the manual, including full coverage for TIMEHIST, one of the key tools. This manual is written around the XV-15 Tilt Rotor database, but does include an appendix on the UH-60 Blackhawk database. This user's guide and reference manual establishes a referrable source for the research community and augments NASA TM-101025, TRENDS: The Aeronautical Post-Test, Database Management System, Jan. 1990, written by the same authors. Author (revised)

N94-37352 Naval Postgraduate School, Monterey, CA.

PLANNING GERMAN ARMY HELICOPTER MAINTENANCE AND MISSION ASSIGNMENT M.S. Thesis

ACHIM SGASLIK Mar. 1994 106 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality

(AD-A280483) Avail: CASI HC A06

German Army light helicopter transportation regimens operate 45 Bell UH-1D helicopters to support demanding missions throughout Europe. Maintenance period scheduling, major exercise and regular mission assignment decisions directly influence the readiness of the helicopter fleet. Currently, all planning is done manually, which is unstructured and time consuming. This thesis describes a decision support system designed to assist with maintenance planning and mission assignment. The yearly maintenance and event scheduling problem and the short term mission assignment tasks are formulated and solved as elastic mixed integer linear programs. Resulting yearly schedules and short term sortie plans are both generated in a fraction of the time previously required with solution quality superior to their manual counterparts. DTIC

02

AERODYNAMICS

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

A94-61620

EFFECTS OF NOZZLE EXIT GEOMETRY ON FOREBODY VORTEX CONTROL USING BLOWING

NATHAN M. GITTNER North Carolina State Univ., Raleigh, NC and NDAONA CHOKANI *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 503-509 refs

(BTN-94-EIX94401358964) Copyright

An experimental study has been undertaken to examine the influence of the blowing nozzle exit geometry on the effectiveness of the aft blowing technique for forebody vortex control. The experiments were conducted with a 3.0-caliber tangent ogive model at subsonic velocities and a Reynolds number of 8.4 x 10(exp 4) based on the model diameter. Asymmetric aft blowing was accomplished using both a single nozzle and a double nozzle configuration. Detailed surface pressure measurements on the model were obtained and local side forces determined. The experimental results show that both the height and the width of the blowing nozzle exit geometry are important parameters that determine the effectiveness of aft blowing; a broad, low-positioned blowing nozzle exit geometry is found to be most effective for the forebody vortex control technique using aft blowing. Author (EI)

A94-61623

INFLUENCE OF AERODYNAMIC FORCES IN ICE SHEDDING

R. J. SCAVUZZO Univ. of Akron, Akron, OH, M. L. CHU, and V. ANANTHASWAMY *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 526-530 refs

(BTN-94-EIX94401358967) Copyright

Stresses in accreted ice on a typical airfoil impact ice caused by aerodynamic forces have been studied using finite element analyses. The objective of this study is to determine the significance of these stresses relative to values needed to cause ice shedding. In the case studied, stresses are not significant (less than 10%) when compared to the fracture value for airspeeds below a Mach number of 0.45. Above this velocity, the influence of aerodynamic forces on impact ice stresses should be considered in the analyses of ice shedding. Author (EI)

A94-61624
UNSTEADY AERODYNAMIC CHARACTERISTICS OF A DUAL-ELEMENT AIRFOIL
ISMAIL H. TUNCER Naval Postgraduate School, Monterey, CA and LAKSHMI N. SANKAR *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 531-537 refs
(BTN-94-EIX94401358968) Copyright

Unsteady aerodynamic behavior and load characteristics of a VR-7 slat/airfoil combination oscillating sinusoidally between 5-25 deg have been studied. The unsteady, compressible Navier-Stokes equations are solved on a multiblock grid using an approximate factorization finite difference scheme. In the case of a single airfoil, a massive flow separation and formation of a strong vortex is observed. The vortex-induced suction and the shedding of the vortex into the wake is responsible for high aerodynamic loads and the subsequent stall of the airfoil. In the case of a slat/airfoil combination, the suction peak at the leading edge of the airfoil is reduced significantly in comparison to the single airfoil. Flow separation is confined to the trailing edge of the main airfoil, and the formation of a strong vortical structure is not observed. The slat/airfoil combination does not experience a massive flow separation, and the aerodynamic lift does not undergo the characteristic deep dynamic stall hysteresis loops. Author (EI)

A94-61626
LIFT ENHANCEMENT OF AN AIRFOIL USING A GURNEY FLAP AND VORTEX GENERATORS
BRUCE L. STORMS Sterling Software, Moffett Field, CA and CORY S. JANG *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 542-547 refs
(BTN-94-EIX94401358970) Copyright

Experimental measurements of surface pressure distributions and wake profiles were obtained for an NACA 4412 airfoil to determine the lift, drag, and pitching-moment coefficients for various configurations. The addition of a Gurney flap increased the maximum lift coefficient from 1.49 up to 1.96, and decreased the drag near the maximum lift condition. There was, however, a drag increment at low-to-moderate lift coefficients. Additional nose-down pitching moment was also generated by increasing the Gurney flap height. Good correlation was observed between the experiment and Navier-Stokes computations of the airfoil with a Gurney flap. Two deployable configurations were also tested with the hinge line forward of the trailing edge by one and 1.5 flap heights, respectively. These configurations provided performance comparable to that of the Gurney flap. The application of vortex generators to the baseline airfoil delayed boundary-layer separation and yielded an increase in the maximum lift coefficient of 0.34. In addition, there was a significant drag penalty associated with the vortex generators, which suggests that they should be placed where they will be concealed during cruise. The two devices were also shown to work well in concert. Author (EI)

A94-61629
CALCULATION OF THREE-DIMENSIONAL LOW REYNOLDS NUMBER FLOWS
TUNCER CEBECI California State Univ., Long Beach, CA, HSUN H. CHEN, and BENG P. LEE *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 564-571 refs
(BTN-94-EIX94401358973) Copyright

An interactive boundary-layer stability-transition approach is used to calculate the performance characteristics of an infinite swept wing at low Reynolds numbers for several angles of attack. The inviscid flow solutions are obtained from an inviscid method based on conformal mapping and the viscous flow solutions from an inverse boundary-layer scheme which uses the Hilbert integral formulation to couple the inviscid and viscous flow. The onset of transition is calculated by the e-double-prime method, based on two- and three-dimensional versions of linear stability theory. Calculated results for an infinite swept wing with an Eppler airfoil cross section are presented for sweep angles corresponding to lambda = 30, 40, and 45 deg, and for Reynolds numbers of 3 x 10(exp 5) and 4.6 x 10(exp 5). The effect of sweep angle on lift and drag coefficients is investigated together with the accuracy of predicting the onset of transition with two versions of the e-double-prime method. Author (EI)

A94-61630
DRAG AND WAKE MODIFICATION OF AXISYMMETRIC BLUFF BODIES USING COANDA BLOWING
J. B. FREUND Stanford Univ., Stanford, CA and M. G. MUNGAL *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 572-578 refs
(BTN-94-EIX94401358974) Copyright

This work investigates the ability of Coanda jet blowing to modify the base pressure of a cylindrical body aligned axially in a flow, and thereby, produce overall drag reduction. It is found that blowing through one or two slot jets concentric to the outer body circumference can significantly influence the entire base flow region. The recirculating wake is eliminated and is replaced by freestream fluid entrained by the Coanda blowing. Base pressure rises significantly and leads to drag reduction of up to 30% beyond the thrusting action of the Coanda jet. A comparison between the power savings through drag reduction and the power requirement of the Coanda jet demonstrates that net benefits are attainable at certain body geometries and flow conditions. By judiciously selecting the jet blowing velocity, it is possible to produce a nearly flat wake velocity profile requiring little net power. Author (EI)

A94-61631
REDUCTION IN SIZE AND UNSTEADINESS OF VTOL GROUND VORTICES BY GROUND FENCES
T. B. HARMAN Pennsylvania State Univ., University Park, PA, J. M. CIMBALA, and M. L. BILLET *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 579-584 refs
(BTN-94-EIX94401358975) Copyright

A ground vortex, produced when a jet impinges on the ground in the presence of crossflow, is encountered by V/STOL aircraft hovering near the ground, and is known to be hazardous to the aircraft. The objective of this research was to identify a ground-based technique by which both the mean size and fluctuation in size of the ground vortex could be reduced. A simple passive method has been identified and examined in the laboratory. Specifically, one or two fine wire mesh screens (ground fences), bent in a horseshoe shape, located on the ground in front of the jet impingement point, proved to be very effective. The ground fences work by decreasing the momentum of the upstream-traveling wall jet, causing an effectively higher freestream-to-jet velocity ratio V/V(sub j), and therefore, a ground vortex smaller in size and unsteadiness. At V/V(sub j) = 0.15, the addition of a single ground fence resulted in a 70% reduction in mean size of the ground vortex. With two ground fences, the mean size decreased by about 85%. Fluctuations in size decreased nearly in proportion to the mean size, for both the single and double fence configurations. These results were consistent over a wide range of jet Reynolds number (10(exp 4) less than Re(sub jet) less than 10(exp 5)); further development and full-scale Reynolds number testing are required, however, to determine if this technique can be made practical for the case of actual VTOL aircraft. Author (EI)

A94-61637
INLET DRAG PREDICTION FOR AIRCRAFT CONCEPTUAL DESIGN
PAUL MALAN Virginia Polytechnic Inst. and State Univ., Blacksburg, VA and EUGENE F. BROWN *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 616-622 refs
(BTN-94-EIX94401358981) Copyright

Recent efforts to upgrade the aircraft conceptual design code ACSYNT prompted a study of inlet drag prediction methods suited to conceptual design. Existing methods were expanded to enable the drag of four different inlet types (subsonic pitot, supersonic pitot, supersonic two-dimensional, and supersonic conical) to be predicted over the complete inlet operating range. These methods have been successfully incorporated into ACSYNT and are presented together with test cases representing a range of inlet geometries. Author (EI)

A94-61638
COMPUTATION OF THREE-DIMENSIONAL HYPERSONIC FLOWS IN CHEMICAL NONEQUILIBRIUM
S. MENNE Deutsche Aerospace A.G., Munich (Germany), C. WEILAND, and M. PFITZNER *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 623-630 refs
(BTN-94-EIX94401358982) Copyright

An algorithm for the simulation of three-dimensional hypersonic flows in chemical nonequilibrium is presented. The basic flow solver is based on a quasiconservative formulation of the Euler or Navier-Stokes equations. The Jacobi matrices are split according to the sign of their eigenvalues. The derivatives of the conservative variables are split accordingly. A third-order upwind space discretization is used in conjunction with an optimized three-stage Runge-Kutta explicit time stepping scheme. The chemistry source terms are treated point-implicitly. For inviscid flow, the code is applied to the complete HERMES 1.0 configuration. The influence of mesh resolution is studied by comparing a fine grid with a coarse grid solution. The coarse grid solution is usually sufficient to describe global flow phenomena. The analysis of local flow details requires refined meshes. For viscous flow, the flow about generic configurations (double-ellipse, hemisphere-cylinder-flare, hyperbola-flare) is investigated by performing grid sensitivity studies as well as by comparing different transport models.
Author (EI)

A94-61639* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NAVIER-STOKES COMPUTATIONS FOR OSCILLATING CONTROL SURFACES
SHIGERU OBAYASHI NASA. Ames Research Center, Moffett Field, CA and GURU P. GURUSWAMY *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 631-636 refs
(BTN-94-EIX94401358983) Copyright

Unsteady Navier-Stokes computations have been performed for simulating transonic flows over wings with oscillating control surfaces using a locally moving grid and a stationary-mismatched zoning scheme. An F-5 wing and a clipped delta wing are chosen for the present study. The computed unsteady pressures and the response characteristics to the control surface motions are compared with experimental data. The results successfully predict main features of the unsteady pressure profiles, such as the double peaks at the shock wave and at the hinge time.
Author (EI)

A94-61640
PREDICTION METHOD FOR UNSTEADY AXISYMMETRIC FLOW OVER PARACHUTES
J. H. STRICKLAND Sandia National Lab., Albuquerque, NM *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 637-643 refs
(BTN-94-EIX94401358984) Copyright

A method which is capable of solving the axisymmetric flowfield over bluff bodies consisting of thin shells such as disks, partial spheres, rings, and other such shapes is presented in this article. The body may be made up to several shells whose edges are separated by gaps. The body may be moved axially according to arbitrary velocity time histories. In addition, the surfaces may possess axial and radial degrees of flexibility such that points on the surfaces may be allowed to move relative to each other according to some specified function of time. The surfaces may be either porous or impervious. The present solution technique is based on the axisymmetric vorticity transport equation. This technique requires relatively large numbers of ring vortices (1000 or more) to obtain good simulations. Since the direct calculation of perturbations from large numbers of ring vortices is computationally intensive, a fast multipole method was used to greatly reduce computer processing time. Several example calculations are presented for disks, disks with holes, hemispheres, and vented hemispheres. These results are compared with steady and unsteady experimental data.
Author (EI)

A94-61642
TWO-DIMENSIONAL EULER ZONAL METHOD USING COMPOSITE STRUCTURED AND UNSTRUCTURED MESHES
H. HEFAZI California State Univ., Long Beach, CA, V. CHIN, and L. T. CHEN *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 651-658 refs
(BTN-94-EIX94401358986) Copyright

A two-dimensional zonal interactive scheme, based on Euler equations, has been developed for computing flows about complex geometries. A composite structured and unstructured grid, using conformal mapping and Delaunay triangulation, respectively, is first generated about the geometry. The finite-volume Euler method is then modified to couple zones with structured and unstructured grids. Solutions about multielement airfoils and iced airfoils are given as examples of the applications of the scheme. The zonal interaction scheme and accuracy and efficiency of the solutions are discussed.
Author (EI)

A94-61645
NUMERICAL INVESTIGATIONS ON TWO-DIMENSIONAL CANARD-WING AERODYNAMIC INTERFERENCE
SAN-YIH LIN Inst. of Aeronautics and Astronautics, Tainan (Taiwan, Province of China), YAN-SHIN CHIN, and YUH-YING WANG *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 672-679 refs
(BTN-94-EIX94401358989) Copyright

A finite element method for solving of the Euler and Navier-Stokes equations is used to study the unsteady aerodynamics of a two-dimensional canard-wing aerodynamic interference. The method used a discontinuous finite element method for spatial discretization and an explicit Runge-Kutta time integration for temporal discretization. The problems of a flow over an airfoil with/without viscosity, a flow over a pitching airfoil, and an airfoil-vortex interaction are tested to show the accuracy of the proposed numerical method. Finally, the results of two-dimensional canard-wing aerodynamic interference in steady and unsteady transonic flows are shown to demonstrate the robustness of the numerical algorithm and qualitative and quantitative aerodynamic influence of one airfoil on the other.
Author (EI)

A94-61646
DESIGN OF OPTIMIZED AIRFOILS IN SUBCRITICAL FLOW
J. OLEJNICZAK Minnesota Univ., Minneapolis, MN and A. S. LYRINTZIS *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 680-687 refs
(BTN-94-EIX94401358990) Copyright

An airfoil design method based on optimization procedures in computational aerodynamics is presented. This article extends the method to include subcritical compressible flow and a modified Stratford recovery distribution to alleviate the hard stall that is typical of Stratford-type airfoils. A procedure for optimizing the drag is also presented based on the Squire-Young drag formula. The performance characteristics of this airfoil are then tested with a compressible panel method and boundary-layer solver. The procedures for both incompressible and compressible flow have generated airfoils which generate more lift and less drag than other comparable airfoils. High-lift airfoils which display a smooth stall region have also been developed which hold promise for general aviation use. In addition, these airfoils offer the potential of improved performance in applications such as high-endurance aircraft, propellers, fans, and windmill blades where high lift-to-drag ratios are desired. A specific example of an airfoil designed for a wind turbine is presented and compared to an existing airfoil.
Author (EI)

A94-61647
LEADING-EDGE VORTEX BREAKDOWN FOR WING PLANFORMS WITH THE SAME SLENDERNESS RATIO
WILLIAM A. STRAKA George Washington Univ., Hampton, VA and MICHAEL J. HEMSCH *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 688-695 refs
(BTN-94-EIX94401358991) Copyright

A dye flow visualization investigation was conducted on two sets of wing planforms to better understand the effects of planform shaping on leading-edge vortex breakdown. The first set of planforms consisted of five cropped planforms, including a 66.3-deg delta, 80/55 double-delta, and three blended 80/55 double-deltas. The second set of planforms consisted of nine planforms of the same slenderness ratio, including a 69.3-deg delta, two gothics, three double-deltas, and three corresponding blended double-deltas. Results of these experiments have indicated that planforms with a common slenderness ratio develop quite similar characteristics for breakdown of the apex vortex at the trailing edge. It was found that planform shaping significantly alters the forward progression of breakdown along the wing as angle of attack is increased. The effect of increasing filleting to double-delta planforms was shown to degrade the apex vortex breakdown characteristics of the planforms. Also, it was found that by moving the kink location of the double-delta aft on the planform, breakdown characteristics are improved. Author (EI)

A94-61810
NEW AIRFOIL-DESIGN CONCEPT WITH IMPROVED AERODYNAMIC CHARACTERISTICS
DEMETER G. FERTIS Akron Univ., Akron, OH *Journal of Aerospace Engineering* (ISSN 0893-1321) vol. 7, no. 3 July 1994 p. 328-339 refs
(BTN-94-EIX94401372110) Copyright

The research in this paper is the result of an experimental study regarding a new airfoil-design concept, which is developed to produce greater lift coefficients over a much broader range of operational angles of attack, to improve or eliminate stall at virtually all operational airspeeds, to increase functional lift-to-drag ratios over a greater range of operational angles of attack, and to be adaptable for aircraft of both the fixed-wing and the rotary-wing types. The writer has combined his effort with L. L. Smith, and a U.S. Patent, entitled 'Airfoil,' Patent No. 4,606,519, was obtained on August 19, 1986. Patents were also obtained or are pending in other countries. The experimental results, obtained by using the new airfoil-design concept, have been compared with experimental results obtained from a conventional NACA 23012 airfoil. Flight performance tests by using a 2.134-m (7.0 ft) model and remote-control devices, as well as flow-separation studies, were also performed. The results were compared with the ones obtained by using the NACA 23012 airfoil. Author (EI)

N94-36261# Naval Surface Warfare Center, Bethesda, MD. Ship Systems Directorate.
TIPJET 80-INCH MODEL ROTOR HOVER TEST: TEST NO. 1198 Final Report, Jan. - Dec. 1991
ALAN W. SCHWARTZ Sep. 1993 97 p
(Contract PROJ. RR22-M59)
(AD-A279680; CDRKNSWC/SSD-93/54) Avail: CASI HC A05/MF A02

An experimental investigation was conducted to examine the aerodynamic properties of a Tipjet integrated pneumatic lift/reaction-drive rotor system in hover. For this rotor system, a single source of compressed air directly powers the rotor as a radial outflow turbine while simultaneously supplying the high velocity jet sheet that produces lift by means of circulation control (CC) along the blades. A sub scale model of such a fully pneumatic Tipjet rotor system was constructed and tested on the hover test facility at the David Taylor Model Basin. The model was tested to identify unique attributes of the integrated lift/drive system including mutual interference between tip nozzle flow and CC jet sheets and the impact of drawing CC supply air from a 'flowing plenum'. Test results are presented for the model is four configurations: CC rotor with tip nozzles closed, rotor locked with nozzles thrusting, tip drive CC rotor with controlled rpm, and tip-jet self drive equilibrium. The basic rotor lifting system, while exhibiting the highest augmentation ratio ever recorded for a CC rotor, suffers an induced power penalty due to the nonlifting region of the blade span where the tip nozzles are located. As expected, an internal pressure drop due to the flow rate in the blade duct was observed. There was no evidence of mutual interference effects between the lift and drive systems. Overall, the rotor exhibited a constant, linear response of lift versus pressure regardless of the slot height or the equilibrium tip speed. Author (revised)

N94-36394*# California Polytechnic State Univ., San Luis Obispo, CA. Dept. of Aeronautical Engineering.
NUMERICAL INVESTIGATION OF MULTI-ELEMENT AIRFOILS Final Technical Report
RUSSELL M. CUMMINGS Oct. 1993 14 p
(Contract NCC2-761)
(NASA-CR-194592; NAS 1.26:194592) Avail: CASI HC A03/MF A01

The flow over multi-element airfoils with flat-plate lift-enhancing tabs was numerically investigated. Tabs ranging in height from 0.25 percent to 1.25 percent of the reference airfoil chord were studied near the trailing edge of the main-element. This two-dimensional numerical simulation employed an incompressible Navier-Stokes solver on a structured, embedded grid topology. New grid refinements were used to improve the accuracy of the solution near the overlapping grid boundaries. The effects of various tabs were studied at a constant Reynolds number on a two-element airfoil with a slotted flap. Both computed and measured results indicated that a tab in the main-element cove improved the maximum lift and lift-to-drag ratio relative to the baseline airfoil without a tab. Computed streamlines revealed that the additional turning caused by the tab may reduce the amount of separated flow on the flap. A three-element airfoil was also studied over a range of Reynolds numbers. For the optimized flap rigging, the computed and measured Reynolds number effects were similar. When the flap was moved from the optimum position, numerical results indicated that a tab may help to reoptimize the airfoil to within 1 percent of the optimum flap case. Author

N94-36466# EMA, Mansfield, TX.
ROTORWASH ANALYSIS HANDBOOK. VOLUME 1: DEVELOPMENT AND ANALYSIS Final Report
SAMUEL W. FERGUSON Jun. 1994 336 p Prepared for Systems Control Technology, Inc., Arlington, VA
(Contract DTFA01-87-C-00014)
(SCT-93RR-17-VOL-1; DOT/FAA/RD-93-31-VOL-1) Avail: CASI HC A15/MF A03

Rotorcraft operations at heliports and airports are investigated to better understand and quantify the potential hazards associated with various types of rotorwash flow fields. Mathematical models for the various types are developed. These mathematical models are used in conjunction with hazard analysis models to develop an analysis methodology for evaluation of the potential for rotorwash-related mishaps in various operational scenarios. Correlation of all developed mathematical models with flight test, scale-model, and laboratory test data is provided wherever possible. Heliport design examples using the developed analysis methodology and the associated ROTWASH computer program are provided. Documentation, a program listing, and a user's guide are provided for version 2.1 of the FORTRAN 77-based ROTWASH computer program in report appendices (see Volume 2 of this report). An extensive bibliography of rotorwash related technical documents is also provided. Author (revised)

N94-36467# EMA, Mansfield, TX.
ROTORWASH ANALYSIS HANDBOOK. VOLUME 2: APPENDIXES Final Report
SAMUEL W. FERGUSON Jun. 1994 192 p Prepared for Systems Control Technology, Inc., Arlington, VA
(Contract DTFA01-87-C-00014)
(SCT-93RR-17-VOL-2; DOT/FAA/RD-93-31-VOL-2) Avail: CASI HC A09/MF A02

Documentation, a program listing, and a user's guide are provided for version 2.1 of the FORTRAN 77-based ROTWASH computer program in report appendices. An extensive bibliography of rotorwash related technical documents is also provided. This listing is subdivided into different rotorwash topics. A companion report, entitled 'Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight,' DOT/FAA/RD-90/16, evaluates rotorwash characteristics of 11 different types of tiltrotor and tiltwing aircraft for comparison purposes. Another companion report, entitled 'Analysis of Rotorwash Effects in Helicopter Mishaps,' DOT/FAA/RD-90/17, presents an analysis of several of the more common types of rotorwash related helicopter mishaps. Much of the information provided in this second companion report is updated by this report. A third report, DOT/FAA/RD-90/25, 'Rotorwash Computer Model - User's Guide,' is replaced by this more comprehensive report and its updated version of the ROTWASH computer program. Author

N94-36686*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

MIXING AND NOISE BENEFIT VERSUS THRUST PENALTY IN SUPERSONIC JETS USING IMPINGEMENT TONES

GANESH RAMAN (NYMA, Inc., Brook Park, OH.) and EDWARD J. RICE May 1994 17 p Proposed for presentation at the 30th Joint Propulsion Conference, Indianapolis, IN, 27-29 Jun.1994; sponsored by AIAA, ASME, SAE, and ASEE

(Contract NAS3-27186; RTOP 537-02-22)

(NASA-TM-106583; E-8844; NAS 1.15:106583; AIAA PAPER 94-2955) Avail: CASI HC A03/MF A01

This paper reports the results of an experimental investigation on the effect of impingement tones generated by obstacles of various geometries on the spreading of a supersonic jet flow. A rectangular supersonic jet was produced using a convergent-divergent nozzle that was operated near its design point (with shocks minimized). The immersion of obstacles in the flow produced an intense impingement tone which then propagated upstream (as feedback) to the jet lip and excited the antisymmetric hydrodynamic mode in the jet, thus setting up a resonant self-sustaining loop. The violent flapping motion of the jet due to excitation of the antisymmetric mode, combined with the unsteady wakes of the obstacles, produced large changes in jet mixing. It was possible to control the frequency and amplitude of the impingement tone excitation by varying the nozzle-to-obstacle distance and the obstacle immersion. By proper shaping of the obstacles it was possible to reduce the thrust penalty significantly. Author

N94-36687*# Eloret Corp., Palo Alto, CA.

EXPERIMENTAL INVESTIGATION OF NOZZLE/PLUME AERODYNAMICS AT HYPERSONIC SPEEDS Final Technical Report, 1 Aug. 1987 - 31 Jan. 1994

DAVID W. BOGDANOFF, JEAN-LUC CAMBIER, and PERIKLES PAPADOPOULOS 29 Apr. 1994 15 p

(Contract NCC2-487)

(NASA-CR-195829; NAS 1.26:195829) Avail: CASI HC A03/MF A01

Much of the work involved the Ames 16-Inch Shock Tunnel facility. The facility was reactivated and upgraded, a data acquisition system was configured and upgraded several times, several facility calibrations were performed and test entries with a wedge model with hydrogen injection and a full scramjet combustor model, with hydrogen injection, were performed. Extensive CFD modeling of the flow in the facility was done. This includes modeling of the unsteady flow in the driver and driven tubes and steady flow modeling of the nozzle flow. Other modeling efforts include simulations of non-equilibrium flows and turbulence, plasmas, light gas guns and the use of non-ideal gas equations of state. New experimental techniques to improve the performance of gas guns, shock tubes and tunnels and scramjet combustors were conceived and studied computationally. Ways to improve scramjet engine performance using steady and pulsed detonation waves were also studied computationally. A number of studies were performed on the operation of the ram accelerator, including investigations of in-tube gasdynamic heating and the use of high explosives to raise the velocity capability of the device. Author (revised)

N94-36729# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

AN AERODYNAMIC AND STATIC-STABILITY ANALYSIS OF THE HYPERSONIC APPLIED RESEARCH TECHNOLOGY (HART) MISSILE Ph.D. Thesis

KENNETH J. MORAN Apr. 1994 124 p

(AD-A280631; AFIT/DS/AA/94-3) Avail: CASI HC A06/MF A02

The flow about the complete Hypersonic Applied Research Technology (HART) missile is simulated for inviscid, laminar, and turbulent conditions and Mach numbers from 2 to 6. An explicit, second-order-accurate, flux-difference-splitting, algorithm is implemented and employed to solve the Navier-Stokes equations. The equations are solved using a finite volume methodology. The aerodynamic and static-stability characteristics are investigated to determine if conventional supersonic missile configurations can be flown at Mach numbers higher than 5. The effects of nosetip blunting and boundary-layer condition are demonstrated. The structure of the flow near the fins is significantly affected by the turbulent transport of momentum in regions of blocked cross flow. Turbulence and the blockage phenomenon cause bleeding around the fin leading edges. Ultimately, this results in lower fin effectiveness and reduced static stability. The aerodynamic characteristics of the HART missile are predicted at Mach numbers beyond the experimental free-flight testing capabilities. The current predictions indicated that the pitching-moment coefficient decreases with increasing Mach number much less than previous numerical computations. The present results also suggest that the clipped-delta-fin configuration is stable beyond Mach 7. DTIC

N94-36942*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AUTOMATIC PROCEDURES FOR COMPUTING COMPLETE CONFIGURATION GEOMETRY FROM INDIVIDUAL COMPONENT DESCRIPTIONS

RAYMOND L. BARGER and MARY S. ADAMS Jul. 1994 14 p

(Contract RTOP 509-10-11-01)

(NASA-TM-4607; L-17395; NAS 1.15:4607) Avail: CASI HC A03/MF A01

Procedures are derived for developing a complete airplane surface geometry starting from component descriptions. The procedures involve locating the intersection lines of adjacent components and omitting any regions for which part of one surface lies within the other. The geometry files utilize the wave-drag (Harris) format, and output files are written in Hess format. Two algorithms are used: one, if both intersecting surfaces have airfoil cross sections; the other, if one of the surfaces has circular cross sections. Some sample results in graphical form are included. Author

N94-36944*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Center, Edwards, CA.

CONTROLLING FOREBODY ASYMMETRIES IN FLIGHT: EXPERIENCE WITH BOUNDARY LAYER TRANSITION STRIPS

DAVID F. FISHER and BRENT R. COBLEIGH Washington Jul. 1994 22 p Presented at the 6th Biennial Flight Test Conference, Colorado Springs, CO, 20-23 Jun. 1994

(Contract RTOP 505-68-71)

(NASA-TM-4595; H-1992; NAS 1.15:4595; AIAA PAPER 94-1826) Copyright Avail: CASI HC A01/MF A01

The NASA Dryden Flight Research Center has an ongoing program to investigate aircraft flight characteristics at high angles of attack. As part of this investigation, longitudinal boundary layer transition strips were installed on the F-18 HARV forebody, a preproduction F/A-18 radome with a nose-slice tendency, and the X-31 aircraft forebody and noseboom to reduce asymmetric yawing moments at high angles of attack. The transition strips were effective on the F-18 HARV at angles of attack above 60 deg. On the preproduction F/A-18 radome at an angle of attack near 50 deg the strips were not effective. When the transition strips were installed on the X-31 noseboom, a favorable effect was observed on the yawing moment dynamics but the magnitude of the yawing moment was not decreased. Author

N94-36950*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AUTOMATIC COMPUTATION OF EULER-MARCHING AND SUBSONIC GRIDS FOR WING-FUSELAGE CONFIGURATIONS

RAYMOND L. BARGER, MARY S. ADAMS, and RAMKI R. KRISHNAN Jul. 1994 20 p

(Contract RTOP 509-10-11-01)

(NASA-TM-4573; L-17364; NAS 1.15:4573) Avail: CASI HC A03/

MF A01

Algebraic procedures are described for the automatic generation of structured, single-block flow computation grids for relatively simple configurations (wing, fuselage, and fin). For supersonic flows, a quasi two-dimensional grid for Euler-marching codes is developed, and some sample results in graphical form are included. A type of grid for subsonic flow calculation is also described. The techniques are algebraic and are based on a generalization of the method of transfinite interpolation. Author

N94-36966*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

NAVIER-STOKES AND POTENTIAL THEORY SOLUTIONS FOR AHELICOPTER FUSELAGE AND COMPARISON WITH EXPERIMENT

MARK S. CHAFFIN (Vigyan Research Associates, Inc., Hampton, VA.) and JOHN D. BERRY (Army Aviation Systems Command, Hampton, VA.) Jun. 1994 31 p Prepared in cooperation with Army Aviation Systems Command, Hampton, VA
(Contract NAS1-19672; RTOP 505-59-36-01; RTOP 023-10-01-01)
(NASA-TM-4566; L-17325; NAS 1.15:4566; ATCOM-TR-94-A-013) Avail: CASI HC A03/MF A01

A thin-layer Navier-Stokes code and a panel method code are used to predict the flow over a generic helicopter fuselage. The computational results are compared with pressure data at four experimental conditions. Both methods produce results that agree with the experimental pressure data. However, separation patterns and other viscous flow features from the Navier-Stokes code solution are shown that cannot be easily modeled with the panel method. Author

N94-37219 *Michigan State Univ., East Lansing, MI.* Dept. of Mechanical Engineering.

UNSTEADY FLOW FIELD OF LARGE-AMPLITUDE PITCHING AIRFOILS Final Technical Report, Jul. 1992 - Nov. 1993

MANOOCHEHR M. KOOCHESFAHANI 1 Feb. 1994 33 p
Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(Contract AF-AFOSR-0417-89)
(AD-A280444; AFOSR-94-0355TR) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

This research program investigated the physical mechanisms involved in the onset of leading edge separation when airfoils pitch to high angles of attack. Both constant pitch rate and variable pitch rate motions were considered. The highlights of results from a combined experimental and computational effort are described in this report. The conclusions from this research indicate the need for boundary-layer resolved measurements of the flow behavior near the leading edge and the evolution of the reverse flow regions on the suction surface. Furthermore, the deliberate shaping of the pitch trajectory for the purpose of optimization of separation delay is suggested as one way to manage the flow and aerodynamic behavior of an airfoil. DTIC

N94-37283*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A METHOD FOR FLOW SIMULATION ABOUT COMPLEX GEOMETRIES USING BOTH STRUCTURED AND UNSTRUCTURED GRIDS

JAMES R. DEBONIS Jul. 1994 60 p
(Contract RTOP 537-02-23)
(NASA-TM-106633; E-8955; NAS 1.15:106633) Avail: CASI HC A04/MF A01

A computational fluid dynamics code which utilizes both structured and unstructured grids was developed. The objective of this study was to develop and demonstrate the ability of such a code to achieve solutions about complex geometries in two dimensions. An unstructured grid generator and flow solver were incorporated into the PARC2D structured flow solver. This new unstructured grid generator capability allows for easier generation and manipulation of complex grids. Several examples of the grid generation capabilities are provided. The coupling of different grid topologies and the manipulation of individual grids is shown. Also, grids for realistic geometries, a NACA 0012 airfoil and a wing/nacelle installation, were created. The flow over a NACA 0012 airfoil was used as a test case for the flow solver. Eight separate cases were run. They were both the inviscid and viscous solutions for two freestream Mach numbers and airfoil angle of attacks of 0 to 3.86 degrees. The Mach numbers chosen were for a subsonic case, Mach 0.6, and a case where supersonic regions and a shock wave exists, Mach 0.8. These test case conditions were selected to match experimentally obtained data for code comparison. The results show that the code accurately predicts the flow field for all cases. Author

N94-37378*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Center, Edwards, CA.

MEASUREMENT UNCERTAINTY AND FEASIBILITY STUDY OF A FLUSH AIRDATA SYSTEM FOR A HYPERSONIC FLIGHT EXPERIMENT

STEPHEN A. WHITMORE and TIMOTHY R. MOES Washington Jun. 1994 18 p Presented at the Applied Aerodynamics Conference, Colorado Springs, CO, 20-23 Jun. 1994
(Contract RTOP 505-68-40)
(NASA-TM-4627; H-2010; NAS 1.15:4627; AIAA PAPER 94-1930) Copyright Avail: CASI HC A03/MF A01

Presented is a feasibility and error analysis for a hypersonic flush airdata system on a hypersonic flight experiment (HYFLITE). HYFLITE heating loads make intrusive airdata measurement impractical. Although this analysis is specifically for the HYFLITE vehicle and trajectory, the problems analyzed are generally applicable to hypersonic vehicles. A layout of the flush-port matrix is shown. Surface pressures are related airdata parameters using a simple aerodynamic model. The model is linearized using small perturbations and inverted using nonlinear least-squares. Effects of various error sources on the overall uncertainty are evaluated using an error simulation. Error sources modeled include boundarylayer/viscous interactions, pneumatic lag, thermal transpiration in the sensor pressure tubing, misalignment in the matrix layout, thermal warping of the vehicle nose, sampling resolution, and transducer error. Using simulated pressure data for input to the estimation algorithm, effects caused by various error sources are analyzed by comparing estimator outputs with the original trajectory. To obtain ensemble averages the simulation is run repeatedly and output statistics are compiled. Output errors resulting from the various error sources are presented as a function of Mach number. Final uncertainties with all modeled error sources included are presented as a function of Mach number. Author

03
AIR TRANSPORTATION AND SAFETY

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

A94-61787

MACH 2 AND MORE

RICHARD PIELLISCH *Aerospace America* (ISSN 0740-722X) vol. 32, no. 1 January 1994 p. 17-19 refs
(BTN-94-EIX94401216108) Copyright

Advanced materials will be the key to a viable High Speed Civil Transport, but profitability is still the major concern for manufacturers and airlines. The author discusses the technological challenges of an aircraft that will carry three times as many passengers as the Concorde at considerably higher speeds, with over 50% more range and a fraction of the older aircraft's emissions. EI

N94-36530 Boeing Commercial Airplane Co., Seattle, WA.

WORLD JET AIRPLANE INVENTORY AT YEAR-END 1993

Mar. 1994 127 p See also PB93-174324
(PB94-164993) Avail: Issuing Activity (National Technical Information Service (NTIS))

The Marketing Department of Boeing Commercial Airplane Group

publishes the World Jet Airplane Inventory. The document contains data on the world commercial jet airplane fleet (including some military derivatives) and reflects the status of this fleet as accurately as possible as of December 31, 1993. (Any fleet changes that have occurred since year-end 1993 will not be reflected in these data). World Jet Airplane Inventory is composed of a selected number of reports from JETTRACK, a computer-based jet airplane inventory systems. Fleet data in this system are obtained from many different sources, including airframe manufacturers, airplane owners and operators, governments, and trade publications. The document provides details for announced orders, deliveries, and inventories for all commercial jet airplanes built in the United States and Western Europe with a capacity of 60 seats or more. In addition, the year-end 1993 inventory data in Sections 5 and 7 include operators of the Soviet built Tupolev TU-134, TU-154, TU-204, Ilyushin IL-62 IL-86, IL-96 and Yakovlev Yak-42 airplanes.
NTIS

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

A94-61682
CAPTURE REGION FOR TRUE PROPORTIONAL NAVIGATION GUIDANCE WITH NONZERO MISS-DISTANCE
DEBASHISH GHOSE Indian Inst. of Science, Bangalore, India *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 627-628 refs
(BTN-94-EIX94401358176) Copyright

In this note, an analytical solution to the problem of job training the capture region of a missile pursuing a nomaneuvering target the using a TPN guidance law, with acceptable nonzero miss-distance, is presented. It is shown that the capture region is enlarged, and deviates from its circular shape, in comparison with the zero miss-distance case. In contrast to previous results, the capture region is obtained without solving the equations of motion in closed form. EI

A94-61769
ON THE GENERALIZATION OF TRUE PROPORTIONAL NAVIGATION
D. GHOSE Indian Inst. of Science, Bangalore (India) *IEEE Transactions on Aerospace and Electronic Syst ems* (ISSN 0018-9251) vol. 30, no. 2 April 1994 p. 545-555 refs
(BTN-94-EIX94401377808) Copyright

A simple framework to define generalized true proportional navigation (GTPN) guidance laws is presented. It is shown that this framework subsumes many of the generalizations presented in the earlier literature. The capture regions of a number of GTPN guidance laws are obtained through a rigorous qualitative analysis. The method of analysis is simpler and lends itself directly to an easy geometrical interpretation. A considerable amount of misinterpretation in the previous results, arising out of certain basic misconceptions, are corrected here. It is shown that a logical application of the guidance philosophy, through a minor modification of GTPN to take into account the direction of rotation of the line-of-sight (LOS), contributes substantially to the expansion of the capture region in the relative velocity space. EI

N94-37013*# Boston Univ., MA.
AN ERROR-RESISTANT LINGUISTIC PROTOCOL FOR AIR TRAFFIC CONTROL Final Report, Jan. - Sep. 1989
STEVEN CUSHING 1989 48 p Prepared in cooperation with Stonehill Coll., North Easton, MA
(Contract NAG2-564)
(NASA-CR-196098; NAS 1.26:196098) Avail: CASI HC A03/MF A01

The research results described here are intended to enhance the effectiveness of the DATALINK interface that is scheduled by the Federal Aviation Administration (FAA) to be deployed during the 1990's to improve the safety of various aspects of aviation. While voice has a natural appeal as the preferred means of communication both among humans themselves and between humans and machines as the form of communication that people find most convenient, the complexity and flexibility of natural language are problematic, because of the confusions and misunderstandings that can arise as a result of ambiguity, unclear reference, intonation peculiarities, implicit inference, and presupposition. The DATALINK interface will avoid many of these problems by replacing voice with vision and speech with written instructions. This report describes results achieved to date on an on-going research effort to refine the protocol of the DATALINK system so as to avoid many of the linguistic problems that still remain in the visual mode. In particular, a working prototype DATALINK simulator system has been developed consisting of an unambiguous, context-free grammar and parser, based on the current air-traffic-control language and incorporated into a visual display involving simulated touch-screen buttons and three levels of menu screens. The system is written in the C programming language and runs on the Macintosh II computer. After reviewing work already done on the project, new tasks for further development are described. Author

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A94-61266
SOME BASIC CONSIDERATIONS ON ANGLES DESCRIBING AIRPLANE FLIGHT MANEUVERS
OSAMU KATO Nagoya Univ., Nagoya (Japan) *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 378-384 refs
(BTN-94-EIX94381311179) Copyright

Several angles to describe the flight maneuvers of an airplane are introduced. First, relative Euler angles, which show one flight attitude relative to another flight attitude, are defined. Next, rolling angle, pitching angle, and yawing angle, which are other than Euler angles, are defined. In addition, nose moving angle is defined as a quantity that shows the length of the attitude path along which the flight attitude changes. Comparative studies between similar angles in the small-disturbance theory are made in large flight maneuvers. A formula which relates the rolling angle to the variation of roll angle is obtained by means of the attitude projection method and Stokes theorem. It is shown that although the differences between the relative roll angle, rolling angle, and variation of roll angle are sufficiently small in small-disturbance flight mechanics, those differences become considerably larger in large flight maneuvers. Numerical examples are presented to illustrate these results. Author (EI)

A94-61267
SOME NONINTUITIVE FEATURES IN TIME-EFFICIENT ATTITUDE MANEUVERS OF COMBAT AIRCRAFT
SPIRO BOCVAROV Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, EUGENE M. CLIFF, and FREDERICK H. LUTZE *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 385-388 refs
(BTN-94-EIX94381311180) Copyright

In some cases, numerical extremal trajectories for time-optimal attitude maneuvers for combat aircraft exhibit a nonintuitive feature in which the extremal roll-control causes the vehicle to initially roll the 'wrong way.' Using data for the high angle-of-attack research vehicle, we present a brief exposition and engineering explanation of this and related phenomena. The explanations are based on analyses of the structure of the aircraft mathematical model. Author (EI)

A94-61268
RANGE OPTIMAL TRAJECTORIES FOR AN AIRCRAFT FLYING IN THE VERTICAL PLANE
HANS SEYWALD Analytical Mechanics Associates, Inc., Hampton, VA, EUGENE M. CLIFF, and KLAUS H. WELL *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 389-398 refs
(BTN-94-EIX94381311181) Copyright

Range optimal trajectories for an aircraft flying in the vertical plane are obtained from Pontryagin's minimum principle. Control variables are the load factor, which appears nonlinearly in the equations of motion, and the throttle setting, which appears only linearly. Both controls are subject to fixed bounds. Additionally, a dynamic pressure limit is imposed, which represents a first-order state-inequality constraint. For fixed flight time, initial coordinates, and final coordinates of the trajectory, the effect of the load factor limit on the resulting optimal switching structure is studied. All trajectories involve singular control along arcs with active dynamic pressure limit. For large flight times the optimal switching structures have not yet been found. Author (EI)

A94-61616
SURVEY AND COMPARISON OF ENGINEERING BEAM THEORIES FOR HELICOPTER ROTOR BLADES
DONALD L. KUNZ McDonnell Douglas Helicopter Co, Mesa, AZ *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 473-479 refs
(BTN-94-EIX94401358960) Copyright

The article presents a review of the development of engineering beam theories for helicopter rotor blades, and history of the development from past to present solutions and the characteristics and differences among these various formulations is also explained. This survey of the state of the art in rotating beam analysis provides practicing engineers with an overview of methodologies from which they can choose for applications. EI

A94-61619
LOADING CHARACTERISTICS OF FINITE WINGS UNDERGOING RAPID UNSTEADY MOTIONS: A THEORETICAL TREATMENT
ERIC J. JUMPER Univ. of Notre Dame, Notre Dame, IN and RONALD J. HUGO *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 495-502 refs
(BTN-94-EIX94401358963) Copyright

This article describes an unsteady, incompressible, lifting-line method for determining spanwise loading and moments on a wing undergoing arbitrary dynamic motions. The method is compared to an unsteady vortex-lattice method and a constant-source, constant-doublet paneling method and appears to predict span loading as well as these methods. The method is also compared to experimental data for an aspect-ratio-four wing undergoing a near-constant pitch-rate motion. Author (EI)

A94-61622
UNIQUE HIGH-ALPHA ROLL DYNAMICS OF A SHARP-EDGED 65 DEG DELTA WING
L. E. ERICSSON Lockheed Missiles and Space Co., Inc, Sunnyvale, CA and E. S. HANFF *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 520-525 refs
(BTN-94-EIX94401358966) Copyright

An analysis has been performed of experimental results obtained in roll oscillation tests at 30-deg angle of attack of a 65-deg sharp-edged delta wing in order to uncover the fluid mechanical phenomena causing the unusual, highly nonlinear .vehicle dynamics. In addition to the expected effect of convective flow time lag, the test results show highly nonlinear effects of the angular rate, which themselves are influenced by the effect of convective time lag. A flow hypothesis is presented that can explain the unusual experimental results. Author (EI)

A94-61625
HUNTING PHENOMENA OF THE BALLOON MOTIONS OBSERVED OVER ANTARCTICA
JUN NISHIMURA Kanagawa Univ., Yokohama (Japan) *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 538-541 refs
(BTN-94-EIX94401358969) Copyright

It was reported that the strong hunting motions of the balloons were observed just after reaching the ceiling altitude for the balloons launched at Antarctica in the daytime. Such hunting motions are observed at middle latitude only for the nighttime launching. In this article, the thermal analysis of the balloon motions is performed by considering the atmospheric temperature and the environmental radiation conditions at the balloon altitudes. We found that the hunting phenomena over summer Antarctica are caused by the fact that the balloons over Antarctica encounter similar thermal conditions of flights at night over the midlatitude. Author (EI)

A94-61627
SIGNIFICANCE OF THE DIHEDRAL EFFECT IN RAPID FUSELAGE-REORIENTATION MANEUVERS
SPIRO BOCVAROV Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, EUGENE M. CLIFF, and FREDERICK H. LUTZE *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 548-555 refs
(BTN-94-EIX94401358971) Copyright

A study is presented about the role the dihedral effect (rolling moment due to sideslip) can have in fuselage-reorientation maneuvers that involve high angles of attack. A mathematical model for attitude maneuvers is developed, which accurately represents the High Angle-of-Attack Research Vehicle, including propulsive moments generated by thrust-vectoring. The fuselage-reorientation problem is posed as an unconstrained time-optimal control problem, and numerical extrenal trajectories are obtained. These trajectories are examined in order to determine if and when the dihedral effect contributes significantly to the maneuvers. Results indicate that for most reorientation maneuvers the dihedral effect is small, and that these minimum-time trajectories occur with small sideslip angles. Author (EI)

A94-61632
WIND-TUNNEL TEST TECHNIQUES FOR UNMANNED AERIAL VEHICLE SEPARATION INVESTIGATIONS
S. A. MOYER Naval Air Warfare Center, Warminster, PA and M. D. TALBOT *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 585-590 refs
(BTN-94-EIX94401358976) Copyright

Wind-tunnel tests of an unmanned aerial vehicle (UAV) separating from two fighter aircraft have been conducted. UAVs present different concerns in separation testing than do conventional stores due to the presence of large lifting surfaces, physical size, and control surface effects. The planning and results of these recent investigations give several new results with respect to the separation testing of complex configurations. Separation trajectory simulations using experimental data have been used to demonstrate the unique requirements of UAV separation testing. The simulation demonstrates that simplifications in the aerodynamic grid proximity testing matrix can be made without sacrificing simulation accuracy. Results indicate that simplification in ejector modeling used with simple stores should not be applied to UAVs. The simulations also indicated that it is important to properly model the aircraft control surface effects on the UAV. Autho(EI)

A94-61643
ACTIVE CONTROL OF WING ROCK USING TANGENTIAL LEADING-EDGE BLOWING
G. S. WONG Stanford Univ., Stanford, CA, S. M. ROCK, N. J. WOOD, and L. ROBERTS *Journal of Aircraft* (ISSN 0021-8669)

vol. 31, no. 3 May-June 1994 p. 659-665 refs
(BTN-94-EIX94401358987) Copyright

Experiments were performed to demonstrate positive poststall roll control of a free-to-roll wind-tunnel delta wing model using tangential leading-edge blowing. Previous static experiments had shown that significant rolling moments could be produced up to an angle of attack of 55 deg using asymmetric tangential leading-edge blowing. The implication was that poststall dynamic roll control ought to be possible using only blowing. To demonstrate experimentally that this was indeed the case, a free-to-roll wind-tunnel model sting mounting system and a pair of fast acting blowing control servo-valves were developed and manufactured. An automatic feedback roll control algorithm using tangential leading-edge blowing was then synthesized and implemented on a digital controller. Results from the present dynamic experiments indicated that with just symmetric blowing alone, wing rock at an angle of attack of 55 deg was damped. Furthermore, with the use of an automatic roll feedback control algorithm employing asymmetric blowing, the same wing rock was stopped in less than one cycle of the limit-cycle oscillation. Author (EI)

A94-61649
COMPREHENSIVE MODEL OF ANISOTROPIC COMPOSITE AIRCRAFT WINGS SUITABLE FOR AEROELASTIC ANALYSES
G. KARPOUZIAN Naval Academy, Annapolis, MD and L. LIBRESCU *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 703-712 refs
(BTN-94-EIX94401358993) Copyright

A comprehensive plate-beam structural model suitable for aeroelastic analyses of aircraft wings made of anisotropic composite materials is developed. The equations governing the static and dynamic aeroelastic equilibrium of cantilevered swept-wing structures and the associated boundary conditions are derived by means of the Hamilton variational principle. These equations incorporate a number of effects: 1) anisotropy of the materials of constituent layers, 2) warping inhibition, 3) transverse shear flexibility, and 4) rotatory inertias. A uniform swept-wing model composed of a transversely isotropic material is considered to illustrate the coupled and separate effects of transverse shear deformation and warping restraint upon its divergence and static aeroelastic load distribution. An exact method based upon the Laplace integral transform technique is used to solve the above mentioned problems. The results displayed in this article reveal the importance of transverse shear and warping restraint effects in predicting more accurately the static aeroelastic response of swept-forward wings. However, for swept-back wings, these effects represent higher-order corrections to the classical theory. Author (EI)

A94-61674
NONDIMENSIONAL FORMS FOR SINGULAR PERTURBATION ANALYSES OF AIRCRAFT ENERGY CLIMBS
A. J. CALISE Georgia Inst. of Technology, Atlanta, GA and N. MARKOPOULOS *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 584-590 refs
(BTN-94-EIX94401358168) Copyright

This paper presents a systematic approach for identifying the perturbation parameter in singular perturbation analysis of aircraft optimal trajectories and guidance. The approach is based on a nondimensionalization of the equations of motion. It is used to evaluate the appropriateness of forced singular perturbation formulations used in the past for transport and fighter aircraft. It is also used to assess the applicability of energy state approximations and singular perturbation analysis for airbreathing transatmospheric vehicles with hypersonic cruise and orbital capabilities. In particular, the family of problems related to aircraft energy climbs is considered. For energy climbs constrained to a vertical plane, it is shown that the singular perturbation parameter can logically be taken as the maximum allowable longitudinal load factor of vehicle. Two-time-scale behavior is suggested when this load factor is sufficiently less than one. Author (EI)

A94-61675
ANALYSIS AND CONTROL OF BIFURCATION PHENOMENA IN AIRCRAFT FLIGHT
MARK A. PINSKY Nevada Univ., Reno, NV and BILL ESAY *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 591-598 refs
(BTN-94-EIX94401358169) Copyright

This paper addresses a theoretical framework for unified methodology which allows analysis of nonlinear stability and efficient control of high-dimensional nonlinear plants modeling aircraft flight. It is shown that analysis of nonlinear transition phenomena (bifurcations) is central to revealing the limitation of robust control (i.e., an accurate estimate of the basin of stability). Omitting transition behavior causes over control and provides a very local stabilization. Analysis and control of bifurcations of aircraft flight are given in the spirit of the generalized normal forms method, which provides one with the nonreducible system that preserves stability characteristics of the initial plant. Stabilization of a plant's bifurcations is then given in terms of the resonance control methodology. Efficiency of the developed methodology is demonstrated by analyzing and controlling an unstable nonlinear plant relevant to the lateral dynamics of an aircraft. Whereas the initial plant is governed by a number of coupled nonlinear equations, the reduced system (the resonance normal form) turns out to be much easier to analyze and even integrable in many cases. Analysis of bifurcations of the resonance normal forms may shape efficient control actions which a pilot may undertake to ensure stability of an aircraft in a prescribed neighborhood of a trim condition and also can furnish a design of a flight's automatic control. Author (EI)

N94-36321# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
RECENT ADVANCES IN LONG RANGE AND LONG ENDURANCE OPERATION OF AIRCRAFT [LES PROGRES RECENTS DANS LE DOMAINE DES OPERATIONS AERIENNES A LONGUE DISTANCE ET DE LONGUE DUREE]
Nov. 1993 317 p In ENGLISH and FRENCH Symposium held in The Hague, Netherlands, 24-27 May 1993
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Over the past few years, the use of aircraft in long range and/or long endurance operations has proved to be a successful use of military resources. Technologies which improve the range and endurance of aircraft have seen considerable advances over the past ten years. Aircraft design for these features has matured considerably while the procedure of air-to-air refuelling has made global deployment and 24+ hour operations a reality. This Symposium attempted to summarize the latest technological advances in the various fields which in a combined manner define the range and endurance of airborne vehicles, i.e.: airframe design technologies, including aerodynamic structures; propulsion technology; the human factors problems associated with these types of missions; and air-to-air refuelling technologies and procedures.

N94-36322# Wright Lab., Wright-Patterson AFB, OH.
HIGH ALTITUDE LONG ENDURANCE AIRCRAFT DESIGN STUDIES
V. B. VENKAYYA and V. A. TISCHLER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 17 p Nov. 1993
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This paper presents the results of structural optimization studies made on a High Altitude Long Endurance (HALE) aircraft at Wright Research and Development Center (now Wright Laboratory) during the late eighties. The purpose of this study is to investigate the feasibility of developing an ultralightweight airframe that can operate at high altitudes for extended periods of time in order to provide continuous reconnaissance, surveillance, communications and targeting functions. A variety of structural concepts and material studies were made prior to settling on a twin boom very high aspect ratio wing airframe. The wing and fuselage structures are made of truss substructures covered with skins, both made of high strength, high modulus, lightweight composite materials. Extensive structural optimization studies were conducted in order to obtain a lightweight structure. The large size of the aircraft drove the design to a stiffness critical structure. Author

N94-36323# Alenia Aeronautica, Turin (Italy). Preliminary Design Dept.

TECHNOLOGICAL CHALLENGES OF HIGH ALTITUDE LONG ENDURANCE UNMANNED CONFIGURATIONS

R. BARGETTO and R. SPEZZAFERRO *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p Nov. 1993

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This paper presents the conceptual work performed in Alenia during the recent years for defining some possible configurations for military and civil HALE (High Altitude Long Endurance) aircraft capable of carrying very different kinds of payloads and with mission durations ranging from one to two days. Also in relation to the aircrew fatigue implied by such a long flight time, they all have been conceived as UMA (UnManned Aircraft), achieving in that way a significant reduction of mass and complexity, withstanding the maturity of automatic control system. The aeromechanical aspect of the configurations (i.e., aerodynamics, propulsion, structures, systems, weights and performances) will be discussed in detail considering that HALE-UMA type of aircraft have to face some technical challenges in many fields generated by the rather demanding requirements in terms of payload and endurance. Author

N94-36324# Aerospatiale, Toulouse (France). Aircraft Div.

FUTURE SUPERSONIC COMMERCIAL TRANSPORT AIRCRAFT: A TECHNOLOGICAL CHALLENGE FOR LONG HAUL TRAFFIC [AVION DE TRANSPORT SUPERSONIQUE FUTUR: UN DEFI TECHNOLOGIQUE POUR LE VOL LONG COURRIER]

J.-L. GALVANI *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 8 p Nov. 1993 In FRENCH

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Long haul traffic is a key sector that is constantly increasing. Since Concorde entry into service in 1976, it has tripled and will again double by the end of the century. There is no doubt that this long haul traffic development will create an increasing interest in high speed. The entry into service of a HSCT will enable flight time to be divided at least by 2 on these long routes, and could capture 20 percent to 40 percent of the long range market. To face up this future air transport landscape Aerospatiale, who jointly with British Aerospace has accumulated an unique experience in high speed transport with the Concorde program, is studying a potential successor: the Alliance project cruising at Mach 2. Due to the significant progress in technology already achieved or foreseen in the near future, the entry into service of a second generation supersonic transport can be envisaged as early as 2005. The success of this project is strongly linked to the capability of the aircraft and the engine manufacturers to provide the appropriate technology level to make the airplane environmentally acceptable and economically attractive. A significant effort in R & D is necessary to make available the challenging technologies: new materials, aerodynamics, propulsion.... Considering the level of investment required and the complexity of the problems to be solved, a close collaboration involving industrial partners is necessary on a world wide basis. This collaboration has already started. Following a long experience of bilateral cooperation, Aerospatiale and British Aerospace joined again in 1990 to study together a second generation supersonic aircraft around their respective concepts (AST and Alliance). Both partners are also cooperating with DASA, Boeing, McDonnell Douglas, the Japanese Industries, Alenia and Tupolev within an International Study Group. Author

N94-36325# Naval Air Warfare Center, Warminster, PA. Aircraft Div.

THE CASE FOR SURFACE EFFECT RESEARCH, PLATFORM APPLICATIONS AND TECHNOLOGY DEVELOPMENT OPPORTUNITIES

J. M. L. REEVES *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 10 p Nov. 1993

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This paper commences by defining the conventional understanding of Surface Effect phenomenon and compares theories which show small reductions in drag occur above one span height above the surface. A discussion on reports of pilots who have flown their aircraft in surface effect ensues. From this, a broader understanding of surface effect is developed supported by low speed wind tunnel tests and Russian published technical documentation. The author divides surface effect platforms or, perhaps, better described as Enhanced Performance Low Flying Platforms (EPLFP's) into three distinct categories. Potential applications of surface effect platforms are discussed based on the changing world, the evolving airline industry and airport constraints. Missions and specific mission examples are given. Reasons for the pursuit of rather large platforms are presented as are some of the major technical hurdles which will have to be overcome for them to succeed. Technology opportunities are discussed. A summary concludes the paper. Author

N94-36326# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

THE FUTURE OF LARGE CAPACITY/LONG RANGE MULTIPURPOSE AIR CARGO FLEETS [L'AVENIR D'AVIONS CARGOS MULTI-ROLES A LARGE CAPACITE ET GRAND RAYON D'ACTION]

PHILIPPE POISSON-QUINTON *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 8 p Nov. 1993 In FRENCH

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Both commercial and military aspects of Cargo Transport Aviation were discussed at the International Symposium organized by the French Aerospace Academy, held in March 1993 in Strasbourg. This paper summarizes some of the contributions and discussions dealing with the future role of the Air Cargo Transportation in relation to a global international policy of military and humanitarian intervention, including their technical and operational aspects. In a first part, the status of the World's Air Cargo activity is reviewed in terms of the main operational cargo airplanes, their capacity and their range, used both for commercial and military purposes; it includes the family of large cargos developed by Antonov in Ukraine and preliminary designs of huge cargo projects by the Russian laboratory TsAGI for 250 to 500 tons payload, and by NASA with spanloader or conventional schemes for intermodal containers transport. In a second part, the present U.S. Military Airlift forces are analyzed, with some comments on their recent global airlift deployment during the Gulf War. It is concluded that, as regards long term global policy, such existing task forces are totally inadequate to either stop immediately some local conflicts around the world, or to save population, in case of major natural or man-made disasters. That is why a much larger airlift system should be developed on an intergovernmental basis, the main objective would be its 'strategic efficiency' instead of a 'profit earning capacity', as used in commercial aviation. For that purpose, a 'supercargo' can be defined, developed and produced in the framework of an international consensus between the major aeronautical powers. Its size, configuration, operational characteristics and performance must be discussed, and a compromise agreed to cope with the main military and humanitarian missions; but such 'supercargo' airplane would be certainly much larger than the present ones, with two to four times their payload, and a transcontinental range capability; for their development, advantage would be taken of the best technologies that would become available in the next decade, and of the availability of design capability in the world's aircraft industry resulting from the present crisis. A flying wing configuration is suggested as a basis for a preliminary project. Finally, there is certainly a commercial spin-off of such massive supercargo production, if used to compete successfully with the surface transportation systems of large intermodal containers already used on major international markets. Author

N94-36327# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft.

OPTIMISATION OF COMPOSITE AIRCRAFT STRUCTURES BY DIRECT MANUFACTURING APPROACHES

G. BERCHTOLD and J. KLENNER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p Nov. 1993

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The present high performance aircraft designs are increasingly using high strength composite structures, mainly made of unidirectional carbon fiber tapes. But the composite technology is still afflicted with several weak points, e.g. the lack of adequate mechanized tape application techniques for complex compound structures, unsatisfying designs and design methods and missing continuous CAD/CAM-linkage. In this paper we will describe an 'Integrated Tape Laying System' (ITLS) which uses a new tape steering technology for automated manufacturing of complex parts. This system integrates the steering technology's potentials and restrictions completely in the design process to avoid time consuming iteration loops and to optimize the structure. To be able to understand the detailed process a short overview about two different geometry models demonstrated on a typical example will be given. From this the optimal detailed process will be derived, with an important influence from the specific manufacturing technology. Finally some remarks on economic potentials are outlined with their impact on typical composite aircraft parts related to different automated manufacturing techniques. Author (revised)

N94-36330# Westland Helicopters Ltd., Yeovil (England).

EH101: A NEW HELICOPTER CAPABLE OF LONG RANGE MISSIONS

C. J. BATTISSON and H. E. TATTON-BROWN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 10 p Nov. 1993

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The EH101 is a new medium helicopter being produced by EH Industries, a company jointly owned by Agusta of Italy and Westland of the UK. The aim of this presentation is to explore the roles in which the EH101 will be called upon to cover long ranges and examine its suitability for these roles. The roles which will be examined fall into the following categories: search and rescue, self-ferry, and special operations. The successful completion of such missions will demand particular capabilities of the crew and the machine. The following aspects of aircraft design will be looked at with respect to the EH101: in-flight refuelling, all-weather capability, maintenance requirements, and crew environment. Because of the wide ranging nature of the subject and the limited time available this is intended to examine only the key points required for these roles and capabilities. Author (revised)

N94-36331# Eurocopter France, Marignane (France).

THE CONVERTIBLE (HELICOPTER/AIRPLANE) EUROFAR: GENERAL CONSIDERATIONS ON THE TECHNICAL PROGRESS AND ON FUTURE ADVANCES [LE CONVERTIBLE TYPE EUROFAR: VUE D'ENSEMBLE DES AVANCEMENTS TECHNIQUES ET MISSIONS FUTURES]

A. MARTINI and J. RENAUD *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993 In FRENCH

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Until the last few years, the idea of a convertible aircraft did not progress into testing because the available technology did not satisfy the cost/efficiency parameters, and because the need for such an aircraft was not felt. Today, conditions are different. Strategic necessities and technical progress have created an atmosphere in the United States and in Europe where this old dream of engineers may be resurrected. Author

N94-36332# Aerospatiale, Toulouse (France). Aerodynamics Conception Dept.

CALCULATIONS USED TO OPTIMIZE THE INSTALLATION OF CIVIL AIRCRAFT ENGINES [UTILISATION DES METHODES DE CALCUL POUR OPTIMISER L'INSTALLATION MOTRICE DES AVIONS DE TRANSPORT]

X. MONTHUS, PH. COLIN, PH. MOGILKA, and A. MOLBAY-ARSAN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 31 p Nov. 1993 In FRENCH

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Within the research program on AIRBUS, the Aerodynamics Conception Department of Aerospacial Avions is responsible for the research on the aerodynamics of the reactor's pylon, air inlet (or technical evaluation on the system provided by the constructor) and for the optimization of aerodynamics in the ensemble of the engine installation. This includes studies on minimizing undesirable effects (loss of carrying capacity, increase in drag) due to the interaction between wings, pylon, and engine pod. This article lists the various tools used by the above department in order to fulfill its task: the C.A.O. system, principally conceived for aerodynamics concerns, the surface and volume representation systems as well as the main systems of 3D calculations on complex geometric arrangements. Three recent applications of these methods are presented within the framework of the development of the AIRBUS A330/A340 aircraft, and associated systems: air flow in the zone of pylon/wing intersection; effects due to the size of the engine in comparison to given wing characteristics and modelization of the jet's effect; and orientation of relationship between engine thrust and aircraft. Author

N94-36340# Aerospace Engineering Test Establishment, Cold Lake (Alberta).

FLIGHT TEST CERTIFICATION OF A 480 GALLON COMPOSITE FUEL TANK ON CF-18

MARIO B. J. LAGRANGE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 22 p Nov. 1993

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The Aerospace Engineering Test Establishment (AETE), as the Canadian Forces (CF) flight test authority, has recently completed flight tests and analysis of a major store certification program to establish an operational flight envelope for the carriage and jettison of a newly designed 480 gallon external fuel tank (EFT) for the CF-18 aircraft. The certification process involved a progressive series of analysis, wind tunnel tests, qualification tests, ground tests, and flight test activities. Most of the preflight activities were performed by the designer, McDonnell Aircraft Company (McAir), while all flight testing was the responsibility of AETE with engineering support from McAir. The progression of events from the qualification testing to the final flight testing recommendations are summarized herein. The primary focus of this paper is on the flying activities such as flutter, loads, stability and control, separation/jettison, and performance. Special instrumentation, flight test techniques, and test concept philosophy are also discussed. This paper highlights various technical problems encountered, such as the near flutter onset condition observed with tanks 50 percent full, the premature failure of the inboard wing spar pylon receptacle discovered after the last maneuvering loads flight, and the localized pitchup phenomena observed during stability and control (S&C) testing. A glance at the increased range and payload capabilities is also included. Overall, the 480 gallon EFT was determined to be a viable option for the CF-18 aircraft. Author

N94-36341# Dassault Aviation, Saint-Cloud (France). Direction Generale Technique.

IN-FLIGHT REFUELING: DASSAULT AVIATION RESEARCH ON THE RAFALE AIRCRAFT [RAVITAILLEMENT EN VOL L'EXPERIENCE DE DASSAULT-AVIATION APPLIQUEE AU RAFALE]

CHARLES DEFREVILLE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 11 p Nov. 1993 In FRENCH

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The Rafale is the latest combat aircraft built by Dassault Aviation. It is equipped with an in-flight refueling system using a fixed pole. This article relates the important steps taken during its conception and the various technologies that were used: structure, aerodynamics, systems, etc. The second part of the article describes the testing that was conducted in-flight as well as on the ground, making it possible to corroborate the performance of the systems and the flight characteristics of this aircraft. Transl. by FLS

N94-36342# *Frontier Technology, Inc., Beavercreek, OH.*
FUTURE TANKER CONSIDERATIONS AND REQUIREMENTS
LAVON JORDAN and MICHAEL KRIMMER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993
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Starting seven years ago, the USAF Aeronautical Systems Center began analyzing future tanker system requirements and developing plans for satisfying these requirements. Frontier Technology, Inc. (FTI) supported the USAF in four of the efforts. Frontier has completed one KC-135 multipoint analysis and is currently doing a second one. The completed effort determined: the pros and cons of hose-drogue refueling and the best fuel pumping rate for the KC-135 using two wing air refueling pods. The current job involves a more in-depth, overall assessment of operational needs, concepts of operation, and alternative wing pods. It emphasizes compatibility with Allied and U.S. Navy aircraft receivers. Frontier Technology is presenting two related papers at this AGARD symposium. This paper covers the rationale and requirements for multipoint refueling. It covers trends and future employment of aerial refueling tankers, as well as the increasing importance of interoperability. Derived from text

N94-36343# Naval Air Warfare Center, Patuxent River, MD. Flight Test and Engineering Group.
AERIAL REFUELING INTEROPERABILITY FROM A RECEIVER FLYING QUALITIES PERSPECTIVE
D. J. LUDWIG *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993
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Over the past decade, there has been increased emphasis on interservice and international operability with respect to aerial refueling (AR). One area concerning interoperability that needs to be considered in light of the increased trend towards large multipoint tankers is receiver flying qualities during AR. This paper stresses the importance of conducting receiver proximity trials to optimize refueling position behind the tanker and providing the pilot with the best receiver flying qualities for AR that can be attained. Receiver flying qualities behind the tanker can be seriously degraded if proper steps to optimize receiver refueling positions are not taken prior to final design. Poor receiver flying qualities in the refueling positions can reduce engagement success rate, increase the amount of training required, increase mishaps, increase refueling cycle time and seriously degrade mission effectiveness of the tanker. There are, of course, many other considerations regarding tanker/receiver compatibility such as airspeed/altitude compatibility, fuel system compatibility, communications, night lighting, etc. But this paper primarily addresses receiver flying qualities and the importance of refueling position behind the tanker as it pertains to flying qualities. Specific programs discussed are Navy trials with the Air Force KC-10 and KC-135 tankers and Navy programs to bring a wing pod tanker capability to the P-3 airplane. Additionally, efforts underway to enhance tanker mission effectiveness of the KC-130 with a variable geometry drogue are discussed and their ramifications explored. Author

N94-36344# McDonnell-Douglas Aerospace, Long Beach, CA. Transport Aircraft.
TANKER SYSTEM AND TECHNOLOGY REQUIREMENTS DEFINITION: A TANKER TECHNOLOGY ROAD MAP
JOHN KORIAGIN and BERTON B. RUND *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p Nov. 1993
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This paper presents a process that leads from comprehensive tanker system requirements analysis to the development of a technology 'road map.' This road map is a matrix listing key technology requirements for future air refueling tanker aircraft capabilities and the current status of research and development activities in these key areas. Generalized examples from material prepared under a U.S. Air Force Contracted Research and Development (CRAD) study are utilized. Multimission capabilities (i.e., tanker, and cargo and passenger transport) are often preferred for these new aircraft. This allows the flexibility of use for many purposes besides that of just air refueling: military cargo and passenger deployments, humanitarian relief, medical air evacuation, executive transport, etc. For this reason these tankers are often referred to as 'tanker/transports' to emphasize these capabilities. In this paper, the term 'tanker' is used to describe what in all likelihood will be a tanker/transport. Author (revised)

N94-36346# Royal Netherlands Air Force, The Hague. Training and Transport Aircraft and Helicopter Div.
THE KDC-10 PROGRAMME OF THE ROYAL NETHERLANDS AIR FORCE
PAUL R. BRINKGREVE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 6 p Nov. 1993
Copyright Avail: CASI HC A02/MF A03

Replacement of the RNLAF F-27 transport fleet, first mooted in 1984, became a serious option a few years later because of a growing need for AAR capacity. Years of discussion and market research resulted in a requirement for (among others) two DC-10 aircraft to be modified into tanker/transport aircraft. The budget was not sufficient to develop new KMD-11 tanker aircraft, nor did it allow buying existing tanker aircraft. On the basis of earlier programs from other countries, involving different aircraft, RNLAF decided that it should be possible to modify two DC-10 aircraft into so-called KDC-10 aircraft. With assistance from McDonnell Douglas Aircraft (MDA), four aircraft were selected on the basis of a number of criteria. These aircraft were studied thoroughly. On the basis of condition and price two Martinair DC10-30 CF aircraft were purchased on 30 June 1992. These will be modified into KDC-10 tanker/transport aircraft. The RNLAF contracted MDA to study feasibility, timetable, and cost of modifying two (Martinair) DC-10-30 CF aircraft into tanker/transport aircraft. The study concluded that the program was feasible within the proposed time frame, given that USAF would cooperate. Also the total cost estimate could be kept within budget. It was not possible to keep the KC-10 Aerial Refuelling Operator (ARO) station, so a new Remote Aerial Refuelling Operator (RARO) station will have to be developed. The design, however, is not completely new as it has been implemented on other aircraft. The RNLAF expects the first KDC-10 aircraft to be in service by January 1995, the second to follow approximately three months later. Based on this, the modification of the first aircraft is scheduled to start on 1 July 1994 and the second in December 1994. Development of the modification program has already begun. USAF has been requested to assist RNLAF in program management, contracting, and purchasing of certain parts. Author

N94-36347# Aerospace Engineering Test Establishment, Cold Lake (Alberta). Flight Dynamics.
CC-130H(T) TACTICAL AERIAL REFUELLING TANKER DEVELOPMENT FLIGHT TEST PROGRAMME
ANDREW REIF and MARC TREMBLAY *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 16 p Nov. 1993
Copyright Avail: CASI HC A03/MF A03

This paper describes the development flight test program for the CC-130H(T) Tactical Aerial Refuelling Tanker. The Canadian operational requirement is first described, followed by a detailed discussion of the test item, receiver aircraft, and the ground/flight test method and preliminary results. The development is significant since it represents the first certification of the Flight Refuelling Limited Mk 32B refuelling pods on a Hercules aircraft. Further flight testing to be conducted in the near future are also mentioned. Author

N94-36380*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

THE REDUCTION OF TAKEOFF GROUND ROLL BY THE APPLICATION OF A NOSE GEAR JUMP STRUT

JOSEPH C. EPPEL, MARTIN D. MAISEL, J. GREER MCCLAIN, and W. LUCE May 1994 16 p

(Contract RTOP 505-59-36)

(NASA-TM-108822; A-94082; NAS 1.15:108822) Avail: CASI HC A03/MF A01

A series of flight tests were conducted to evaluate the reduction of takeoff ground roll distance obtainable from a rapid extension of the nose gear strut. The NASA Quiet Short-haul Research Aircraft (QSRA) used for this investigation is a transport-size short take off and landing (STOL) research vehicle with a slightly swept wing that employs the upper surface blowing (USB) concept to attain the high lift levels required for its low-speed, short-field performance. Minor modifications to the conventional nose gear assembly and the addition of a high-pressure pneumatic system and a control system provided the extendable nose gear, or jump strut, capability. The limited flight test program explored the effects of thrust-to-weight ratio, wing loading, storage tank initial pressure, and control valve open time duration on the ground roll distance. The data show that a reduction of takeoff ground roll on the order of 10 percent was achieved with the use of the jump strut, as predicted. Takeoff performance with the jump strut was also found to be essentially independent of the pneumatic supply pressure and was only slightly affected by control valve open time within the range of the parameters examined. Author (revised)

N94-36465 Air Univ., Maxwell AFB, AL. Airpower Research Inst.

AIRCRAFT BATTLE DAMAGE REPAIR FOR THE 1990'S AND BEYOND

DARRELL H. HOLCOMB 20 Jul. 1994 55 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality

(AD-A278635; AU-ARI-93-4) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

Combat aircraft that are damaged and sitting on the ground are completely useless to air component commanders. The goal of the United States Air Force's Aircraft Battle Damage Repair (ABDR) Program is to rapidly restore these damaged aircraft to some level of combat capability. To be effective, the repairs must allow the aircraft to return to combat in time to affect the outcome of the battle. Effective battle damage repair capability can truly be a force multiplier. This research project suggests methods to improve the Air Force's ability to provide this critical service to operational field commanders. Recent changes to the way the Air Force accomplishes its mission necessitate improvements to the ABDR Program. New technology, defense downsizing, and the introduction of composite wings all affect the Air Force and consequently its aircraft battle damage repair philosophy. A comprehensive review of the current ABDR Program with emphasis on areas of improvement is therefore in order. This study begins with a review of the ABDR Program and is followed by a brief historical background of battle damage repair, an outline of the current USAF program status, and a description of basic repair techniques and philosophies. Next is a comparison of different approaches to ABDR by other military services. The study then identifies both technical and programmatic challenges which the program must address to remain viable. The final chapter contains conclusions, recommendations for improvements, and highlights of areas requiring further research. DTIC

N94-36618# Dornier-Werke G.m.b.H., Friedrichshafen (Germany).

LANDING OF AN UNMANNED HELICOPTER ON A MOVING PLATFORM. HIGH ACCURACY NAVIGATION AND TRACKING

HANS-PETER ENGELBERT and JOHANNES SCHROEDER *In* AGARD, Pointing and Tracking Systems 9 p May 1994

Copyright Avail: CASI HC A02/MF A02

Drones are of great importance for reconnaissance and surveillance in military applications. In regard to maritime drones Dornier demonstrated the automatic landing of a drone on a moving ship motion simulator in December 1991. The landing accuracy is determined by the tracking process. The tracking is performed by a laser tracker, which measures the drone position relative to the ship. Not only the drone but also the ship is equipped with an INS (Inertial Navigation System). The landing computations are performed in earth-fixed coordinates, whereby the earth-fixed positions are delivered by the INS. The determination of the drone position results from a combination of measurement values from the airborne INS and data from the ship laser tracker. The combination of the different information in the drone is performed in a Kalman-filter. The concept was verified in an experimental program. During the experimental program 13 flights were performed. The tracking accuracy was approximately 0.2 m. Author

N94-36644*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

CORRELATION OF ANALYTICAL AND EXPERIMENTAL HOT STRUCTURE VIBRATION RESULTS

MICHAEL W. KEHOE and VIVIAN C. DEATON Aug. 1993 21 p Presented at the SEM Structural Testing Technology at High Temperatures 2 Conference, Ojai, CA, 8-10 Nov. 1993

(Contract RTOP 505-63-50)

(NASA-TM-104269; H-1943; NAS 1.15:104269) Avail: CASI HC A03/MF A01

High surface temperatures and temperature gradients can affect the vibratory characteristics and stability of aircraft structures. Aircraft designers are relying more on finite-element model analysis methods to ensure sufficient vehicle structural dynamic stability throughout the desired flight envelope. Analysis codes that predict these thermal effects must be correlated and verified with experimental data. Experimental modal data for aluminum, titanium, and fiberglass plates heated at uniform, nonuniform, and transient heating conditions are presented. The data show the effect of heat on each plate's modal characteristics, a comparison of predicted and measured plate vibration frequencies, the measured modal damping, and the effect of modeling material property changes and thermal stresses on the accuracy of the analytical results at nonuniform and transient heating conditions. Author

N94-36767*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

FORWARD SWEEP, LOW NOISE ROTOR BLADE Patent Application

THOMAS F. BROOKS, inventor (to NASA) 2 May 1994 8 p

(NASA-CASE-LAR-14569-1; NAS 1.71:LAR-14569-1; US-PATENT-APPL-SN-238044) Avail: CASI HC A02/MF A01

A forward-swept, low-noise rotor blade includes an inboard section, an aft-swept section, and a forward-swept outboard section. The rotor blade reduces the noise of rotorcraft, including both standard helicopters and advanced systems such as tiltrotors. The primary noise reduction feature is the forward sweep of the planform over a large portion of the outer blade radius. The rotor blade also includes an aft-swept section. The purpose of the aft-swept region is to provide a partial balance to pitching moments produced by the outboard forward-swept portion of the blade. The noise source showing maximum noise reduction is blade-vortex interaction (BVI) noise. Also reduced are thickness, noise, high speed impulsive noise, cabin vibration, and loading noise. NASA

06
AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A94-61644* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TAKEOFF PERFORMANCE MONITORING SYSTEM DISPLAY OPTIONS
DAVID B. MIDDLETON NASA. Langley Research Center, Hampton, VA, LEE H. PERSON, JR., and RAGHAVACHARI SRIVATSAN *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 666-671 refs
(BTN-94-EIX94401358988) Copyright

This article summarizes the development of head-up and head-down cockpit displays for an airplane takeoff performance monitoring system (TOPMS). Basic TOPMS displays provide pilots with real-time graphic information concerning their airplane's current and projected runway performance. The displays also indicate the status of associated airplane systems (e.g., flaps, engines) and, optionally, they provide 'GO/NO-GO' advice and a continually updated prediction of where the airplane can be braked to a stop. The displays have been developed and evaluated on the NASA Transport System Research Vehicle (TSRV) B-737 simulator by more than 40 government, airline, and industry pilots who rated the displays favorably and judged them easy to monitor. The TOPMS has also been flight tested successfully on the TSRV B-737. Based on these evaluations and on discussions with the commercial aircraft community, the displays have evolved to a baseline final configuration containing basic performance and system-status data to which GO/NO-GO advisory and predicted stop point information can be added as options. Author (EI)

N94-37401*# General Electric Co., Cincinnati, OH. Aircraft Engines
FIBER OPTIC (FLIGHT QUALITY) SENSORS FOR ADVANCED AIRCRAFT PROPULSION Final Report, Jan. 1990 - Jun. 1994
GARY L. POPPEL Jul. 1994 90 p
(Contract NAS3-25805; RTOP 505-62-50)
(NASA-CR-191195; NAS 1.26:191195; R94AEB175) Avail: CASI HC A05/MF A01

Development of flight prototype, fiber-optic sensing system components for measuring nine sensed parameters (three temperatures, two speeds, three positions, and one flame) on an F404-400 aircraft engine is described. Details of each sensor's design, functionality, and environmental testing, and the electro-optics architecture for sensor signal conditioning are presented. Eight different optical sensing techniques were utilized. Design, assembly, and environmental testing of an engine-mounted, electro-optics chassis unit (EOU), providing MIL-C-1553 data output, are related. Interconnection cables and connectors between the EOU and the sensors are identified. Results of sensor/cable/circuitry integrated testing, and installation and ground testing of the sensor system on an engine in October 1993 and April 1994 are given, including comparisons with the engine control system's electrical sensors. Lessons learned about the design, fabrication, testing, and integration of the sensor system components are included. Author

07
AIRCRAFT PROPULSION AND POWER

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

A94-61114
PT6 ENGINE: 30 YEARS OF GAS TURBINE TECHNOLOGY EVOLUTION
M. BADGER Pratt & Whitney Canada, Inc, Montreal, Que, Canada, A. JULIEN, A. D. LEBLANC, S. H. MOUSTAPHA, A. PRABHU, and A. A. SMAILYS *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 322-330 refs
(BTN-94-EIX94311331064) Copyright

The PT6 engine entered service in the mid-1960s. Since then, application of new technology has enabled low-cost development of engines approaching 1500 kW, the introduction of electronic controls, improved power-to-weight ratio, higher cycle temperature, and reduced specific fuel consumption. At the same time, PT6 field experience in business, commuter, helicopter, and trainer applications has resulted in engines with low Direct Operating Cost and a reputation for rugged design and a high standard of engine reliability. This paper will highlight some interesting examples of this technical evolution, including the development of electronic controls and the application of the latest three-dimensional aerodynamic and stress analysis to both compressor and turbine components. Author (EI)

A94-61115
COMMENTS ON THE DEVELOPMENT OF THE EARLY WESTINGHOUSE TURBOJETS, 1941-1946
S. WAY *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 315-321 refs
(BTN-94-EIX94311331063) Copyright

The early thinking leading to the American Turbojet engine is reviewed. This included ideas pertaining to ramjets and rockets, and culminated in the axial flow turbojet engine concept. The role of the NACA Subcommittee on Jet Propulsion under the leadership of Dr. W. F. Durand is stressed. Early problems with the new engine are mentioned, including flame tube light-off, interconnecting tubes, and fuel injection problems. An early major design innovation was the change to a single annular combustion chamber, replacing the 24 cans. This change culminated in the 19XB engine. The purposes of this paper are to show the magnitude of the problems encountered, and to give credit to the many dedicated persons who made the American Axial Flow Turbojet Engine a success. Author (EI)

A94-61459
RESEARCH ON THE ENGINEERING APPLICATION OF THE ANTI-SWIRL MEASURES IN ENGINE/INLET COMPATIBILITY
GUOCAI YANG 61st Research Inst., China Aerospace Corp., Chengdu (China) *Tuijin Jishu/Journal of Propulsion Technology* (ISSN 1001-4055) no. 2 April 1994 p. 17-24 In CHINESE refs
(BTN-94-EIX94381353571) Copyright

Based on the mechanism of inlet swirl, the measures were studied to prevent and restrain the inlet swirl of present aircraft in an all-round way from the inlet design point of view. It is expected that this thinking will benefit the solution of the problems in engine/inlet compatibility arising from swirl. EI

A94-61460
EXPERIMENTAL INVESTIGATION ON SELECTING THE RAMP AND LIP PARAMETERS OF A TWO-DIMENSIONAL EXTERNAL COMPRESSION INLET
XUELIANG ZHANG Chengdu Aircraft Industrial Corp., Chengdu (China) *Tuijin Jishu/Journal of Propulsion Technology* (ISSN 1001-4055) no. 2 April 1994 p. 12-16, 57 In CHINESE refs
(BTN-94-EIX94381353570) Copyright

A l/ll-scale model of a two-dimensional external compression supersonic inlet with M(sub max) = 1.8 was tested from M = 0.8 to 1.8. The ramp of the inlet is side-mounted vertically, and its duct is bifurcated. The effects of the ramp angles, internal lip angles and circle lip radius on the internal performances of the inlet were presented. The experimental results showed that a small change in ramp angle caused a large changes in inlet total pressure recovery, in circumferential steady-pressure distortion, and in buzz margin; whereas a small change in the internal lip angle and lip radius effects the change of inlet performances not as significantly as expected at subsonic speed, but does effect it significantly at supersonic speed. EI

A94-61636* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

INVISCID PARAMETRIC ANALYSIS OF THREE-DIMENSIONAL INLET PERFORMANCE

SCOTT D. HOLLAND NASA. Langley Research Center, Hampton, VA and JOHN N. PERKINS *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 610-615 refs (BTN-94-EIX94401358980) Copyright

The advantages and design requirements of propulsion/airframe integration for the high Mach number flight of air-breathing vehicles have led to extensive study of the three-dimensional sidewall-compression scramjet inlet in recent years. Inlets of this genre afford a relatively simple, generic geometry while producing a highly complex, three-dimensional flowfield dominated by shock/shock and shock/boundary-layer interactions. While the importance of the viscous effects in high-speed inlet interactions is recognized, the present work addresses in a parametric fashion the inviscid effects of leading-edge sweep (between 0-70 deg) and inflow Mach number (between 2-12) on the inlet performance. Two-dimensional oblique shock theory is appropriately modified to account for the three-dimensional effects of leading-edge sweep and is applied throughout the inlet configuration to obtain inviscid shock impingement locations, mass capture, inlet compression, total pressure recovery, and kinetic energy efficiency. Comparison of these results with CFD indicates that the parametric trends are identified by this computationally quick and inexpensive method for preliminary design applications. Author (EI)

A94-61650

WHIRL-FLUTTER SUPPRESSION IN ADVANCED TURBOPROPS AND PROPFANS BY ACTIVE CONTROL TECHNIQUES

F. NITZSCHE DLR - Inst. of Aeroelasticity, Gottingen (Germany) *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 713-719 refs (BTN-94-EIX94401358994) Copyright

The feasibility of using the active control technique to suppress the whirl-flutter instability of advanced turboprops is investigated. Aerodynamic vanes are incorporated at the engine nacelle to generate control airloads. The actuator system is driven by a control law that is based on the Kalman filter estimation of the critical aeroelastic modes of the structure. The results demonstrate that the compensator provides enough controllability to prevent the whirl-flutter onset well beyond the design speed. The present study suggests that a very efficient vibration isolation in advanced turboprops may be achieved both by optimizing the engine-propeller suspension in the actual flying envelope and by employing the active control technique to deal with the safe margins required by the present aircraft certification regulations. Author (EI)

A94-61652

UNSTEADY BLADE PRESSURES ON A PROPFAN: PREDICTED AND MEASURED COMPRESSIBILITY EFFECTS

M. NALLASAMY Sverdrup Technology, Inc., Brook Park, OH *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 730-736 refs (BTN-94-EIX94401358996) Copyright

The effect of compressibility on unsteady blade pressures is studied by solving the three-dimensional Euler equations. The operation of the eight-bladed SR7L propfan at 4.75-deg angle of attack was considered. Euler solutions were obtained for three Mach numbers, 0.6, 0.7, and 0.8, and the predicted blade pressure waveforms were compared with flight data. The predictions show that the change in pressure waveforms are minimal when the Mach number is increased from 0.6 to 0.7, as observed in the flight experiments. Increasing the Mach number from 0.7 to 0.8 produces significant changes in predicted pressure levels. The predicted amplitudes, however, differ from measurements at some transducer locations. Also, the predicted appearance of a shock in the highly loaded portion of the blade revolution is not indicated by the measurements. At all three Mach numbers the measured (installed propfan) pressure waveforms at the majority of transducer locations show a relative phase lag compared to the computed (propfan alone) waveforms. This appears to be due to installation effects. Measured waveforms in the blade tip region show nonlinear variations which are not captured by the present numerical procedure. Author (EI)

N94-36333# Naval Air Warfare Center, Warminster, PA. Aircraft Div.

PROPULSION SYSTEM SELECTION FOR A HIGH ALTITUDE LONG ENDURANCE AIRCRAFT

JOHN D. CYRUS and JOSEPH FRANZ *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993

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This paper addresses the major propulsion system options for High Altitude Long Endurance aircraft internal combustion engines, turbine engines and fuel cells. The paper identifies the technology drivers for the vehicle and assesses the secondary equipment requirements for the various system options. Critical technologies and development requirements are addressed in terms of mission capability for both near-term and advanced systems. This AGARDograph was sponsored by the Flight Mechanics Panel. Author

N94-36334# Rolls-Royce Ltd., Bristol (England).

PROPULSION SYSTEM TECHNOLOGIES FOR LONG RANGE AND LONG ENDURANCE AIRCRAFT

K. R. GARWOOD *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993

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The NATO requirement for increased range and endurance of aircraft is also associated with the necessity to reduce the initial and life cycle costs of these aircraft. Consideration of these conflicting requirements leads to the prioritization of engine technologies for different vehicle types and presented here are views of engine manufacturers addressing these challenges over the range of aircraft. This paper will discuss the prioritization of technologies required for the range of air vehicles and examine how increases in endurance and range affect the balance of technology within each propulsion unit type. It is convenient to group the vehicles in the following way: transport, tanker, AWACS; maritime patrol; combat; and special purpose. Each grouping has the challenges of range or duration subject to its class, although clearly in absolute terms the range of transport vehicles is significantly different from that of a combat aircraft. It is primarily these differences in the groupings that give rise to the differences in technology prioritization. Derived from text

N94-36335# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).

THE STRATO 2C PROPULSION SYSTEM: A LOW COST APPROACH FOR A HIGH ALTITUDE LONG ENDURANCE AIRCRAFT

H. TOENSKOETTER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 6 p Nov. 1993

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For the STRATO 2C - a High Altitude Long Endurance Research

Aircraft - a low cost propulsion system was designed and is now under development. The approach to achieve the aim of low development procurement and in-service costs is a compound propulsion system based on a highly supercharged liquid cooled piston engine with charge air inter-cooling and the extensive usage of available components. The concept of the propulsion system and the main components are described. Aspects of controlling the three-stage turbocharger system are discussed. The way to realize the power plant in three years is presented and the test program is addressed. Author

N94-37448*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

PREDICTION OF FILM COOLING ON GAS TURBINE AIRFOILS

VIJAY K. GARG and RAYMOND E. GAUGLER Jul. 1994 31 p
Presented at the 39th International Gas Turbine and Aeroengine Congress and Exposition, The Hague, Netherlands, 13-16 Jun. 1994; sponsored by ASME
(Contract RTOP 505-62-52)
(NASA-TM-106653; E-8965; NAS 1.15:106653) Avail: CASI HC A03/MF A01

A three-dimensional Navier-Stokes analysis tool has been developed in order to study the effect of film cooling on the flow and heat transfer characteristics of actual turbine airfoils. An existing code (Arnone et al., 1991) has been modified for the purpose. The code is an explicit, multigrid, cell-centered, finite volume code with an algebraic turbulence model. Eigenvalue scaled artificial dissipation and variable-coefficient implicit residual smoothing are used with a full-multigrid technique. Moreover, Mayle's transition criterion (Mayle, 1991) is used. The effects of film cooling have been incorporated into the code in the form of appropriate boundary conditions at the hole locations on the airfoil surface. Each hole exit is represented by several control volumes, thus providing an ability to study the effect of hole shape on the film-cooling characteristics. Comparison is fair with near mid-span experimental data for four and nine rows of cooling holes, five on the shower head, and two rows each on the pressure and suction surfaces. The computations, however, show a strong spanwise variation of the heat transfer coefficient on the airfoil surface, specially with shower-head cooling. Author

08

AIRCRAFT STABILITY AND CONTROL

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

A94-61254

OPTIMUM FLIGHT TRAJECTORY GUIDANCE BASED ON TOTAL ENERGY CONTROL OF AIRCRAFT

SHU-FAN WU Nanjing Univ. of Aeronautics and Astronautics, Nanjing (China) and SUO-FENG GUO *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 291-296 refs
(BTN-94-EIX94381311167) Copyright

The guidance technique for optimal vertical flight trajectory with a total energy control system (TECS) is discussed. The flight profile is optimized based on the point-mass energy state approximation model of aircraft with direct operating cost as its index function. The guidance law is developed with the total energy control concept used in TECS. To improve the guidance precision, several methods are adopted in the optimizations and tracking process, and two preprocessing algorithms, the lead-compensation algorithm and the smooth filtering algorithm, are developed for the ideal optimal trajectory. Satisfactory digital simulation results for a Boeing-707 transport model are finally obtained. Author (EI)

A94-61259

CONSTRAINED CONTROL ALLOCATION: THREE-MOMENT PROBLEM

WAYNE C. DURHAM Virginia Polytechnic Inst. and State Univ., Blacksburg, VA *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 330-336 refs
(BTN-94-EIX94381311172) Copyright

This paper presents a method for the solution of the constrained control allocation problem for the case of three moments. The control allocation problem is to find the 'best' combination of several flight control effectors for the generation of specified body-axis moments. The number of controls is greater than the number of moments being controlled, and the ranges of the controls are constrained to certain limits. The controls are assumed to be individually linear in their effect throughout their ranges of motion and complete in the sense that they generated moments in arbitrary combinations. The best combination of controls is taken to be an apportioning of the controls that yields the greatest total moment in a specified ratio of moments without exceeding any control constraint. The method of solving the allocation problem is presented as an algorithm and is demonstrated for a problem of seven aerodynamic controls on an F-18 airplane. Author (EI)

A94-61261

REDUCED-ORDER H(INF) COMPENSATOR DESIGN FOR AN AIRCRAFT CONTROL PROBLEM

ROBERT C. OSBORNE Massachusetts Univ., Amherst, MA, RICHARD J. ADAMS, CHIN S. HSU, and SIVA S. BANDA *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 341-345 refs
(BTN-94-EIX94381311174) Copyright

A recently introduced method for designing H-infinity compensators based on minimal-order observers is considered for an aircraft control problem. The purpose of this paper is to bridge the gap between theory and application by presenting a practical utilization of a new design approach. Manual flight control systems for the lateral axis of a fighter aircraft are developed using both full-order and reduced-order compensators, and the results are compared. It is demonstrated that this method can be used to directly design reduced-order compensators that result in a system satisfying a closed-loop H-infinity bound. Author (EI)

A94-61617

CHINE-SHAPED FOREBODY EFFECTS ON DIRECTIONAL STABILITY AT HIGH-ALPHA

R. RAVI Virginia Polytechnic Inst. and State Univ., Blacksburg, VA and WILLIAM H. MASON *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 480-487 refs
(BTN-94-EIX94401358961) Copyright

Computational fluid dynamics has been used to study the flowfields over chine-shaped forebodies at low-speed high angle-of-attack conditions with sideslip. The purpose is to define forebody geometries that provide good directional stability characteristics under these conditions. An analytically defined generic forebody model is described, and a parametric study of various forebody shapes was then conducted to determine which shapes promote a positive contribution to directional stability at high angle of attack. An unconventional way of presenting the results is used to illustrate how the positive contribution arises. The effect of cross-sectional shape on directional stability was found to be very significant. Broad chine-shaped cross sections were found to promote directional stability. Also, directional stability is improved if the chine is placed closer to the top of the cross section. Planform shapes also played an important role in determining the forebody directional stability characteristics. Based on the results of this initial parametric study, some guidelines for aerodynamic design to promote positive directional stability are presented. Author (EI)

A94-61618

COMPUTATIONAL STUDY OF THE F-5A FOREBODY EMPHASIZING DIRECTIONAL STABILITY

WILLIAM H. MASON Virginia Polytechnic Inst. and State Univ., Blacksburg, VA and R. RAVI *Journal of Aircraft* (ISSN 0021-8669)

vol. 31, no. 3 May-June 1994 p. 488-494 refs
(BTN-94-EIX94401358962) Copyright

Computational fluid dynamics (CFD) has been used to study the F-5A forebody flowfield at low-speed high angle-of-attack conditions combined with sideslip. The classic wind-tunnel experiment demonstrating the dominant contribution of the F-5A forebody to directional stability at high angle of attack has been simulated computationally over an angle-of-attack range from 10 to 45 deg. The key wind-tunnel trend for C(sub n beta) was obtained computationally using the CFL3D code to solve the Reynolds' equations employing the Baldwin-Lomax turbulence model with the Degani-Schiff modification to account for massive crossflow separation. The computations provide detailed and fascinating insights into the physics of flowfield. The results of the investigation show that CFD has reached a level of development where computational methods can be used for high angle-of-attack aerodynamic design. Author (EI)

A94-61621
EVALUATION OF PARAMETER ESTIMATION METHODS FOR UNSTABLE AIRCRAFT
R. V. JATEGAONKAR German Aerospace Research Establishment (DLR), Braunschweig (Germany) and F. THIELECKE *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 510-519 refs
(BTN-94-EIX94401358965) Copyright

While continuing to be of wide interest, the estimation of aerodynamic derivatives from flight data of an unstable aircraft poses several difficulties. The objective of this article is to provide an overview of some of the more recently introduced estimation methods together with some of the conventional ones. Five options addressed here are 1) regression startup, 2) equation decoupling, 3) filter error, 4) output error with artificial stabilization, and 5) multiple shooting method. An evaluation is made based on the parameter estimates both from simulated and flight data. The various methods yield comparable estimates from simulated responses pertaining to the short period motion of an unstable aircraft. Their application to X-31A aircraft flight data in unstable flight regime brings out some practical aspects. It is found that the application of the conventionally used output error method with artificial stabilization and of the multiple shooting method requires considerable engineering effort, and can still pose difficulties when analyzing longer duration maneuvers. The estimates from the filter error and equation decoupling methods compare with each other well. It is demonstrated that they provide an attractive and less laborious alternative to analyze longer duration maneuvers, e.g., consecutive elevator doublets or sweep inputs up to 30 s. Author (EI)

A94-61658
APPROXIMATE RECOVERY OF H-INFINITY LOOP SHAPES USING FIXED-ORDER DYNAMIC COMPENSATION
EDWARD V. JR. BYRNS Systems Planning and Analysis, Inc., Falls Church, VA and ANTHONY J. CALISE *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 458-465 refs
(BTN-94-EIX94401358152) Copyright

This paper presents a method for designing fixed-order dynamic compensator that approximates the H(sub infinity) full state feedback, closed-loop transfer function properties from disturbance inputs to controlled outputs. The formulation uses an observer canonical form to represent the dynamic compensator which allows the design to be treated as a modified constant gain feedback problem. The approximate is accomplished through a unique selection of the quadratic performance index weighting matrices. This design procedure is demonstrated by two design examples. The first example is a simple fourth-order model used to demonstrate the procedure. The second example is a longitudinal flight controller for the F-18/HARV 'supermaneuverable' aircraft. The flight controller is compared to both a full and reduced order H(sub infinity) compensator. Author (EI)

A94-61669
EXPERIMENTAL DESIGN OF H(SUB INFINITY) WEIGHTING FUNCTIONS FOR FLIGHT CONTROL SYSTEMS
CIANN-DONG YANG National Cheng Kung Univ., Tainan (Taiwan), HANN-SHING JU, and SHIN-WHAR LIU *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 544-552 refs
(BTN-94-EIX94401358163) Copyright

This paper introduces an experimental solution for H(sub infinity) weighting function selection by exploiting an experimental planning method that has been used in quality control. Conducting matrix experiments using special matrices, called orthogonal arrays, allows the effects of several weighting parameters to be determined efficiently so that the resulting H(sub infinity) controller can satisfy many design specifications simultaneously in the environment for which the controller is designed. To show the feasibility and efficiency of this methodology, a flight control system for an airplane is designed to satisfy 11 performance specifications simultaneously, when the airplane is undergoing a large shift in c.g. position. Author (EI)

A94-61672
NONLINEAR MODEL-FOLLOWING CONTROL APPLICATION TO AIRPLANE CONTROL
WAYNE C. DURHAM Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, FREDERICK H. LUTZE, M. REMZI BARLAS, and BRUCE C. MUNRO *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 570-577 refs
(BTN-94-EIX94401358166) Copyright

Nonlinear model-following control design is applied to the problem of control of the six degrees of freedom of an airplane that lacks direct control of lift and side force. The nonlinear expressions for the error dynamics of the model-following control are examined using Lyapunov stability analysis. The analysis results in nonlinear feedforward and feedback gains that are functions of the airplane and model states. As a consequence, gain scheduling requirements for the implementation of the model-following control are reduced to only those involving the estimation of stability and control derivatives of the airplane. The use of these gains is shown through an example application to the control of a nonlinear aerodynamic and engine model provided by NASA Ames-Dryden Flight Research Facility. The model being followed is based on a trajectory generation algorithm, and represents a form of dynamic inversion. Author (EI)

A94-61673
IMPLEMENTATION OF A FULL-ENVELOPE CONTROLLER FOR A HIGH-PERFORMANCE AIRCRAFT
RICHARD J. ADAMS Wright Lab., Wright-Patterson AFB, OH, JAMES M. BUFFINGTON, and SIVA S. BANDA *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 578-583 refs
(BTN-94-EIX94401358167) Copyright

The design, implementation, and evaluation of a full-envelope control system for the AIAA controls design challenge aircraft is presented.The control problem is divided into separate longitudinal and lateral/directional designs. The longitudinal controller is a Mach number and flight path angle command system, and bank angle is commanded through the lateral/directional autopilot. A cross-axis filter minimizes transient error during coupled maneuvers. Proportional plus integral plus derivate structure is built into a linear quadratic synthesis problem to generate state feedback gains. An implementable output feedback solution is found through a linear transformation of the state feedback gain matrix. The control system is gain scheduled with dynamic pressure through polynomial curve fits of linear point design gains. Required maneuvers are demonstrated within design specifications except in cases where the physical limitations of the aircraft restrict achievable performance. Author (EI)

N94-36329# Technische Univ., Munich (Germany). Inst. of Flight Mechanics and Flight Control.
IMPROVEMENT OF ENDURANCE PERFORMANCE BY PERIODIC OPTIMAL CONTROL OF VARIABLE CAMBER
G. SACHS and R. MEHLHORN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p Nov. 1993
Copyright Avail: CASI HC A02/MF A03

Other than in classical theory, endurance cruise is considered as an optimal periodic control problem where the state and control variables change in a periodic manner. Variable camber is introduced as a further control in addition to angle of attack and thrust setting. By periodically varying camber in a coordinated process with the two other controls, it is possible to fully exploit its potential of improving the lift/drag ratio for increasing the endurance of aircraft. It is quantitatively shown which gain in endurance performance can be achieved. Results are presented for an idealized engine model showing no control rate limitations as well as for a realistic model with constraints on control rates imposed. The numerical values for the constraints are chosen such that only slow thrust changes are admitted. Author

N94-36384 Purdue Univ., West Lafayette, IN. School of Aeronautics and Astronautics.
AEROSERVOELASTIC TAILORING WITH PIEZOELECTRIC MATERIALS: ACTUATOR OPTIMIZATION STUDIES Final Report, 1 Oct. 1991 - 30 Sep. 1993
TERRENCE A. WEISSHAAR and MARIO A. ROTEA 9 Feb. 1994 48 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(Contract AF-AFOSR-0386-91)
(AD-A278640; AERO-3; AFOSR-94-0263TR) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

This report summarizes aeroservoelastic tailoring studies in which adaptive material actuators are used to control structural deflection of aeroelastic systems. The problem is to furnish enough directed control of a system to make the control of the phenomenon feasible. Specific research problems considered are: choice of the actuator material for effective control; geometric arrangement for active control; and optimum coverage of surface panels for effective control. A specific method of controller design is suggested to determine the limits of control. It is applied to a typical section whose response to random atmospheric turbulence is to be controlled. A finite element method is developed to model actuator and sensor output for plate-like actuators and its use is illustrated for wing-like configurations to demonstrate the benefits of orthotropic material actuators. Finally, the problem of optimum actuators to supply deflection of panels for wing surfaces is examined to determine optimality criteria for such panels and to use strain energy as a guide for efficient use of actuator/host plate combinations. DTIC

N94-36436*# Sterling Software, Inc., Moffett Field, CA.
ALLEVIATION OF WHIRL-FLUTTER ON A JOINED-WING TILT-ROTOR AIRCRAFT CONFIGURATION USING ACTIVE CONTROLS
JOHANNES M. VANAKEN 1991 27 p Presented at the International Specialists' Meeting on Rotorcraft Basic Research of the American Helicopter Society, Atlanta, GA, 25-27 Mar. 1991 See also A92-14423
(Contract NCC2-417)
(NASA-CR-196103; NAS 1.26:196103) Avail: CASI HC A03/MF A01

The feasibility of using active controls to delay the onset of whirl-flutter on a joined-wing tilt rotor aircraft was investigated. The CAMRAD/JA code was used to obtain a set of linear differential equations which describe the motion of the joined-wing tilt-rotor aircraft. The hub motions due to wing/body motion is a standard input to CAMRAD/JA and were obtained from a structural dynamics model of a representative joined-wing tilt-rotor aircraft. The CAMRAD/JA output, consisting of the open-loop system matrices, and the airframe free vibration motion were input to a separate program which performed the closed-loop, active control calculations. An eigenvalue analysis was performed to determine the flutter stability of both open- and closed-loop systems. Sensor models, based upon the feedback of pure state variables and based upon hub-mounted sensors, providing physically measurable accelerations, were evaluated. It was shown that the onset of tilt-rotor whirl-flutter could be delayed from 240 to above 270 knots by feeding back vertical and span-wise accelerations, measured at the rotor hub, to the longitudinal cyclic pitch. Time response calculations at a 270-knot cruise condition showed an active cyclic pitch control level of 0.009 deg, which equates to a very acceptable 9 pound active-control force applied at the rotor hub. Author

N94-36733# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
MIXED H2/H-INFINITY OPTIMIZATION WITH MULTIPLE H INFINITY CONSTRAINTS M.S. Thesis
JULIO C. ULLAURI Jun. 1994 136 p
(AD-A280572; AFIT/GAE/ENY/94J-04) Avail: CASI HC A07/MF A02

A general mixed H2/H-infinity optimal control design with multiple H-infinity constraints is developed and applied to two systems, one SISO and the other MIMO. The SISO design model is normal acceleration command following for the F-16. This design constitutes the validation for the numerical method, for which boundaries between the H2 design and the H-infinity constraints are shown. The MIMO design consists of a longitudinal aircraft plant (short period and phugoid modes) with stable weights on the H2 and H-infinity transfer functions, and is linear-time-invariant. The controller order is reduced to that of the plant augmented with the H2 weights only. The technique allows singular, proper (not necessarily strictly proper) H-infinity constraints. The analytical nature of the solution and a numerical approach for finding suboptimal controllers which are as close as desired to optimal is developed. The numerical method is based on the Davidon-Fletcher-Powell algorithm and uses analytical derivatives and central differences for the first order necessary conditions. The method is applied to a MIMO aircraft longitudinal control design to simultaneously achieve Nominal Performance at the output and Robust Stability at both the input and output of the plant. DTIC

N94-36820*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GAIN WEIGHTED EIGENSPACE ASSIGNMENT
JOHN B. DAVIDSON and DOMINICK ANDRISANI, II May 1994 32 p
(Contract RTOP 505-64-30-01)
(NASA-TM-109130; NAS 1.15:109130) Avail: CASI HC A03/MF A01

This report presents the development of the gain weighted eigenspace assignment methodology. This provides a designer with a systematic methodology for trading off eigenvector placement versus gain magnitudes, while still maintaining desired closed-loop eigenvalue locations. This is accomplished by forming a cost function composed of a scalar measure of error between desired and achievable eigenvectors and a scalar measure of gain magnitude, determining analytical expressions for the gradients, and solving for the optimal solution by numerical iteration. For this development the scalar measure of gain magnitude is chosen to be a weighted sum of the squares of all the individual elements of the feedback gain matrix. An example is presented to demonstrate the method. In this example, solutions yielding achievable eigenvectors close to the desired eigenvectors are obtained with significant reductions in gain magnitude compared to a solution obtained using a previously developed eigenspace (eigenstructure) assignment method. Author

N94-36965*# Washington Univ., Seattle, WA. Dept. of Mechanical Engineering.
MULTIRATE FLUTTER SUPPRESSION SYSTEM DESIGN FOR THE BENCHMARK ACTIVE CONTROLS TECHNOLOGY WING Final Report, 16 Jun. 1991 - 15 Jun. 1994
MARTIN C. BERG and GREGORY S. MASON 1994 79 p

(Contract NCC1-156)
(NASA-CR-196112; NAS 1.26:196112) Avail: CASI HC A05/MF A01

To study the effectiveness of various control system design methodologies, the NASA Langley Research Center initiated the Benchmark Active Controls Project. In this project, the various methodologies will be applied to design a flutter suppression system for the Benchmark Active Controls Technology (BACT) Wing (also called the PAPA wing). Eventually, the designs will be implemented in hardware and tested on the BACT wing in a wind tunnel. This report describes a project at the University of Washington to design a multirate flutter suppression system for the BACT wing. The objective of the project was two fold. First, to develop a methodology for designing robust multirate compensators, and second, to demonstrate the methodology by applying it to the design of a multirate flutter suppression system for the BACT wing. The contributions of this project are (1) development of an algorithm for synthesizing robust low order multirate control laws (the algorithm is capable of synthesizing a single compensator which stabilizes both the nominal plant and multiple plant perturbations; (2) development of a multirate design methodology, and supporting software, for modeling, analyzing and synthesizing multirate compensators; and (3) design of a multirate flutter suppression system for NASA's BACT wing which satisfies the specified design criteria. This report describes each of these contributions in detail. Section 2.0 discusses our design methodology. Section 3.0 details the results of our multirate flutter suppression system design for the BACT wing. Finally, Section 4.0 presents our conclusions and suggestions for future research. The body of the report focuses primarily on the results. The associated theoretical background appears in the three technical papers that are included as Attachments 1-3. Attachment 4 is a user's manual for the software that is key to our design methodology. Derived from text

N94-37014*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DESIGN AND EVALUATION OF A STOCHASTIC OPTIMAL FEED-FORWARD AND FEEDBACK TECHNOLOGY (SOFFT) FLIGHT CONTROL ARCHITECTURE
AARON J. OSTROFF and MELISSA S. PROFFITT Jun. 1994 20 p
(Contract RTOP 505-64-30-01)
(NASA-TP-3419; L-17273; NAS 1.60:3419) Avail: CASI HC A03/MF A01

This paper describes the design and evaluation of a stochastic optimal feed-forward and feedback technology (SOFFT) control architecture with emphasis on the feed-forward controller design. The SOFFT approach allows the designer to independently design the feed-forward and feedback controllers to meet separate objectives and then integrate the two controllers. The feed-forward controller has been integrated with an existing high-angle-of-attack (high-alpha) feedback controller. The feed-forward controller includes a variable command model with parameters selected to satisfy level 1 flying qualities with a high-alpha adjustment to achieve desired agility guidelines, a nonlinear interpolation approach that scales entire matrices for approximation of the plant model, and equations for calculating feed-forward gains developed for perfect plant-model tracking. The SOFFT design was applied to a nonlinear batch simulation model of an F/A-18 aircraft modified for thrust vectoring. Simulation results show that agility guidelines are met and that the SOFFT controller filters undesired pilot-induced frequencies more effectively during a tracking task than a flight controller that has the same feedback control law but does not have the SOFFT feed-forward control. Author

N94-37059*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PREDICTING THE EFFECTS OF UNMODELED DYNAMICS ON AN AIRCRAFT FLIGHT CONTROL SYSTEM DESIGN USING EIGENSPACE ASSIGNMENT
ERIC N. JOHNSON (George Washington Univ., Washington, DC.), JOHN B. DAVIDSON, and PATRICK C. MURPHY Jun. 1994 40 p
(Contract RTOP 505-64-52-01)
(NASA-TM-4548; L-17333; NAS 1.15:4548) Avail: CASI HC A03/MF A01

When using eigenspace assignment to design an aircraft flight control system, one must first develop a model of the plant. Certain questions arise when creating this model as to which dynamics of the plant need to be included in the model and which dynamics can be left out or approximated. The answers to these questions are important because a poor choice can lead to closed-loop dynamics that are unpredicted by the design model. To alleviate this problem, a method has been developed for predicting the effect of not including certain dynamics in the design model on the final closed-loop eigenspace. This development provides insight as to which characteristics of unmodeled dynamics will ultimately affect the closed-loop rigid-body dynamics. What results from this insight is a guide for eigenstructure control law designers to aid them in determining which dynamics need or do not need to be included and a new way to include these dynamics in the flight control system design model to achieve a required accuracy in the closed-loop rigid-body dynamics. The method is illustrated for a lateral-directional flight control system design using eigenspace assignment for the NASA High Alpha Research Vehicle (HARV). Author

09
RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

N94-36437# Wichita State Univ., KS. Aerodynamic Labs.
THREE-DIMENSIONAL FORCE DATA ACQUISITION AND BOUNDARY CORRECTIONS FOR THE WALTER H. BEECH MEMORIAL 7 X 10 FOOT LOW SPEED WIND TUNNEL
BONNIE L. JOHNSON, JAMES E. LEIGH, and KEVIN A. MOORE Jun. 1993 47 p
(AR93-2) Avail: CASI HC A03/MF A01

The Walter H. Beech Memorial 7 X 10 Foot Low-Speed Wind Tunnel at The Wichita State University has gone through many recent upgrades. One significant major upgrade has been the streamlining of the data acquisition and reduction system. This report covers the upgrades to the software and supersedes previous reports on the data reduction routines for three-dimensional models tested in the wind tunnel. A HP 9000/380 workstation processes the data by reduction and correction equations in a HP BASIC/UX program. For the data to be corrected, model and test section correction constants are required. These constants are used to correct the force and moment data for tunnel boundary and interference effects and to facilitate the reduction of the force and moment data into coefficient form. The data reduction methods and equations needed to calculate the proper model constants are presented as well as examples illustrating the methods. These examples and the methods presented in this report are only for three-dimensional models. Accuracy and rapid processing of data are of high importance in wind tunnel testing; accuracy and speed are achieved in this tunnel through the use of a HP 3852 Data Acquisition System. The final corrected data are presented to the customer in both graphical and tabulated forms in the reference axis or axes of their choice (body, wind, or stability). The on-line system is capable of providing immediate corrected tabulated data and plotted results affording real time monitoring of the test objectives and thus providing the wind tunnel user with an invaluable management tool for the customer's particular test requirements. Examples of the plotting capability are included. Author (revised)

N94-36763# Federal Aviation Administration, Washington, DC. Office of Airport Planning and Programming.
ACCOMPLISHMENTS UNDER THE AIRPORT IMPROVEMENT PROGRAM Annual Report No. 12, Fiscal Year 1993
1993 124 p
(AD-A280661; DOT/FAA/PP-94-2) Avail: CASI HC A06/MF A02

Annual report of the Airport Improvement Program (AIP) for the fiscal year ending September 30, 1993, is the twelfth report of activity under authority granted by the Airport and Airway Improvement Act of 1982, as amended. Section 521 of the Airport and Airway Improvement Act of 1982, as amended, requires that the Secretary of Transportation submit an annual report to Congress describing the accomplishments of the airport grant program. DTIC

N94-37424# Systems Control Technology, Inc., Arlington, VA.
ANALYSIS OF VERTIPORT STUDIES FUNDED BY THE AIRPORT IMPROVEMENT PROGRAM (AIP) Final Report
DEBORAH J. PEISEN, WILLIAM T. SAMPSON, LINDA J. LABELLE, BRIAN M. SAWYER, J. RICHARD LUDDERS, STEPHEN V. BERARDO, RICHARD J. DYMENT, SAMUEL W. FERGUSON, ROBERT M. WINICK, and CLIFFORD R. BRAGDON
May 1994 111 p
(Contract DTFA01-93-C-00030)
(SCT-93RR-21; DOT/FAA/RD-93/37) Avail: CASI HC A06/MF A02

It is expected that Advanced Vertical Flight (AVF) aircraft such as the Civil TiltRotor (CTR) will become viable, important vehicles for the relief of both ground and airport congestion. Furthermore, it is expected this will lead to expanded use of rotorcraft for scheduled passenger service. To prepare for this eventuality, the FAA in 1988 funded a program of vertiport feasibility studies. Thirteen locations, encompassing a range of cities, states, and regions, applied for and received funds. Canada conducted its own study. The purpose of these studies was to facilitate the use of AVF aircraft by identifying areas in the United States where the potential for missions using these aircraft is greatest so that infrastructure requirements could be identified and implemented in a timely manner. This report evaluates the fourteen studies to portray an overview of the status of potential scheduled passenger service and required vertiport development within the United States, Puerto Rico, and Canada. The report also evaluates the methodologies and assumptions used in these studies to reach conclusions regarding the feasibility of AVF aircraft service in these areas. Most studies concluded that the primary mission would be short-haul passenger service between city centers and major urban areas. Some studies, particularly in the lesser developed areas (Puerto Rico and Alaska), concluded that small package delivery and cargo missions were also feasible. Final conclusions and recommendations include suggestions for planning guidelines specifically for vertiports/large heliports developed primarily for passenger operations. Author

N94-37450*# Old Dominion Univ., Norfolk, VA. Dept. of Aerospace Engineering.
LARGE ANGLE MAGNETIC SUSPENSION TEST FIXTURE Progress Report, period ending 30 Apr. 1994
COLIN P. BRITCHER Jul. 1994 21 p
(Contract NAG1-1056)
(NASA-CR-196138; NAS 1.26:196138) Avail: CASI HC A03/MF A01

Over the past few decades, research has proven the feasibility of the concept of noncontacting magnetic bearing systems which operate with no wear or vibration. As a result, magnetic bearing systems are beginning to emerge as integral parts of modern industrial and aerospace systems. Further applications research is still required. NASA has loaned an existing magnetic bearing device, the Annular Suspension and Pointing System (ASPS), to ODU to permit student design teams the opportunity to pursue some of these studies. The ASPS is a protoype for a high-accuracy space payload pointing and vibration isolation system. The project objectives are to carry out modifications and improvements to the ASPS hardware to permit recommissioning in a 1-g (ground-based) environment. Following recommissioning, new applications will be studied and demonstrated, including a rotary joint for solar panels. The first teams designed and manufactured pole shims to reduce the air-gaps and raise the vertical force capability as well as on control system studies. The most recent team concentrated on the operation of a single bearing station, which was successfully accomplished with a PC-based digital controller. The paper will review the history and technical background of the ASPS hardware, followed by presentation of the progress made and the current status of the project. Author

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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.

A94-61628* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRELIMINARY PILOTED SIMULATION STUDIES OF THE HL-20 LIFTING BODY
ROBERT A. RIVERS NASA. Langley Research Center, Hampton, VA, E. BRUCE JACKSON, and W. A. RAGSDALE *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 556-563 refs
(BTN-94-EIX94401358972) Copyright

NASA Langley Research Center is developing a lifting body vehicle, designated the HL-20, as one option of the proposed Personnel Launch System for NASA's future manned access to space requirements. Data derived from wind-tunnel and computational fluid dynamics analyses of the conceptual design led to the derivation of a flight simulator model to investigate the potential flight characteristics of the HL-20. A simulation investigation was initiated to determine if satisfactory unpowered horizontal landings could be accomplished. Control law design and trajectory development were directed toward this end. The study uncovered several deficiencies subsequently corrected through design changes, and it validated the predicted subsonic aerodynamic properties. Expanding the investigation to the Mach 4 to Mach 1 regime revealed flight characteristics necessitating the development of innovative control techniques. This article will present the significant results uncovered to date by flight simulator evaluations of a lifting body class of vehicle, and will demonstrate the effectiveness of flight simulation as an integrated part of the conceptual design phase. Author (EI)

A94-61679
ANALYTIC SOLUTION OF THE RICCATI EQUATION FOR THE HOMING MISSILE LINEAR-QUADRATIC CONTROL PROBLEM
NEDELJKO LOVEREN Sarajevo Univ. (Yugoslovia) and MILOS TOMIC *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 3 May-June 1994 p. 619-621 refs
(BTN-94-EIX94401358173) Copyright

This Note has presented the analytic derivation of the optimal closed-loop guidance law for a finite-bandwidth homing missile intercepting a maneuvering target and has provided a simple analytic means of solving the matrix Riccati differential equation. The resulting optimal guidance law agrees with the result obtained by Cottrel and Asher. The major contribution of this Note lies in the analytic solution of the matrix Riccati differential equation. Author (EI)

N94-37000# Joint Publications Research Service, Arlington, VA.
JPRS REPORT: CENTRAL EURASIA. AVIATION AND COSMONAUTICS, NO. 5, MAY 1993

15 Mar. 1994 22 p Transl. into ENGLISH from various Russian articles
(JPRS-UAC-94-004) Avail: CASI HC A03/MF A01

Translated articles cover the following topics: mathematical modeling assists investigations of flight accidents; and SLBM conversion for civilian launches continues. 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.

A94-61113
MATERIALS PERFORMANCE IN ADVANCED COMBUSTION SYSTEMS
K. NATESAN Argonne Natl. Lab., Argonne, IL *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 331-337 refs
(BTN-94-EIX94311331065) Copyright

A number of advanced technologies are being developed to convert coal into clean fuels for use as feedstock in chemical plants and for power generation. From the standpoint of component materials, the environments created by coal conversion and combustion in these technologies and their interactions with materials are of interest. The trend in the new or advanced systems is to improve thermal efficiency and reduce the environmental impact of the process effluents. This paper discusses several systems that are under development and identifies requirements for materials application in those systems. Available data on the performance of materials in several of the environments are used to examine the performance envelopes for materials for several of the systems and to identify needs for additional work in different areas. Author (EI)

A94-61473
COATING THE BORON PARTICLES TO INCREASE THE COMBUSTION EFFICIENCY OF BORON FUEL
CHENFANG LI Xi'an Modern Chemistry Research Inst., Xi'an (China) *Tuijin Jishu/Journal of Propulsion Technology* (ISSN 1001-4055) no. 2 April 1994 p. 53-57 In CHINESE refs
(BTN-94-EIX94381353577) Copyright

To coat the boron particles is an effective way to increase combustion efficiency of boron fuel. The latest two processes to coat the boron fuel with titanium and boron carbide were introduced, and the study on the effect of boron with different coatings on the combustion property of ramjet rocket propellant was also described. EI

N94-36306 Argonne National Lab., IL.
WEAR-RESISTING OXIDE FILMS FOR 900 C
M. B. PETERSON (Wear Sciences, Inc., Arnold, MD.), S. Z. LI (Institute of Metal Research, Shenyang, China.), and S. F. MURRAY (Rensselaer Polytechnic Inst., Troy, NY.) Mar. 1994 56 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(Contract W-31-109-ENG-38)
(DE94-010093; ANL/OTM/CR-5) Avail: CASI HC A04

For the past 50 years, temperatures in advanced heat engines have been increasing. New-generation engines will require lubricants for 1000 C and higher. One of the most critical applications is the regenerator seals on the automotive gas turbine. In this seal, a metal plate slides against a porous ceramic surface for several thousand hours at speeds on the order of 10 cm/sec. For long-term usage above 900 C it will probably be necessary to use oxide lubricants. If effective ones can be found, then a simple solution would be available for an application like the regenerator seal: fabricate it with an alloy which forms a lubricating oxide. The objective of this study was to explore this concept for the regenerator seal. A study was conducted to develop low-friction, wear-resistant surfaces on high-temperature alloys for the temperature range 26 to 900 C. The approach investigated consisted of modifying the naturally occurring oxide film in order to improve its tribological properties. Improvement was needed at low temperatures where the oxide film, previously formed at high temperature, spalls due to stresses induced by sliding. Experiments with titanium, tungsten, and tantalum additions showed a beneficial effect when added to nickel and nickel alloys. Low friction was maintained down to 100 C from 900 C. For unalloyed nickel friction and surface damage increased at 400 to 500 C. Other approaches proved less successful and require further study. DOE

N94-36413*# Aluminum Co. of America, Alcoa Center, PA. Alloy Technology Div.
NEW DEVELOPMENTS IN ALUMINUM FOR AIRCRAFT AND AUTOMOBILES
JOCELYN I. PETIT *In* NASA. Langley Research Center, National Educators' Workshop: Update 1993. Standard Experiments in Engineering Materials Science and Technology p 419-450 Apr. 1994
Avail: CASI HC A03/MF A04

A common bond for the aircraft and automobile industry is the need for cost-efficient, lightweight structures such as provided by aluminum based materials. The topics are presented in viewgraph form and cover the following: new developments in aluminum for aircraft and automobiles; forces shaping future automotive materials needs; aluminum strength/weakness versus competitive materials; evolution of aluminum aerospace alloys; forces shaping future aircraft materials needs; fiber/metal structural laminates; and property requirements for jetliner and military transport applications. CASI

N94-36474# Allied-Signal Aerospace Co., Kansas City, MO.
REPLACEMENT OF SILICONE POLYMER A WITH SILICONE POLYMER B AND THE SUBSEQUENT CHARACTERIZATION OF THE NEW CELLULAR SILICONE MATERIALS
J. W. SCHNEIDER Apr. 1994 58 p
(Contract DE-AC04-76DP-00613)
(DE94-010105; KCP-613-5266) Avail: CASI HC A04/MF A01

The purpose of this project is to replace silicone polymer A with silicone polymer B produced by Vendor B. Silicone polymer B and the resulting B-50 cellular silicone have been used to produce cushions for the W87 program. Approximately 5.5 years of stress relaxation aging study data as well as actual part surveillance data have been collected, characterizing the stockpile life performance of the B-50 cellular silicone cushion material. Process characterization of new cellular silicone materials as a result of replacing silicone polymer A with silicone polymer B has been completed. Load deflection requirements for the new cellular silicone materials based on silicone polymer B have been met. The silicone polymer B based cellular silicone materials must be compounded at densities of approximately 0.03 g/cu cm less than the silicone polymer A based cellular silicone materials in order to achieve the same load deflection requirements has also been demonstrated. The change in silicone polymers from A to B involved a decrease in volatile content as well as a decrease in part shrinkage. DOE

N94-36505 Sandia National Labs., Albuquerque, NM.
ADVANCED THERMALLY STABLE, COAL-DERIVED, JET FUELS DEVELOPMENT PROGRAM. EXPERIMENT SYSTEM AND MODEL DEVELOPMENT Annual Report, Oct. 1992 - Sep. 1993
E. A. KLAVETTER, S. J. MARTIN, W. TROTT, and T. J. OHERN Dec. 1993 50 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(Contract DE-AC04-94AL-85000; DA PROJ. 3048)
(AD-A278968; WL-TR-94-2003) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

A program entitled 'Thermally Stable Jet Fuels Development' was initiated in FY89 by the U.S. Air Force, Aero Propulsion and Power Directorate, working jointly with the Department of Energy, Pittsburgh Energy Technology Center. Thermal stability of aviation fuels is of concern because of the potential operation problems arising from fuel degradation under thermal stress conditions. Sandia National Laboratories has been conducting efforts to develop instrumentation for monitoring characteristics of jet fuel degradation and solids deposition and develop models of those mechanisms from the data acquired using that instrumentation. This report describes the instrumentation development, data acquisition, and model parameter determination. DTIC

N94-36649# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
CHARACTERISATION OF FIBRE REINFORCED TITANIUM MATRIX COMPOSITES [LA CARACTERISATION DES MATERIAUX COMPOSITES A MATRICE DE TITANE RENFORCES PAR FIBRES]
Feb. 1994 260 p In ENGLISH and FRENCH The 77th Meeting was held in Bordeaux, France, 27-28 Sep. 1993 Original contains color illustrations
(AD-A2775206; AGARD-R-796; ISBN-92-835-0735-5) Copyright Avail: CASI HC A12/MF A03

The combination of stiffness, strength, and high temperature resistance provided by fiber reinforced titanium matrix composites offers major benefits for aircraft engine and airframe applications, where these materials could be used to reduce weight or improve performance. This workshop on the subject of characterization of titanium composites was intended to provide a forum for the exchange of information in this important area. Characterization in this case refers to the understanding of the behavior of the composites as it relates to the ability to predict their performance in real-life applications. It covers various topics that include mechanical test techniques, NDE methods, life prediction models, and other factors that will affect the level of confidence with which these relatively new materials will be accepted for application.

N94-36650# Wright Lab., Wright-Patterson AFB, OH. Materials Directorate.
POSSIBILITIES AND PITFALLS IN AEROSPACE APPLICATIONS OF TITANIUM MATRIX COMPOSITES
JAMES M. LARSEN, STEPHAN M. RUSS, and J. WAYNE JONES *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 21 p Feb. 1994 Sponsored by Systran Corp.
(Contract AF PROJ. 2302)
Copyright Avail: CASI HC A03/MF A03

High-temperature, light-weight materials represent enabling technology in the continued evolution of high-performance aerospace vehicles and propulsion systems being pursued by the U.S. Air Force. In this regard, titanium matrix composites (TMC's) appear to offer unique advantages in terms of a variety of weight-specific properties at high temperatures. However, a key requirement for eventual structural use of these materials is a balance of mechanical properties that can be suitably exploited by aircraft and engine designers without compromising reliability. An overview of the current capability of titanium matrix composites is presented, with an effort to assess the balance of properties offered by this class of materials. Emphasis is given to life-limiting cyclic and monotonic properties and the roles of high-temperature, time-dependent deformation and environmental effects. An attempt is made to assess the limitations of currently available titanium matrix composites with respect to application needs and to suggest avenues for improvements in key properties. Author

N94-36651# McDonnell-Douglas Corp., Saint Louis, MO.
APPLICATIONS OF TITANIUM MATRIX COMPOSITE TO LARGE AIRFRAME STRUCTURE
TIMOTHY M. WILSON *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 31 p Feb. 1994
Copyright Avail: CASI HC A03/MF A03

Advanced Titanium Matrix Composite (TMC) materials are being developed for structures that must withstand high temperatures, possess high stiffness and be lighter. Scale-up of the TMC material system from the laboratory environment to large structural components has required significant advancements in design, manufacturing and assembly technology. Numerous large scale, TMC components have been developed, fabricated and tested to verify the feasibility of structural/material concepts for hypersonic vehicles. These articles include thick laminate TMC wing structure, minimum gage TMC fuselage sections, and integrated TMC fuselage/cryogenic tank structure. A summary of the development and testing of these articles is presented. Author (revised)

N94-36652# Textron Specialty Materials, Lowell, MA.
SCS-6 (TM) FIBER REINFORCED TITANIUM
JIM HENSHAW *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 6 p Feb. 1994
Copyright Avail: CASI HC A02/MF A03

The low weight structurally efficient SCS-6 Fiber Reinforced Titanium, as produced by Textron Specialty Materials, is a material awaiting the development of production applications. A multitude of airframe and engine parts have been produced for test and developmental purposes and a production facility has been established to fabricate preforms, intermediary products, and component shapes. Author

N94-36655# British Petroleum Co. Ltd., Sunbury-on-Thames (England). Research and Engineering Centre.
MANUFACTURE AND PROPERTIES OF SIGMA FIBRE REINFORCED TITANIUM
J. G. ROBERTSON *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 8 p Feb. 1994
Copyright Avail: CASI HC A02/MF A03

Titanium Matrix Composites have long been known to offer pot ential for use in aeroengine components. The cost of producing the fiber and fabricating components has delayed large scale developments because of concern over long term component costs. The slow development pace has, in turn, kept the fiber and composite price high through low demand. Composite manufacturing routes using foil and filament wound fiber has been used for many years. The difficulties of maintaining a suitable fiber distribution during hot isostatic pressing and the availability of cheap foil have effectively put this technique on the shelf. However excellent fiber distributions have been achieved even in difficult geometries by a BP proprietary process. Mechanical properties comparable with the most expensive routes can be achieved with this, one of the cheapest manufacturing routes. Author

N94-37323# British Columbia Univ., Vancouver. Dept. of Metals and Materials Engineering.
ALTERNATE MELTING AND REFINING ROUTES
ALEC MITCHELL *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p Apr. 1993
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Although most research and development effort in turbine alloys has been in the past directed towards the understanding and improvement of basic properties, it is a telling comment on the results that at present we can only manufacture the components with a reliability which, in the example case of a high pressure turbine disk, leads to a service life of less than one-fifth of the theoretical life of the alloy component. The purpose of this presentation is to examine the reasons for this situation and to indicate ways in which we can improve on it. We conclude that the techniques of melting, refining and casting which are now being developed have the potential to make a large change in the in-service life of turbine components without any significant change in the state of alloy development. Author

N94-37324# Wright Lab., Wright-Patterson AFB, OH. Materials Dirctorate.
PROCESS ENHANCEMENTS OF SUPERALLOY MATERIAL
RONALD H. WILLIAMS, KRISTINE A. LARK, SHARON VUKELICH, DONALD R. PARILLE, and RICHARD W. SALKELD *In* AGARD, Impact of Materials Defects on Engine Structures

Integrity 6 p Apr. 1993
Copyright Avail: CASI HC A02/MF A02

Due to the ever-increasing demand for improvements in engine performance and better fuel efficiency, complex high pressure turbine (HPT) blade designs have been introduced into military engines. Greater emphasis has, therefore, been placed on increasing the structural integrity and life of engine components. Materials defects must be of a small enough size and sparse enough in population to enable the design of high thrust-to-weight ratio engines. This requirement has demanded the industry attainment of cleaner materials. In order to meet this requirement, possible process improvements were evaluated. Enhancements were incorporated into the melting and casting processes to reduce the size and number of dross defects within high pressure turbine blades. The accomplishment of this goal was through the efforts of a joint United States Air Force, Pratt & Whitney Task Force Team. Process implementation has been successful in reducing the remaining deleterious defects present in directionally solidified single crystal and polycrystalline nickel-base superalloy turbine blade materials. In conjunction with the introduction of melting and casting process improvements, the refinement of nondestructive inspection techniques was investigated. Author

N94-37325# Imphy S.A., Imphy (France).
THE CONTROL OF CLEANNESS IN POWDER METALLURGY MATERIALS FOR TURBINE DISKS
G. RAISSON *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 14 p Apr. 1993
Copyright Avail: CASI HC A03/MF A02

The origins of exogenous inclusions in powder metallurgy products are described and methodologies for assuring the quality of these alloys are reviewed. Elutriation, chemical dissolution, micrography, electron beam button melting, ultrasonic inspection, and other techniques are described and compared. CASI

N94-37326# Forge Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Gennevilliers (France).
MAINTAINING CONSTANT STANDARDS DURING THE FORGING PROCESS [MAITRISE DE LA REPRODUCTIBILITE DU PROCEDE DE FORGEAGE]
F. CHEVET and M. CARALP *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 23 p Apr. 1993
In FRENCH
Copyright Avail: CASI HC A03/MF A02

The properties of aircraft engine discs made of a titanium and nickel alloy may be notably improved if deformations and temperatures are monitored during the forging process. On engines of recent fabrication, this optimization through thermomechanical treatment is also systematically applied. As an answer to this need SNECMA is using a monitoring system in its metal processing plant: monitoring devices positioned on the heat deformation machinery record and statistically document the important parameters. This new monitoring system, taking place at the time of fabrication, makes it possible to immediately detect any variance in the fabrication and to rapidly correct any possible abnormality. Thus checking and ensuring total duplication of the fabrication becomes systematic and the quality control checks on the finished project (strongly linked to the conditions of transformation) have improved. Finally, because of the knowledge that was thus gained on the forging process, our command of the thermomechanical treatments was improved. Variations in parameters which were not recorded in the past and had an important influence on the microstructure of the parts were observed. Transl. by FLS

N94-37328# *Defence Research Agency, Farnborough, Hampshire (England).*
DEFECTS AND THEIR EFFECTS ON THE INTEGRITY OF NICKEL BASED AEROENGINE DISCS
G. F. HARRISON, P. H. TRANTER, and L. GRABOWSKI *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 16 p Apr. 1993
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By specific reference to the powder metallurgy alloy API the paper examines the role of defects in generating local residual stress fields. The effects of defect size and location on crack initiation and low cycle fatigue life are discussed. It is shown that at stress levels consistent with those experienced by current engine components, defects can act under cyclic loading as crack nucleators from cycle 1. Methods of calculating appropriate stress intensity factors are briefly reviewed and it is shown that at existing turbine disc operating temperatures, a linear elastic fracture mechanics stress intensity factor can be used to calculate crack growth rates. Finally, the major lifting methods used for aeroengine discs are briefly reviewed, and attention is drawn to the specific problems created by the presence of macrostructural defects. Author

12
ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A94-61050
WINDOW FUNCTIONS FOR THE CALCULATION OF THE TIME DOMAIN AVERAGES OF THE VIBRATION OF THE INDIVIDUAL PLANET GEARS AND SUN GEAR IN AN EPICYCLIC GEARBOX
P. D. MCFADDEN Oxford Univ., Oxford (England) *Journal of Vibration and Acoustics, Transactions o f the ASME* (ISSN 1048-9002) vol. 116, no. 2 April 1994 p. 179-187 refs
(BTN-94-EIX94311331047) Copyright

An existing technique which enables the estimation of the time domain averages of the tooth meshing vibration of the individual planet and sun gears in an epicyclic gearbox from measured vibration signals has been revised. A key feature of the existing technique is the sampling of the vibration signal within a rectangular window in the time domain when one of the planet gears is close to the vibration transducer. The revised technique permits the use of other window functions, and a detailed analysis shows that the errors in the estimate of the time domain average can be expressed in terms of the window function. Several suitable window functions which enable a reduction in the level of the errors are demonstrated by numerical examples and by the analysis of data from a test on a helicopter gearbox with deliberate damage to one of the planet gears. Author (EI)

A94-61057
MAINSTREAM INGRESS SUPPRESSION IN GAS TURBINE DISK CAVITIES
V. I. KHILNANI *Auburn Univ., Auburn, AL,* L. C. TSAI, S. H. BHAVNANI, J. M. KHODADADI, J. S. GOODLING, and J. WAGGOTT *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 339-346 refs
(BTN-94-EIX94311330101) Copyright

The sealing characteristics of an air-cooled gas turbine disk cavity have been studied using laser sheet flow visualization. Experiments were performed on a simplified half-scale model of an actual gas turbine disk cavity. This type of rotor-stator geometry with a double-toothed-rim (DTR) seal at the outer periphery and a labyrinth seal at the inner periphery of the cavity has been tested for its ability in preventing ingress of hot mainstream gases. The results show good agreement with previously estimated design data. Experiments were conducted for various labyrinth seal flow rates and rotational Reynolds numbers up to 1.52 x 10(exp 6). The effects of rotor eccentricity on minimum purge flows have also been discussed. Author (EI)

A94-61058
STUDY OF ROTOR CAVITIES AND HEAT TRANSFER IN A COOLING PROCESS IN A GAS TURBINE
R. S. AMANO Wisconsin Univ., Milwaukee, WI, K. D. WANG, and V. PAVELIC *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 333-338 *refs*
(BTN-94-EIX94311330100) Copyright

A high-temperature flow through a gas turbine produces a high rate of turbulent heat transfer between the fluid flow field and the turbine components. The heat transfer process through rotor disks causes thermal stress due to the thermal gradient just as the centrifugal force causes mechanical stresses; thus, an accurate analysis for the evaluation of thermal behavior is needed. This paper presents a numerical study of thermal flow analysis in a two-stage turbine in order to understand better the detailed flow and heat transfer mechanisms through the cavity and the rotating rotor-disks. The numerical computations were performed to predict thermal fields throughout the rotating disks. The method used in this paper is the segregation method, which requires a much smaller number of grids than actually employed in the computations. The results are presented for temperature distributions through the disk and the velocity fields, which illustrate the interaction between the cooling air flow and gas flow created by the disk rotation. The temperature distribution in the disks shows a reasonable trend. The numerical method developed in this study shows that it can be easily adapted for similar computations for air cooling flow patterns through any rotating blade disks in a gas turbine. Author (EI)

A94-61059
INGESTION INTO THE UPSTREAM WHEELSPACE OF AN AXIAL TURBINE STAGE
T. GREEN Univ of Sussex, Sussex, United Kingdom and A. B. TURNER *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 327-332 refs
(BTN-94-EIX94311330099) Copyright

The upstream wheelspace of an axial air turbine stage complete with nozzle guide vanes (NGVs) and rotor blades (430 mm mean diameter) has been tested with the objective of examining the combined effect of NGVs and rotor blades on the level of mainstream ingestion for different seal flow rates. A simple axial clearance seal was used with the rotor spun up to 6650 rpm by drawing air through it from atmospheric pressure with a large centrifugal compressor. The effect of rotational speed was examined for several constant mainstream flow rates by controlling the rotor speed with an air brake. The circumferential variation in hub static pressure was measured at the trailing edge of the NGVs upstream of the seal gap and was found to affect ingestion significantly. The hub static pressure distribution on the rotor blade leading edges was rotor speed dependent and could not be measured in the experiments. The Denton three-dimensional CFD computer code was used to predict the smoothed time-dependent pressure field for the rotor together with the pressure distribution downstream of the NGVs. The level and distribution of mainstream ingestion, and thus, the seal effectiveness, was determined from nitrous oxide gas concentration measurements and related to static pressure measurements made throughout the wheelspace. With the axial clearance rim seal close to the rotor the presence of the blades had a complex effect. Rotor blades in connection with NGVs were found to reduce mainstream ingestion seal flow rates significantly, but a small level of ingestion existed even for very high levels of seal flow rate. Author (EI)

A94-61060
TRANSFER OF HEAT BY SELF-INDUCED FLOW IN A ROTATING TUBE
S. GILHAM Atkins (W. S.) Consultants Ltd., Surrey (United Kingdom), P. C. IVEY, and J. M. OWEN *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 316-326 refs
(BTN-94-EIX94311330098) Copyright

This paper provides a review of recently published research on self-induced flow and heat transfer in a rotating tube, together with additional theoretical work on heat transfer to the cylindrical wall of the tube. Earlier work has shown that self-induced flow can occur when a tube, with one end open and the other sealed, is rotated about its axis: Fluid flows along the axis toward the sealed end and returns in an annular layer on the cylindrical wall. The flow and heat transfer on the end wall are similar to those associated with the so-called free disk, and measured velocity distributions in the tube and Nusselt numbers for the end wall are in good agreement with those computed from numerical solutions of the Navier-Stokes and energy equations. The Reynolds analogy is used in this paper to provide a correlation for the computed Nusselt numbers for the cylindrical wall, and design correlations are provided to enable the results to be applied to anti-icing systems for the nose bullets of aero-engines. Author (EI)

A94-61061
SIMULATION OF THE SECONDARY AIR SYSTEM OF AERO ENGINES
K. J. KUTZ Muenchen G.m.b.H., Munich (Germany) and T. M. SPEER *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 306-315 refs
(BTN-94-EIX94311330097) Copyright

This paper describes a computer program for the simulation of secondary air systems. Typical flow system elements are presented, such as restrictors, tappings, seals, vortices, and coverplates. Two-phase flow as occurring in bearing chamber vent systems is briefly discussed. An algorithm is described for the solution of the resulting nonlinear equations. The validity of the simulation over the engine operation envelope is demonstrated by a comparison with test results. Author (EI)

A94-61062
DETAILED FLOW MEASUREMENTS AND PREDICTIONS FOR A THREE-STAGE TRANSONIC FAN
W. J. CALVERT Defence Research Agency, Farnborough (England) and A. W. STAPLETON *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 298-305 refs
(BTN-94-EIX94311330096) Copyright

Detailed flow measurements were taken at DRA Pyestock on a Rolls-Royce three-stage transonic research fan using advanced laser transit velocimetry and holography techniques to supplement the fixed pressure and temperature instrumentation. The results have been compared with predictions using the DRA S1-S2 quasi-three-dimensional flow calculation system at a range of speeds. The agreement was generally encouraging, both for the overall performance and for details of the internal flow such as positions of shock waves. Taken together with the computational efficiency of the calculations and previous experience on single-stage transonic fans and core compressors, this establishes the S1-S2 system as a viable design tool for future multistage transonic fans. Author (EI)

A94-61063
ADVANCED TRANSONIC FAN DESIGN PROCEDURE BASED ON A NAVIER-STOKES METHOD
C. M. RHIE United Technologies Corp., East Hartford, CT, R. M. ZACHARIAS, D. E. HOBBS, K. P. SARATHY, B. P. BIEDERMAN, C. R. LEJAMBRE, and D. A. SPEAR *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 291-297 refs
(BTN-94-EIX94311330095) Copyright

A fan performance analysis method based upon three-dimensional steady Navier-Stokes equations is presented in this paper. Its accuracy is established through extensive code validation effort. Validation data comparisons ranging from a two-dimensional compressor cascade to three-dimensional fans are shown in this paper to highlight the accuracy and reliability of the code. The overall fan design procedure using this code is then presented. Typical results of this design process are shown for a current engine fan design. This new design method introduces a major improvement over the conventional design methods based on inviscid flow and boundary layer concepts. Using the Navier-Stokes design method, fan designers can confidently refine their designs prior to rig testing. This results in reduced rig testing and cost savings as the bulk of the iteration between design and experimental verification is transferred to an iteration between design and computational verification. Author (EI)

A94-61098
INCREASED USE OF GAS TURBINES AS COMMERCIAL MARINE ENGINES
C. O. BRADY General Electric Co., Evendale, OH and D. L. LUCK *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 428-433 refs
(BTN-94-EIX94311331080) Copyright

Over the last three decades, aeroderivative gas turbines have become established naval ship propulsion engines, but use in the commercial marine field has been more limited. Today, aeroderivative gas turbines are being increasingly utilized as commercial marine engines. The primary reason for the increased use of gas turbines is discussed and several recent GE aeroderivative gas turbine commercial marine applications are described with particular aspects of the gas turbine engine installations detailed. Finally, the potential for future commercial marine aeroderivative gas turbine applications is presented. Author (EI)

A94-61099
MASHPROEKT SCIENTIFIC AND PRODUCTION ASSOCIATION: A DESIGNER OF GAS TURBINES FOR MARINE AND INDUSTRIAL APPLICATIONS
V. I. ROMANOV SPA Mashproekt, Nikolayev (Ukraine) *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 424-427
(BTN-94-EIX94311331079) Copyright

The paper describes the history of the development of gas turbine engines by the Mashproekt scientific and production association for marine and industrial applications. EI

A94-61100
INVESTIGATION OF THE PART-LOAD PERFORMANCE OF TWO 1.12 MW REGENERATIVE MARINE GAS TURBINES
T. KORAKIANITIS Washington Univ., St. Louis, MO and K. J. BEIER *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 418-423 refs
(BTN-94-EIX94311331078) Copyright

Regenerative and intercooled-regenerative gas turbine engines with low pressure ratio have significant efficiency advantages over traditional aero-derivative engines of higher pressure ratios, and can compete with modern diesel engines for marine propulsion. Their performance is extremely sensitive to thermodynamic-cycle parameter choices and the type of components. The performances of two 1.12 MW (1500 hp) regenerative gas turbines are predicted with computer simulations. One engine has a single-shaft configuration, and the other has a gas-generator/power-turbine combination. The latter arrangement is essential for wide off-design operating regime. The performance of each engine driving fixed-pitch and controllable-pitch propellers, or an AC electric bus (for electric-motor-driven propellers) is investigated. For commercial applications the controllable-pitch propeller may have efficiency advantages (depending on engine type and shaft arrangements). For military applications the electric drive provides better operational flexibility. Author (EI)

A94-61101
ELECTRIC DRIVES ON THE LV100 GAS TURBINE ENGINE
W. D. JONES General Electric Aircraft Engines, Lynn, MA and A. R. FLETCHER, JR. *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 411-417 refs
(BTN-94-EIX94311331077) Copyright

The LV100 gas turbine engine is being developed for U.S. Army ground vehicle use. A unique approach for controls and accessories is being used whereby the engine has no accessory gearbox. Instead a high-speed starter/generator is mounted directly on the compressor shaft and powers all engine accessories as well as supplies the basic electrical power needs of the vehicle. This paper discusses the evolution of the electrically driven LV100 accessory system starting with the Advanced Integrated Propulsion System (AIPS) demonstrator program, through the current system to future possibilities with electric vehicle propulsion. Issues in electrical vehicle propulsion are discussed including machine type, electrical power type, and operation with a gas turbine. Author (EI)

A94-61102
SELECTION CRITERIA FOR PLAIN AND SEGMENTED FINNED TUBES FOR HEAT RECOVERY SYSTEMS
D. R. REID FINTUBE Corp., Tulsa, OK and J. TABOREK *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 406-410 refs
(BTN-94-EIX94311331076) Copyright

Heat recovery heat exchangers with gas as one of the streams depend on the use of finned tubes to compensate for the inherently low gas heat transfer coefficient. Standard frequency welded 'plain' fins were generally used in the past, until the high-frequency resistance welding technology permitted a cost-effective manufacture of 'segmented' fins. The main advantage of this fin design is that it permits higher heat flux and hence smaller, lighter weight units for most operating conditions. While the criteria that dictate optimum design, such as compactness, weight, and cost per unit area favor the segmented fin design, a few other considerations such as fouling, ease of cleaning, and availability of dependable design methods have to be considered. This paper analyzes the performance parameters that affect the selection of either fin type. Author (EI)

A94-61104
INFLUENCE OF HIGH ROTATIONAL SPEEDS ON HEAT TRANSFER AND OIL FILM THICKNESS IN AERO-ENGINE BEARING CHAMBERS
S. WITTIG Universitaet Karlsruhe (T.H.), Karlsruhe, Germany, A. GLAHN, and J. HIMMELSBACH *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 395-401 refs
(BTN-94-EIX94311331074) Copyright

Increasing the thermal loading of bearing chambers in modern aero-engines requires advanced techniques for the determination of heat transfer characteristics. In the present study, film thickness and heat transfer measurements have been carried out for the complex two-phase oil/air flow in bearing chambers. In order to ensure real engine conditions, a new test facility has been built up, designed for rotational speeds up to n = 16,000 rpm and maximum flow temperatures of T(sub max) = 473 K. Sealing air and lubrication oil flow can be varied nearly in the whole range of aero-engine applications. Special interest is directed toward the development of an ultrasonic oil film thickness measuring technique, which can be used without any reaction on the flow inside the chamber. The determination of local heat transfer at the bearing chamber housing is based on a well-known temperature gradient method using surface temperature measurements and a finite element code to determine temperature distributions within the bearing chamber housing. The influence of high rotational speed on the local heat transfer and the oil film thickness is discussed. Author(EI)

A94-61105
NEW HIGH-EFFICIENCY HEAVY-DUTY COMBUSTION TURBINE 701F
I. FUKUE Mitsubishi Heavy Industries, Ltd., Takasago, Japan, S. AOKI, K. AOYAMA, S. UMEMURA, A. MEROLA, M. NOCETO, and M. ROSSO *Journal of Engineering for Gas Turbines and*

Power, Transactions of the ASME (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 389-394 refs
(BTN-94-EIX94311331073) Copyright

The 701F is a high-temperature 50 Hz industrial grade 220 MW size engine based on a scaling of the 501F 150 MW class 60 Hz machine, and incorporates a higher compressor pressure ratio to increase the thermal efficiency. The prototype engine is under a two-year performance and reliability verification testing program at MHI's Yokohama Plant and was initially fired in June of 1992. This paper describes the 701F design features design changes made from 501F. The associated performance and reliability verification test program are also presented. Author (EI)

A94-61106
MODELS FOR PREDICTING THE PERFORMANCE OF BRAYTON-CYCLE ENGINES
T. KORAKIANITIS Washington Univ., St. Louis, MO and D. G. WILSON *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 381-388 refs
(BTN-94-EIX94311331072) Copyright

Gas turbine performance is the result of choices of type of cycle, cycle temperature ratio, pressure ratio, cooling flows, and component losses. The output is usually given as efficiency (thermal, propulsive, specific thrust, overall efficiency) versus specific power. This paper presents a set of computer programs for the performance prediction of shaft-power and jet-propulsion cycles: simple, regenerative, intercooled-regenerative, turbojet, and turbofan. Each cycle is constructed using individual component modules. Realistic assumptions are specified for component efficiencies as functions of pressure ratio, cooling mass-flow rate as a function of cooling technology levels, and various other cycle losses. The programs can be used to predict design point and off-design point operation using appropriate component efficiencies. The effects of various cycle choices on overall performance are discussed. Author (EI)

A94-61107
FAULT DIAGNOSIS IN GAS TURBINES USING A MODEL-BASED TECHNIQUE
G. L. MERRINGTON DSTO, Victoria, Australia *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 374-380 refs
(BTN-94-EIX94311331071) Copyright

Reliable methods for diagnosing faults and detecting degraded performance in gas turbine engines are continually being sought. In this paper, a model-based technique is applied to the problem of detecting degraded performance in a military turbofan engine from take-off acceleration-type transients. In the past, difficulty has been experienced in isolating the effects of some of the physical processes involved. One such effect is the influence of the bulk metal temperature on the measured engine parameters during large power excursions. It will be shown that the model-based technique provides a simple and convenient way of separating this effect from the faster dynamic components. The important conclusion from this work is that good fault coverage can be gleaned from the resultant pseudo-steady-state gain estimates derived in this way. Author (EI)

A94-61108
ASSESSMENT OF WEIGHTED-LEAST-SQUARES-BASED GAS PATH ANALYSIS
D. L. DOEL GE Aircraft Engines, Evendale, OH *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 366-373 refs
(BTN-94-EIX94311331070) Copyright

Manufacturers of gas turbines have searched for three decades for a reliable way to use gas path measurements to determine the health of jet engine components. They have been hindered in this pursuit by the quality of the measurements used to carry out the analysis. Engine manufacturers have chosen weighted-least-squares techniques to reduce the inaccuracy caused by sensor error. While these algorithms are clearly an improvement over the previous generation of gas path analysis programs, they still fail in many situations. This paper describes some of the failures and explores their relationship to the underlying analysis technique. It also describes difficulties in implementing a gas path analysis program. The paper concludes with an appraisal of weighted-least-squares-based gas path analysis. Author (EI)

A94-61109
PERFORMANCE AND ECONOMIC ENHANCEMENT OF COGENERATION GAS TURBINES THROUGH COMPRESSOR INLET AIR COOLING
M. DELUCIA Universita di Firenze, Firenze, Italy, R. BRONCONI, and E. CARNEVALE *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 360-365 refs
(BTN-94-EIX94311331069) Copyright

Gas turbine air cooling systems serve to raise performance to peak power levels during the hot months when high atmospheric temperatures cause reductions in net power output. This work describes the technical and economic advantages of providing a compressor inlet air cooling system to increase the gas turbine's power rating and reduce its heat rate. The pros and cons of state-of-the-art cooling technologies, i.e., absorption and compression refrigeration, with and without thermal energy storage, were examined in order to select the most suitable cooling solution. Heavy-duty gas turbine cogeneration systems with and without absorption units were modeled, as well as various industrial sectors, i.e., paper and pulp, pharmaceuticals, food processing, textiles, tanning, and building materials. The ambient temperature variations were modeled so the effects of climate could be accounted for in the simulation. The results validated the advantages of gas turbine cogeneration with absorption air cooling as compared to other systems without air cooling. Author (EI)

A94-61111
EFFECT OF PRESSURE ON SECOND-GENERATION PRESSURIZED FLUIDIZED BED COMBUSTION PLANTS
A. ROBERTSON Foster Wheeler Development Corp, Livingston, NJ and D. BONK *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 345-351 refs
(BTN-94-EIX94311331067) Copyright

In the search for a more efficient, less costly, and more environmentally responsible method for generating electrical power from coal, research and development has turned to advanced pressurized fluidized bed combustion (PFBC) and coal gasification technologies. A logical extension of this work is the second-generation PFBC plant, which incorporates key components of each of these technologies. In this new type of plant, coal is devolatilized/carbonized before it is injected into the PFB combustor bed, and the low-Btu fuel gas produced by this process is burned in a gas turbine topping combustor. By integrating coal carbonization with PFB coal/char combustion, gas turbine inlet temperatures higher than 1149 deg C (2100 deg F) can be achieved. The carbonizer, PFB combustor, and particulate-capturing hot gas cleanup systems operate at 871 deg C (1600 deg F), permitting sulfur capture by lime-based sorbents and minimizing the release of coal contaminants to the gases. This paper presents the performance and economics of this new type of plant and provides a brief overview of the pilot plant test programs being conducted to support its development. Author (EI)

A94-61116
WORKING GROUP ACTIVITIES OF AGARD PROPULSION AND ENERGETICS PANEL
A. S. UCER METU, Ankara, Turkey *Journal of Engineering for Gas Turbines and Power, Transactions of the ASME* (ISSN 0742-4795) vol. 116, no. 2 April 1994 p. 307-314 refs
(BTN-94-EIX94311331062) Copyright

One of the major activities of AGARD panels is to form working groups, which assemble experts who work on the particular subject for two or three years. As a result of the work, an advisory report is published, which complies the state-of-the-art knowledge on the chosen specific topic. This paper explains the philosophy and procedures adopted during the formation of working groups of the Propulsion and Energetics Panel. Working groups concerning gas turbine technologies are presented. The selected working groups aim to improve the computational and experimental knowledge that would lead to the design of advanced aero gas turbine engines. Objective, scope, procedure, and important results of each working group will be explained. Working groups that were active during the 1980s and which were presently active are covered. Author (EI)

A94-61125

INVISCID-VISCOUS INTERACTION METHOD FOR THREE-DIMENSIONAL INVERSE DESIGN OF CENTRIFUGAL IMPELLERS

M. ZANGENEH Univ. Coll. of London, London (United Kingdom) *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 280-290 refs
(BTN-94-EIX94311330094) Copyright

A three-dimensional design method for the design of the blade geometry of centrifugal compressor impellers is presented. In this method the blade shape is computed for a specified circulation distribution, normal (or tangential) thickness distribution, and meridional geometry. As the blade shapes are computed by using an inviscid slip (or flow tangency) condition, the viscous effects are introduced indirectly by using a viscous/inviscid procedure. The three-dimensional Navier-Stokes solver developed by Dawes is used as the viscous method. Two different approaches are described for incorporating the viscous effects into the inviscid design method. One method is based on the introduction of an aerodynamic blockage distribution throughout the meridional geometry, while in the other approach a vorticity term directly related to the entropy gradients in the machine is introduced. The method is applied to redesign the blade geometry of Eckardt's 30 deg backswept impeller as well as a generic high pressure ratio (transonic) impeller. The results indicate that the entropy gradient approach can fairly accurately represent the viscous effects in the machine. Author (EI)

A94-61126

EXPERIMENTAL INVESTIGATION OF THE STEADY AND UNSTEADY RELATIVE FLOW IN A MODEL CENTRIFUGAL IMPELLER PASSAGE

M. ABRAMIAN Pratt and Whitney Canada, Mississauga (Ontario) and J. H. G. HOWARD *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 269-279
(BTN-94-EIX94311330093) Copyright

The behavior of the relative flow in centrifugal turbomachines is extremely complex due to the existence of various fluid dynamic phenomena and their interaction. At design and off-design operating conditions, the relative flow is subject to stationary unsteadiness, which includes flow separation and wakes associated with passage pressure gradients, secondary flows, and boundary layer stability. It may also be subject to periodic unsteadiness, as are the rotating stall and cyclic flow phenomena induced by the casing. This paper describes detailed measurements of the relative velocity field in a very low specific speed centrifugal pump impeller (N(sub s) = 515). Measurements were conducted by means of a recently developed rotating laser-Doppler anemometry system. Detailed quantitative descriptions of the mean and fluctuating components of the primary and secondary velocity fields are presented for an impeller without volute at design, 50 percent design, and shut-off conditions. The flow pattern in this low specific speed impeller with high blade loading is dominated by the relative eddy (a phenomenon also present in potential flow), which has suppressed suction side separation. The cyclic variation of the impeller exit flow, induced by the volute at low flow rates, is also presented for an impeller fitted with a volute. Author (EI)

A94-61127

ROTATING LASER-DOPPLER ANEMOMETRY SYSTEM FOR UNSTEADY RELATIVE FLOW MEASUREMENTS IN MODEL CENTRIFUGAL IMPELLERS

M. ABRAMIAN Pratt and Whitney Canada, Mississauga (Ontario) and J. H. G. HOWARD *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 260-268 refs
(BTN-94-EIX94311330092) Copyright

The behavior of the relative flow in centrifugal turbomachines is extremely complex due to the existence of various fluid dynamic phenomena and their interaction. At design and off-design operating conditions, the relative flow is subject to stationary unsteadiness, which includes the flow separation and wakes associated with passage pressure gradients, secondary flows, and boundary layer stability. It is also subject to periodic unsteadiness from the rotating stall and the cyclic flow phenomena induced by the casing. This paper describes the mechanical and optical design of a rotating laser-Doppler anemometry system, which allows direct measurement of the relative flow by means of an optical derotator. By isolating the impeller rotational frequency from the sampling frequency, it allows direct time-averaged measurements of the stationary behavior of the relative flow along with the ensemble (phase)-averaged measurements of its periodic behavior. Its success is demonstrated with measurements conducted in a low specific speed centrifugal impeller fitted with a single volute. Sample results of the time-averaged blade-to-blade variation of total relative velocities along with their associated turbulence intensities are reported. The (periodic) cyclic variations of the impeller exit flow, induced by the volute at low flow rates, are also presented for the suction and pressure sides. Author (EI)

A94-61128

OPERATIONAL STABILITY OF A CENTRIFUGAL COMPRESSOR AND ITS DEPENDENCE ON THE CHARACTERISTICS OF THE SUBCOMPONENTS

R. HUNZIKER ETH Swiss Federal Inst. of Tech., Zurich (Switzerland) and G. GYARMATHY *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 250-259
(BTN-94-EIX94311330091) Copyright

A centrifugal compressor was tested with three different diffusers with circular-arc vanes. The vane inlet angle was varied from 15 to 30 deg. Detailed static wall pressure measurements show that the pressure field in the diffuser inlet is very sensitive to flow rate. The stability limit regularly occurred at the flow rate giving the maximum pressure rise for the overall stage. Mild surge arises as a dynamic instability of the compression system. The analysis of the pressure rise characteristic of each individual subcomponent (impeller, diffuser inlet, diffuser channel,...) reveals their contribution to the overall pressure rise. The diffuser channels play an inherently destabilizing role while the impeller and the diffuser inlet are typically stabilizing. The stability limit was mainly determined by a change in the characteristic of the diffuser inlet. Further, the stability limit was found to be independent of the development of inducer-tip recirculation. Author (EI)

A94-61129

DEVELOPMENTS IN CENTRIFUGAL COMPRESSOR SURGE CONTROL: A TECHNOLOGY ASSESSMENT

K. K. BOTROS NOVACOR Research and Technology Corp., Calgary (Alberta) and J. F. HENDERSON *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 240-249
(BTN-94-EIX94311330090) Copyright

There are a number of surge control schemes in current use for centrifugal compressors employed in natural gas transmission systems. Basically, these schemes consist of a set of detection devices that either anticipate surge or detect it at its inception, and a set of control devices that act to prevent surge from occurring. A patent search was conducted in an attempt to assess the level and direction of technology development over the last 20 years and to define the focus for future R&D activities. In addition, the paper presents the current state of technology in three areas: surge control, surge detection, and surge suppression. Patent data obtained from on-line databases showed that most of the emphasis has been on surge control rather than on detection and control and that the current trend in surge control will likely continue toward incremental improvement of a basic or conventional surge control strategy. Various surge suppression techniques can be grouped in two categories: (i) those that are focused on better compressor interior design, and (ii) others that attempt to suppress surge by external and operational means. Author (EI)

A94-61130

ACTIVE STABILIZATION OF ROTATING STALL IN A THREE-STAGE AXIAL COMPRESSOR

J. M. HAYNES Massachusetts Inst. of Tech., Cambridge, MA, G. J. HENDRICKS, and A. H. EPSTEIN *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 226-239 refs
(BTN-94-EIX94311330089) Copyright

A three-stage, low-speed axial research compressor has been actively stabilized by damping low-amplitude circumferentially traveling waves, which can grow into rotating stall. Using a circumferential array of hot-wire sensors, and an array of high-speed individually positioned control vanes as the actuator, the first and second spatial harmonics of the compressor were stabilized down to a characteristic slope of 0.9, yielding an 8 percent increase in operating flow range. Stabilization of the third spatial harmonic did not alter the stalling flow coefficient. The actuators were also used open loop to determine the forced response behavior of the compressor. A system identification procedure applied to the forced response data then yielded the compressor transfer function. The Moore-Greitzer two-dimensional stability model was modified as suggested by the measurements to include the effect of blade row time lags on the compressor dynamics. This modified Moore-Greitzer model was then used to predict both the open and closed-loop dynamic response of the compressor. The model predictions agreed closely with the experimental results. In particular, the model predicted both the mass flow at stall without control and the design parameters needed by, and the range extension realized from, active control.
Author (EI)

A94-61131

STALL INCEPTION AND DEVELOPMENT IN AN AXIAL FLOW AEROENGINE

A. G. WILSON Rolls-Royce PLC, Derby (United Kingdom) and C. FREEMAN *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 216-225 refs
(BTN-94-EIX94311330088) Copyright

This paper describes the phenomenon of stall and surge in an axial flow aeroengine using fast response static pressure measurements from the compressor of a Rolls-Royce VIPER engine. It details the growth of flow instability at various speeds, from a small zone of stalled fluid involving only a few blades into the violent surge motion of the entire machine. Various observations from earlier theoretical and compressor rig results are confirmed by these new engine measurements. The main findings are as follows: (1) The point of stall inception moves rearward as engine speed increases, and is shown to be simply related to the axial matching of the compressor. (2) The final unstable operation of the machine can be divided into rotating stall at low speed and surge or multiple surge at high speed. (3) The inception process is independent of whether the final unstable operation is rotating stall or multiple surge. (4) Stall/surge always starts as a circumferentially small flow disturbance, rotating around the annulus at some fraction of rotor speed. Author (EI)

A94-61132

REVIEW OF NONSTEADY FLOW MODELS FOR COMPRESSOR STABILITY

J. P. LONGLEY Cambridge Univ., Cambridge (United Kingdom) *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 202-215
(BTN-94-EIX94311330087) Copyright

This paper presents a review of the different approaches to modeling the nonsteady fluid dynamics associated with two-dimensional compressor flow fields. These models are used to predict the time development of flow field disturbances and have been found useful in both the study of rotating stall and the development of active control. The opportunity to digest the earlier investigations has now made it possible to express the modeling ideas using only a very simple mathematical treatment. Here, the emphasis is on the underlying physical processes that the models simulate and how the assumptions within the models affect predictions. The purpose of this work is to produce, in a single document, a description of compressor modeling techniques, so that prospective users can assess which model is the most suitable for their application. Author (EI)

A94-61133

UNSTABLE BEHAVIOR OF LOW AND HIGH-SPEED COMPRESSORS

I. J. DAY Cambridge Univ., Cambridge (United Kingdom) and C. FREEMAN *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 194-201 refs
(BTN-94-EIX94311330086) Copyright

By far the greater part of our understanding about stall and surge in axial compressors comes from work on low-speed laboratory machines. As a general rule, these machines do not model the compressibility effects present in high-speed compressors and therefore doubt has always existed about the application of low-speed results to high-speed machines. In recent years interest in active control has led to a number of studies of compressor stability in engine-type compressors. The instrumentation used in these experiments has been sufficiently detailed that, for the first time, adequate data are available to make direct comparisons between high-speed and low-speed compressors. This paper presents new data from an eight-stage fixed geometry engine compressor and compares them with low-speed laboratory data. The results show remarkable similarities in both the stalling and surging behavior of the two machines, particularly when the engine compressor is run at intermediate speeds. The engine results also show that, as in the laboratory tests, surge is precipitated by the onset of rotating stall. This is true even at very high speeds where it had previously been thought that surge might be the result of a blast wave moving through the compressor. This paper therefore contains new information about high-speed compressors and confirms that low-speed testing is an effective means of obtaining insight into the behavior of high-speed machines. Author (EI)

A94-61134

SPANWISE TRANSPORT IN AXIAL-FLOW TURBINES. PART 2: THROUGHFLOW CALCULATIONS INCLUDING SPANWISE TRANSPORT

K. L. LEWIS Cambridge Univ., Cambridge (United Kingdom) *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 187-193 refs
(BTN-94-EIX94311330085) Copyright

In Part 1 of this paper, a repeating stage condition was shown to occur in two low aspect ratio turbines, typically after two stages. Both turbulent diffusion and convective mechanisms were responsible for spanwise transport. In this part, two scaling expressions are determined that account for the influence of these mechanisms in effecting spanwise transport. These are incorporated into a throughflow model using a diffusive term. The inclusion of spanwise transport allows the use of more realistic loss distributions by the designer as input to the throughflow model and therefore focuses attention on areas where losses are generated. In addition, modeling of spanwise transport is shown to be crucial in predicting the attenuation of a temperature profile through a turbine. Author (EI)

A94-61135

SPANWISE TRANSPORT IN AXIAL-FLOW TURBINES. PART 1: THE MULTISTAGE ENVIRONMENT

K. L. LEWIS Cambridge Univ., Cambridge (United Kingdom) *Journal of Turbomachinery, Transactions of the ASME* (ISSN 0889-504X) vol. 116, no. 2 April 1994 p. 179-186 refs (BTN-94-EIX94311330084) Copyright

Selected experimental results, obtained from a detailed investigation into the flow fields within two low-speed multistage turbines, are presented. A repeating stage condition occurred typically after two stages, with the secondary flows an important factor in the low aspect ratio geometry. A tracer gas technique was employed to identify the dominant mechanisms of spanwise transport and their relative significance. In the first stages of both machines, tracer transport was more intense near the endwalls than at midspan, while in the multistage environment the transport was approximately constant across the whole span. The convective influence of classical secondary flow, shroud leakage, and wake passage through a downstream blade was identified and shown to be as significant as turbulent diffusion in effecting cross-passage and spanwise transport. The data show that spanwise transport should be included within any throughflow model and are used to calibrate two scaling models. These models are presented in Part 2, where the influence of incorporating spanwise transport into a throughflow model is investigated. Author (EI)

A94-61203

DESIGN OF A MULTI-CHANNEL TRUE FLAT FLUORESCENT LAMP FOR AVIONIC AM-LCD BACKLIGHTING

MUNISAMY ANANDAN Thomas Electronics, Inc., Wayne, NJ, DOUGLAS KETCHUM, HANK ETLINGER, ROBERT KIRKER, and WILLIAM CARR *IEEE Transactions on Electron Devices* (ISSN 0018-9383) vol. 41, no. 4 April 1994 p. 504-510 refs (BTN-94-EIX94311330477) Copyright

For backlighting a direct view avionic liquid crystal display (LCD), a multi-channel true flat fluorescent lamp (T-FFL) has been designed and developed. The design and development was accomplished through 1) electric field plot for various ratios of depth to height of the hollow cathode, 2) decrease of charge losses, 3) employment of internal dielectric mirror, 4) monitoring of the penetration of internal positive column, and 5) design of a constant current drive for T-FFL. A luminance of 3000 fL. with a luminous efficiency of 16.2 l/w has been achieved on a 3double prime diagonal T-FFL. Author (EI)

A94-61615

STABILITY OF SKEW PLATES SUBJECTED TO AERODYNAMIC AND IN-PLANE FORCES

T. H. YOUNG National Taiwan Inst. of Tech., Taipei (Taiwan, Province of China) and F. Y. CHEN *Journal of Sound and Vibration* (ISSN 0022-460X) vol. 171, no. 5 April 14, 1994 p. 603-615 refs (BTN-94-EIX94321331202) Copyright

In this paper an investigation is presented into the stability of skew plates acted upon by both aerodynamic and in-plane forces simultaneously. The in-plane force is assumed to be small in magnitude compared to the aerodynamic force. Due to this small in-plane force, the system may become unstable before the aerodynamic force reaches its critical value. A finite element formulation is used to obtain the discretized system equations. The system equations are then partially uncoupled and reduced in size by the modal truncation method. Finally, the method of multiple scales is used to determine the transition curves of the system. The effects of system parameters on the boundaries of the unstable regions are studied numerically. Author (EI)

A94-61641

UNSTRUCTURED MESH QUALITY ASSESSMENT AND UPWIND EULER SOLUTION ALGORITHM VALIDATION

PAUL R. WOODARD Purdue Univ., West Lafayette, IN, JOHN T. BATINA, and HENRY T. Y. YANG *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 644-650 refs (BTN-94-EIX94401358985) Copyright

Quality assessment procedures are described for two and three dimensional unstructured meshes. The procedures include measurement of minimum angles, element aspect ratios, stretching, and element skewness. Meshes about the ONERA M6 wing and the Boeing 747 transport configuration are generated using an advancing front method grid generation package of programs. Solutions of the Euler equations for these meshes are obtained at low angle of attack, transonic conditions. Results for these cases, obtained as part of a validation study, investigate accuracy of an implicit upwind Euler solution algorithm. Author (EI)

A94-61767

ADAPTIVE MODEL ARCHITECTURE AND EXTENDED KALMAN-BUCY FILTERS

PETER J. COSTA Univ. of Saint Thomas, St. Paul, MN *IEEE Transactions on Aerospace and Electronic Systems* (ISSN 0018-9251) vol. 30, no. 2 April 1994 p. 525-533 refs (BTN-94-EIX94401377806) Copyright

In radar systems, extended Kalman-Bucy filters (EKBFs) are used to estimate state vectors of objects in track. Filter models accounting for fundamental aerodynamic forces on reentry vehicles are well known. A general model structure accommodating the dynamics of reentry vehicles in both exoatmospheric and endoatmospheric flight is presented. The associated EKBFs for these various models are described and the resulting associated parameter estimation and identification problems are discussed. The effects of position, velocity, drag, and aerodynamic lift are described within a nested set of EKBF models. Author (EI)

A94-61805

BUCKLING AND VIBRATION ANALYSIS OF LAMINATED PANELS USING VICONOPT

DAVID KENNEDY University Coll., Cardiff (United Kingdom), FRED W. WILLIAMS, and MELVIN S. ANDERSON *Journal of Aerospace Engineering* (ISSN 0893-1321) vol. 7, no. 3 July 1994 p. 245-262 refs (BTN-94-EIX94401372105) Copyright

The analysis aspects of the 23,000-line FORTRAN program VICONOPT are described. Overall stiffness matrices assembled from the earlier exact VIPASA flat plate stiffnesses are optionally coupled by Lagrangian multipliers to find critical buckling loads, or natural frequencies of undamped vibration, of prismatic assemblies of anisotropic flat plates with arbitrarily located point supports or simple transverse supporting frames. The longitudinal continuity of typical wing and fuselage panels is closely approximated because the solutions are for the infinitely long structure obtained by repeating a bay and its supports longitudinally. Any longitudinally invariant in-plane plate stresses are permitted, and very rapid solutions are guaranteed by numerous refinements, including multilevel substructuring and a method for repetitive cross sections that is exact for regular polygons used to represent cylinders. Modal displacements and stresses in or between plies of laminated plates are calculated and plotted, with values being recovered at all nodes of substructures. Comparison with usual approximate finite-element methods confirms that, for comparably converged solutions, VICONOPT is typically between 100 and 10(sup 4) times faster. Author (EI)

A94-61853

NUMERICAL SIMULATION OF VORTEX-WEDGE INTERACTION

JIN-HO PARK Korea Advanced Institute of Science and Technology, Taejon, Korea and DUCK JOO LEE *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1126-1134

refs
(BTN-94-EIX94421374955) Copyright

Interactions between vortical flows and a solid surface cause one of the primary sources of noise and unsteady loading. The mechanism of the interaction is studied numerically for single Rankine vortex impinging upon a wedge. A Euler-Lagrangian method is used to describe the vorticity dominant field. EI

A94-61862
BOUNDARY CONDITIONS FOR UNSTEADY SUPERSONIC INLET ANALYSES
DAVID W. MAYER Boeing Commercial Airplane Group, Seattle, WA and GERALD C. PAYNTER *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1200-1206 refs
(BTN-94-EIX94421374964) Copyright

New bleed and compressor face boundary conditions have been developed to improve the accuracy of unsteady supersonic inlet calculations. The new bleed boundary conditions relate changes in the bleed hole discharge coefficient to changes in the local flow conditions; the local bleed flow rate can more than double as a shock moves forward over a bleed band in response to inlet flow disturbances. The effects of inlet flow disturbances on the flow at the compressor face are represented more realistically with this new boundary condition than with traditional fixed static pressure or mass flow conditions.
Author (revised by EI)

A94-61867
SENSITIVITY DERIVATIVES FOR THREE-DIMENSIONAL SUPERSONIC EULER CODE USING INCREMENTAL ITERATIVE STRATEGY
VAMSHI MOHAN KORIVI Old Dominion Univ., Norfolk, VA, ARTHUR C. TAYLOR, GENE W. HOU, PARRY A. NEWMAN, and HENRY E. JONES *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1319-1321 refs
(BTN-94-EIX94421374969) Copyright

An incremental strategy was proposed to iteratively solve the very large system of linear equations that are required to obtain quasianalytical sensitivity derivatives from advanced computational fluid dynamics (CFD) codes. The technique was successfully demonstrated for two large two-dimensional problems; a subsonic and a transonic airfoil. The principal feature of this incremental iterative strategy is that it allows the use of the identical approximate coefficient matrix operator and algorithm to solve the nonlinear flow and the linear sensitivity equations. A computationally efficient general methodology has been successfully demonstrated for iteratively solving the very large systems of linear equations required for obtaining quasianalytical sensitivity derivatives from three-dimensional CFD codes. Author (revised by EI)

A94-61872
LASER INTERFEROMETER SKIN-FRICTION MEASUREMENTS OF CROSSING-SHOCK-WAVE/TURBULENT-BOUNDARY-LAYER INTERACTIONS
T. J. GARRISON Pennsylvania State Univ., Univ Park, PA, G. S. SETTLES, N. NARAYANSWAMI, and D. D. KNIGHT *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1234-1241 refs
(BTN-94-EIX94421374974) Copyright

Wall shear stress measurements beneath crossing-shock-wave / turbulent boundary-layer interactions have been made for three interactions of different strengths. The interactions are generated by two sharp fins at symmetric angles of attack mounted on a flat plate. The shear stress measurements were made for fin angles of 7 and 11 deg at Mach 3 and 15 deg at Mach 3.85. The measurements were made using a laser interferometer skin-friction meter, a device that determines the wall shear by optically measuring the time rate of thinning of an oil film placed on the test model surface. Author (revised by EI)

A94-61873
AERODYNAMIC INVESTIGATION WITH FOCUSING SCHLIEREN IN A CRYOGENIC WIND TUNNEL
EHUD GARTENBERG Old Dominion Univ., Norfolk, VA, LEONARD M. WEINSTEIN, and EDWIN E. LEE *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1242-1249 refs
(BTN-94-EIX94421374975) Copyright

A flow visualization study was performed using a focusing schlieren system in the 0.3 m Transonic Cryogenic Tunnel at NASA Langley Research Center. The system proved to be a useful flow visualization tool for flows as low as M = 0.4. This study marked the first verification of the focusing schlieren technique in a major subsonic/transonic wind tunnel and the first time that high-quality, detailed pictures of high-Reynolds-number flows were obtained in a cryogenic wind tunnel.
Author (revised by EI)

N94-36328# Dassault Aviation, Saint-Cloud (France). Div. des Etudes Avancees.
LAMINAR FLOW STUDIES AT DASSAULT AVIATION: CALCULATIONS AND FLIGHT TESTS [ETUDES D'ECOULEMENTS LAMINAIRES CHEZ DASSAULT AVIATION: CALCULS ET ESSAIS EN VOL]
J. C. COURTY, C. BULGUBURE, and D. ARNAL *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 14 p Nov. 1993 In FRENCH
Copyright Avail: CASI HC A03/MF A03

The tools used at Dassault Aviation to calculate the limits on laminar layers, transition criteria and analyses on linear stability are presented and analyzed as far as their precision but also as far as their effectiveness when they have to be used to optimize the design of aircrafts' wing systems. These calculations were used in the concept of laminar deviation that was tested in the air on a FALCON 50, and in the concept of a wing with an hybrid laminarity that was tested in the air on a FALCON 50 during a second phase, 1987-1990. Author

N94-36420*# Virginia Univ., Charlottesville, VA. Dept. of Mechanical, Aerospace and Nuclear Engineering.
ANALYSIS OF HIGH SPEED FLOW, THERMAL AND STRUCTURAL INTERACTIONS Final Report, 1 Jun. 1989 - 31 Mar. 1994
EARL A. THORNTON Jun. 1994 217 p
(Contract NAG1-1013)
(NASA-CR-196017; NAS 1.26:196017; UVA/528308/MANE94/101)
Avail: CASI HC A10/MF A03

Research for this grant focused on the following tasks: (1) the prediction of severe, localized aerodynamic heating for complex, high speed flows; (2) finite element adaptive refinement methodology for multi-disciplinary analyses; (3) the prediction of thermoviscoplastic structural response with rate-dependent effects and large deformations; (4) thermoviscoplastic constitutive models for metals; and (5 coolant flow/structural heat transfer analyses. Derived from text

N94-36617# McDonnell-Douglas Aerospace, Saint Louis, MO.
ICAAS PILOTED SIMULATION RESULTS
R. J. LANDY, P. J. HALSKI, and R. P. MEYER *In* AGARD, Pointing and Tracking Systems 14 p May 1994
Copyright Avail: CASI HC A03/MF A02

This paper reports piloted simulation results from the Integrated Control and Avionics for Air Superiority (ICAAS) piloted simulation evaluations. The program was to develop, integrate, and demonstrate critical technologies which will enable United States Air Force tactical fighter 'blue' aircraft to achieve superiority and survive when outnumbered by as much as four to one by enemy aircraft during air combat engagements. Primary emphasis was placed on beyond visual range (BVR) combat with provisions for effective transition to close-in combat. The ICAAS system was developed and tested in two stages. The first stage, called low risk ICAAS, was defined as employing aircraft and avionics technology with an initial operational date no later than 1995. The second stage, called medium risk ICAAS, was defined as employing aircraft and avionics technology with an initial operational date no later than 1998. Descriptions of the low risk and medium risk simulation configurations are given. Normalized (unclassified) results from both the low risk and medium risk ICAAS simulations are discussed. The results show the ICAAS system provided a significant improvement in air combat performance when compared to a current weapon system. Data are presented for both current generation and advanced fighter aircraft. The ICAAS technologies which are ready for flight testing in order to transition to the fighter fleet are described along with technologies needing additional development. Author (revised)

N94-36620# Thomson-TRT Defense, Guyancourt (France).
LASER DESIGNATION PODS OPTIMIZED CONCEPT FOR DAY/NIGHT OPERATIONS [PODS DE DESIGNATION LASER UN CONCEPT OPTIMISE POUR LES OPERATIONS JOUR/NUIT]
YVES HUGUENIN *In* AGARD, Pointing and Tracking Systems 7 p May 1994 In FRENCH
Copyright Avail: CASI HC A02/MF A02

The conception of an optimized laser guided weapon that can be used at any time requires some technologies which, today, are not always compatible within the same equipment. From the 'day' ATLIS concept, Thomson-CSF developed a complementary 'night' pod. This convertible laser designation pod is the result of technical and operational optimization. Transl. by FLS

N94-36627# McDonnell-Douglas Aerospace, Saint Louis, MO.
AEROSERVOELASTIC STABILIZATION CONSIDERATIONS FOR POINTING AND TRACKING SYSTEMS
PETER Y. CHENG and RALPH E. LAMBERT *In* AGARD, Pointing and Tracking Systems 6 p May 1994
Copyright Avail: CASI HC A02/MF A02

The high gain, wide bandwidth precision tracking/pointing systems used on advanced aircraft necessitate the consideration of aeroservoelasticity (ASE) early in the design process. Aircraft control systems are designed to meet stability, performance and, in the case of manned aircraft, handling qualities criteria defined by the Mil-Spec requirements. As digital controllers are introduced, airframes are made statically unstable, and as the push for increased dynamic response continues, the aeroservoelastic influences become increasingly important in the overall system performance. At times, the ASE considerations may dominate the rigid body control law design effort. This paper summarizes an approach to the ASE stabilization of a fighter aircraft when used as the integral part of a high bandwidth manual or automatic fire control tracking system. The same approach can be applied to standard manual control aircraft where a more thorough ASE analysis is desired. Author

N94-36808*# MCAT Inst., San Jose, CA.
TURBULENCE MODELING OF FREE SHEAR LAYERS FOR HIGH PERFORMANCE AIRCRAFT Final Report
DOUGLAS SONDAK Oct. 1993 11 p
(Contract NCC2-663)
(NASA-CR-196137; NAS 1.26:196137; MCAT-94-12) Avail: CASI HC A03/MF A01

In many flowfield computations, accuracy of the turbulence model employed is frequently a limiting factor in the overall accuracy of the computation. This is particularly true for complex flowfields such as those around full aircraft configurations. Free shear layers such as wakes, impinging jets (in V/STOL applications), and mixing layers over cavities are often part of these flowfields. Although flowfields have been computed for full aircraft, the memory and CPU requirements for these computations are often excessive. Additional computer power is required for multidisciplinary computations such as coupled fluid dynamics and conduction heat transfer analysis. Massively parallel computers show promise in alleviating this situation, and the purpose of this effort was to adapt and optimize CFD codes to these new machines. The objective of this research effort was to compute the flowfield and heat transfer for a two-dimensional jet impinging normally on a cool plate. The results of this research effort were summarized in an AIAA paper titled 'Parallel Implementation of the k-epsilon Turbulence Model'. Appendix A contains the full paper. Derived from text

N94-36812*# Pennsylvania State Univ., University Park, PA. Dept. of Computer Science and Engineering.
A MODEL-BASED APPROACH FOR DETECTION OF RUNWAYS AND OTHER OBJECTS IN IMAGE SEQUENCES ACQUIRED USING AN ON-BOARD CAMERA Final Technical Report, 24 Jan. 1992 - 31 May 1994
RANGACHAR KASTURI, SADASHIVA DEVADIGA, and YUAN-LIANG TANG 18 Aug. 1994 125 p
(Contract NAG1-1371)
(NASA-CR-196424; NAS 1.26:196424) Avail: CASI HC A06/MF A02

This research was initiated as a part of the Advanced Sensor and Imaging System Technology (ASSIST) program at NASA Langley Research Center. The primary goal of this research is the development of image analysis algorithms for the detection of runways and other objects using an on-board camera. Initial effort was concentrated on images acquired using a passive millimeter wave (PMMW) sensor. The images obtained using PMMW sensors under poor visibility conditions due to atmospheric fog are characterized by very low spatial resolution but good image contrast compared to those images obtained using sensors operating in the visible spectrum. Algorithms developed for analyzing these images using a model of the runway and other objects are described in Part 1 of this report. Experimental verification of these algorithms was limited to a sequence of images simulated from a single frame of PMMW image. Subsequent development and evaluation of algorithms was done using video image sequences. These images have better spatial and temporal resolution compared to PMMW images. Algorithms for reliable recognition of runways and accurate estimation of spatial position of stationary objects on the ground have been developed and evaluated using several image sequences. These algorithms are described in Part 2 of this report. A list of all publications resulting from this work is also included. Derived from text

N94-36839*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
PRELOAD RELEASE MECHANISM Patent Application
ROBERT M. GENEROLI, inventor (to NASA) (McDonnell-Douglas Corp., Houston, TX.) and HARRY J. YOUNG, inventor (to NASA) (McDonnell-Douglas Corp., Houston, TX.) 20 Apr. 1994 18 p
(NASA-CASE-MSC-22327-1; NAS 1.71:MSC-22327-1; US-PATENT-APPL-SN-230571) Avail: CASI HC A03/MF A01

This invention relates to a preload release mechanism comprising a preload spring assembly adapted to apply a preload to a first connector member which is mounted on a support structure and adapted for connection with a second connector member on an object. The assembly comprises telescoped bushings and a preload spring. A tubular shaft extends through the spring assembly and openings in the first connector member and support structure, on which it is clamped. A plunger rod in the shaft is provided with a tip end and a recess in the rod near the other end thereof. A retainer precludes passage of the rod through the shaft in one direction and an end cap closes the bore of the shaft at the other end and provides a shoulder which extends radially of the shaft. A plunger return spring biases the plunger rod against the plunger retainer with the plunger tip protruding from the shaft and a spring assembly return spring engages at its ends the shoulder of the end cap and one end of the spring assembly. Detents received in lateral openings in the tubular shaft are held captive by the plunger rod and one end of the spring assembly to lock the spring assembly on the tubular shaft and apply a preload to the first connector member. Upon completion of the connection, detents and spring assembly are released by plunger contact with the object to be connected, thereby releasing the preload while the connection is maintained. NASA

N94-37125 Utah State Univ., Logan, UT. Dept. of Mechanical Engineering.
LITERATURE REVIEW AND PRELIMINARY STUDIES OF FRETTING AND FRETTING FATIGUE INCLUDING SPECIAL APPLICATIONS TO AIRCRAFT JOINTS Final Report

DAVID HOEPPNER, SAEED ADIBNAZARI, and MARK W. MOESSER Apr. 1994 70 p Sponsored by FAA Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(AD-A280310; DOT/FAA/CT-93/2) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

This report contains a review of the literature pertinent to fretting and fretting fatigue including special applications to aircraft joints. An introduction is given outlining the importance of fretting and fretting fatigue failures. Proposed mechanisms of fretting and fretting fatigue are then discussed. Research in the literature indicates there are three stages to fretting fatigue life. The first is a period of crack nucleation, usually by adhesion and plastic deformation of contacting asperities in relative motion. Several other possible mechanisms are discussed as well. In the second stage, propagation of nucleated cracks is determined by the stress resulting from the surface tractions imposed by fretting. The results of several investigations of the stress state and its effect on the propagation of nucleated cracks are discussed. The stress state can either dramatically increase early crack propagation rates or retard crack propagation, depending upon the specifics of the contact under study. The third stage is a period of crack propagation during which fretting contact stresses are not significant to crack propagation.
DTIC

N94-37128 Maryland Univ., College Park, MD.
A FUNDAMENTAL STUDY OF HYPERSONIC UNSTARTS Final Report, 1 Oct. 1991 - 30 Sep. 1993
MARK J. LEWIS 29 May 1994 65 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality
(Contract F49620-92-J-0006)
(AD-A280506; AFOSR-94-0362TR) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

Activities for the first year were primarily focused on laying the groundwork for accomplishing the ultimate goals of this investigation. Required hardware and software was obtained and implemented. Grid generators were tested and one was selected, as was the primary computational tool. Activities in the second year were directed towards beginning the three dimensional Euler, then Navier-Stokes calculations, to establish a steady-state time accurate baseline, which could then be perturbed to study the influence of downstream disturbances. Both Euler and laminar Navier-Stokes solutions were calculated.
DTIC

N94-37321# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
IMPACT OF MATERIALS DEFECTS ON ENGINE STRUCTURES INTEGRITY [L'IMPACT DES DEFAUTS DES MATERIAUX SUR L'INTEGRITE DES STRUCTURES DES MOTEURS]
Apr. 1993 118 p In ENGLISH and FRENCH The 74th meeting was held in Patras, Greece, 27-28 May 1992
(AGARD-R-790; ISBN-92-835-0711-8) Copyright Avail: CASI HC A06/MF A02

Engine failures due to materials defects are rare, but are still a cause for concern to both manufacturers and lifting authorities. In these circumstances it is recognized that the introduction of higher strength materials, new production routes and improved non-destructive evaluation methods may have significant implications for engine lifing and safety. The impact of inherent defects on present and future component manufacture and on aircraft engine operation is considered. Materials processing and control aspects are reviewed, placing particular emphasis on nickel and titanium engine disc materials. Variations in engineers', scientists' and lawyers' interpretation of the work 'defect' was perhaps the most significant point to emerge from the meeting; so much so, that a small group agreed to develop a definition, and when established recommend it as standard AGARD materials technology.

N94-37322# Utah Univ., Salt Lake City, UT. Dept. of Mechanical Engineering.
HISTORY AND PROGNOSIS OF MATERIAL DISCONTINUITY EFFECTS ON ENGINE COMPONENTS STRUCTURAL INTEGRITY
DAVID W. HOEPPNER In AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p Apr. 1993
Copyright Avail: CASI HC A02/MF A02

Ever since the development of aeroengines, 'defects' have been of significant concern to the assurance of structural integrity. Many of these issues have been the focus of recent Structures and Materials Panel (SMP) workshops and conferences. Although engine idealizations of materials being homogeneous, continuous, and 'free of defects' are invoked to make the complex issues of load, stress and strain, tractable, they were recognized as early as 1916, and later in the 1930's, as being oversimplistic and potentially in error. The epistemology of the role of discontinuities ('defects') in the design, selection, and lifing of critical aeroengine components is reviewed herein. Utilization of 'defect-free' and 'initiation' based fatigue criteria (as well as other time dependent failure modes such as creep, wear, etc.) have led to much success in the aeroengine industry. However, 'defects' also have led to numerous engine component failures in military and civilian aeroengines. And, as increasing demands are made on materials used in aeroengines, the role of 'defects' will, undoubtedly, become more important and critical. The history and prognosis of these issues is discussed with a review of on-condition lifing, defect-tolerant and damage-tolerant approaches, including, but not limited to, Engine Structural Integrity Program (ENSIP). The prognosis will suggest the need for the following: (1) development of increased understanding of the physics of failure processes of aeroengine materials; (2) integration of 'defect' considerations in the lifing methodologies from conceptual to detail design (the new paradigm of lifing); (3) assurance that knowledge of intrinsic materials behavior, including manufacturing specification and control, is a prime consideration in the defect-tolerant approach; (4) nondestructive inspection and evaluation should be one of many tools used to monitor and assure the state of the materials and should be a consideration in the lifing methodology at the earliest stage; (5) evaluation and integration of the role of extraneous influences, such as fretting, environmental attack, and the like, and how they are factored into the lifing procedure; and (6) development of consistent terminology with standardized definitions.
Author

N94-37329# Fiat Aviazione S.p.A., Turin (Italy).
TURBINE DISKS: LIFING AGAINST DEFECTS AND MATERIALS DEVELOPMENT
E. CAMPO, G. PASQUERO, ALDO FREDIANI, and ROBERTO GALATOLO In AGARD, Impact of Materials Defects on Engine Structures Integrity 12 p Apr. 1993
Copyright Avail: CASI HC A03/MF A02

Structural integrity of turbine disks must be guaranteed with a high safety level. The Engine Structural Integrity Program as contained in NIL-STD-1783 is aimed to enhance disk safety. A major design requirement is the implementation of the Damage Tolerance concepts by assessing the disk life in presence of defects. This paper illustrates the MIL-STD-1893 impact on turbine design as well as on material requirements, putting more emphasis on induced discontinuity features than on evolutionary ones. Targets for future developments in lifing procedures as well as in innovative materials are defined taking into account possible differences in life management among NATO countries.
Author

N94-37330# General Electric Co., Cincinnati, OH. Aircraft Engines.
SUBSTANTIATING POWDER METAL LIFE METHODOLOGIES FOR ENGINES
P. A. DOMAS In AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p Apr. 1993
Copyright Avail: CASI HC A02/MF A02

The application of powder metal (PM) superalloys in aircraft turbine engine rotating components is prompted by performance driven high strength and creep resistance requirements. Fine grain, precipitation strengthened nickel-base alloys such as IN100, Rene'95, and Rene'88DT meet these requirements up to operating temperatures in the 1200-1300F (649-704C) range. In addition to burst and deformation limits, design constraints include durability (fatigue) and damage tolerance (crack growth resistance) capability to insure reliability and safety. Fatigue life for these alloys can be influenced by inhomogeneities (inclusions) intrinsic to the microstructure as the result of processing, and by perturbations of the surface integrity during component manufacture and subsequent usage. Understanding of PM fatigue behavior and substantiation of life assessment methodology must appropriately recognize these potential influences. New testing, modeling, and analysis schemes are necessitated in engineering development programs addressing generation and validation of life prediction techniques for these materials. This paper outlines one approach to substantiating PM fatigue life prediction that attempts to recognize homogeneous fatigue initiation by incorporating probabilistic models and development testing methods that address material volume and component feature effects. Complications and limitations being addressed in ongoing work are discussed. Author

N94-37331# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

PREDICTING DEFECT BEHAVIOUR

G. W. KOENIG and J. W. BERGMANN *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 11 p Apr. 1993 Copyright Avail: CASI HC A03/MF A02

Fatigue is a statistical phenomenon with contributing factors which are statistical in nature too. Therefore probabilistic lifing concepts appear to be appropriate. Major components of any probabilistic lifting concept are: (1) microstructural characterization; (2) load history; and (3) material behavior. The results of any lifing model can only be as significant as the input data. This paper reviews some important aspects regarding input data which are necessary for the prediction of defect behavior by probabilistic models. Author

N94-37457*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

DYNAMICS OF A SPLIT TORQUE HELICOPTER TRANSMISSION M.S. Thesis - Cleveland State Univ.

TIMOTHY L. KRANTZ Jun. 1994 69 p

(Contract DA PROJ. 1L1-62211-A-47-A; RTOP 505-62-10)

(NASA-TM-106410; E-7881; NAS 1.15:106410; ARL-TR-291) Avail: CASI HC A04/MF A01

Split torque designs, proposed as alternatives to traditional planetary designs for helicopter main rotor transmissions, can save weight and be more reliable than traditional designs. This report presents the results of an analytical study of the system dynamics and performance of a split torque gearbox that uses a balance beam mechanism for load sharing. The Lagrange method was applied to develop a system of equations of motion. The mathematical model includes time-varying gear mesh stiffness, friction, and manufacturing errors. Cornell's method for calculating the stiffness of spur gear teeth was extended and applied to helical gears. The phenomenon of sidebands spaced at shaft frequencies about gear mesh fundamental frequencies was simulated by modeling total composite gear errors as sinusoid functions. Although the gearbox has symmetric geometry, the loads and motions of the two power paths differ. Friction must be considered to properly evaluate the balance beam mechanism. For the design studied, the balance beam is not an effective device for load sharing unless the coefficient of friction is less than 0.003. The complete system stiffness as represented by th stiffness matrix used in this analysis must be considered to precisely determine the optimal tooth indexing position. Author

N94-36919*# Aerojet Delft Corp., Azusa, CA.

EARTH OBSERVING SYSTEM/ADVANCED MICROWAVE SOUNDING UNIT-A (EOS/AMSU-A) SOFTWARE MANAGEMENT PLAN Final Report

ROBERT SCHWANTJE 20 Jun. 1994 39 p

(Contract NAS5-32314; RTOP 422-00-00)

(NASA-CR-189362; NAS 1.26:189362; REPT-9803-1; REPT-10339; CDRL-008) Avail: CASI HC A03/MF A01

This document defines the responsibilites for the management of the like-cycle development of the flight software installed in the AMSU-A instruments, and the ground support software used in the test and integration of the AMSU-A instruments. Author (revised)

N94-37126 Massachusetts Inst. of Tech., Cambridge. Lincoln Lab.

AN AUTOMATED METHOD FOR LOW LEVEL WINDSHEAR ALERT SYSTEM (LLWAS) DATA QUALITY ANALYSIS

DAVID A. CLARK and F. W. WILSON 26 May 1994 59 p Limited Reproducibility: More than 20% of this document may be affected by microfiche quality

(Contract DTFA01-91-Z-02036)

(AD-A280313; ATC-207) Avail: Issuing Activity (Defense Technical Information Center (DTIC))

The Low Level Windshear Alert System (LLWAS) is an anemometer-based surface network used for detection of hazardous wind shear and acquisition of operational wind information in the airport terminal area. The quality of wind data provided by the LLWAS anemometers is important for the proper performance of the LLWAS wind shear detection algorithms. This report describes the development of an automated method for anemometer data quality analysis (DQA). This method identifies potential data quality problems through comparison of wind data from each sensor within a network to the mean wind speed and direction of the entire network. The design approach and implementation are described, and results from testing using data from the demonstration Phase III LLWAS network in Orlando, FL are reported. Potential improvements to the automated DQA algorithm are presented based on experience gained during analysis of the Orlando data. These recommended improvements are provided to assist future development and refinement of the DQA methodology to be performed by the FAA Technical Center. DTIC

N94-37155# Lawrence Livermore National Lab., Livermore, CA.

PROJECT REPORT: AIRCRAFT

DONALD J. WUEBBLES, STEVE BAUGHCUM, MUNIR METWALLY, and ROBERT SEALS Apr. 1994 4 p Presented at the 4th International Workshop on Global Emissions Inventories, Boulder, CO, 30 Nov. - 2 Dec. 1993

(Contract W-7405-ENG-48)

(DE94-011759; UCRL-JC-116530; CONF-9311208-1) Avail: CASI HC A01/MF A01

Analyses of scenarios of past and possible future emissions are an important aspect of assessing the potential environmental effects from aircraft, including the proposed high speed civil transport (HSCT). The development of a detailed three-dimensional database that accurately represents the integration of all aircraft emissions along realistic flight paths for such scenarios requires complex computational modeling capabilities. Such a detailed data set is required for the scenarios evaluated in this interim assessment. Within the NASA High-Speed Research Program, the Emissions Scenarios Committee provides a forum for identifying the required scenarios and evaluating the resulting database being developed with the advanced emissions modeling capabilities at the Boeing Company and McDonnell Douglas Corporation. DOE

15
MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A94-61255
MULTIOBJECTIVE TRAJECTORY OPTIMIZATION BY GOAL PROGRAMMING WITH FUZZY DECISIONS
SHINJI SUZUKI Tokyo Univ., Tokyo (Japan) and TAKESHI YOSHIZAWA *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 297-303 refs
(BTN-94-EIX94381311168) Copyright

A sequential goal programming approach is considered for not only well-defined flight trajectory problems but also ill-defined problems that have no feasible solutions satisfying all design requirements due to strict boundary conditions or tight path constraints. By using a time integration algorithm, trajectory optimization problems are transformed into numerical optimization problems that seek optimal control variables at discrete time points to minimize an objective function and satisfy various design constraints. By defining the target goal values of both the constraints and the objective functions and by prioritizing each goal according to its significance, the GP formulation modifies ill-defined problems as multiobjective design problems. Additionally, a fuzzy decision making method is applied for those goals that are prioritized, not precisely, but in a fuzzy manner. Numerical applications for simple ascent trajectory problems show that this method can efficiently find the trajectories when various kinds of design requirements are imposed for the ill-defined problem. Author (EI)

A94-61260
NEW OUTPUT FEEDBACK DESIGN IN VARIABLE STRUCTURE SYSTEMS
WEN-JUNE WANG National Central Univ., Chung Li (Taiwan, Province of China) and YANG-TA FAN *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090) vol. 17, no. 2 March-April 1994 p. 337-340 refs
(BTN-94-EIX94381311173) Copyright

This paper proposes an output feedback variable structure control to stabilize a class of uncertain systems in which the state is unavailable and no estimated state is required. The special sliding hyperplane is introduced so that the output of the system is initially on the hyperplane no matter where the initial output is, and the stability of the equivalent reduced-order system in the sliding mode is assured under a certain condition. Further, based on the concept of the equivalent motion and the known bound of the initial state, the constant control gain is derived to guarantee the existence of the sliding mode. Finally, an aircraft model is given to illustrate this design approach. Author (EI)

N94-36495*# Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA.
APPLYING FORMAL METHODS AND OBJECT-ORIENTED ANALYSIS TO EXISTING FLIGHT SOFTWARE
BETTY H. C. CHENG (Michigan State Univ., East Lansing, MI.) and BRENT AUERNHEIMER (California State Univ., Fresno, CA.) *In* NASA. Goddard Space Flight Center, Proceedings of the Eighteenth Annual Software Engineering Workshop p 274-296 Nov. 1993
(Contract NSF CCR-92-09873)
Avail: CASI HC A03/MF A04

Correctness is paramount for safety-critical software control systems. Critical software failures in medical radiation treatment, communications, and defense are familiar to the public. The significant quantity of software malfunctions regularly reported to the software engineering community, the laws concerning liability, and a recent NRC Aeronautics and Space Engineering Board report additionally motivate the use of error-reducing and defect detection software development techniques. The benefits of formal methods in requirements driven software development ('forward engineering') is well documented. One advantage of rigorously engineering software is that formal notations are precise, verifiable, and facilitate automated processing. This paper describes the application of formal methods to reverse engineering, where formal specifications are developed for a portion of the shuttle on-orbit digital autopilot (DAP). Three objectives of the project were to: demonstrate the use of formal methods on a shuttle application, facilitate the incorporation and validation of new requirements for the system, and verify the safety-critical properties to be exhibited by the software. Author

N94-36498*# Reliable Software Technology Corp., Reston, VA.
AN EMPIRICAL COMPARISON OF A DYNAMIC SOFTWARE TESTABILITY METRIC TO STATIC CYCLOMATIC COMPLEXITY
JEFFREY M. VOAS, KEITH W. MILLER, and JEFFREY E. PAYNE *In* NASA. Goddard Space Flight Center, Proceedings of the Eighteenth Annual Software Engineering Workshop p 343-365 Nov. 1993
(Contract NAG1-884)
Avail: CASI HC A03/MF A04

This paper compares the dynamic testability prediction technique termed 'sensitivity analysis' to the static testability technique termed cyclomatic complexity. The application that we chose in this empirical study is a CASE generated version of a B-737 autoland system. For the B-737 system we analyzed, we isolated those functions that we predict are more prone to hide errors during system/reliability testing. We also analyzed the code with several other well-known static metrics. This paper compares and contrasts the results of sensitivity analysis to the results of the static metrics. Author

N94-36501*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
IMPACT OF ADA IN THE FLIGHT DYNAMICS DIVISION: EXCITEMENT AND FRUSTRATION
JOHN BAILEY (Software Metrics, Inc., Haymarket, VA.), SHARON WALIGORA (Computer Sciences Corp., Lanham, MD.), and MIKE STARK *In its* Proceedings of the Eighteenth Annual Software Engineering Workshop p 422-448 Nov. 1993
Avail: CASI HC A03/MF A04

In 1985, NASA Goddard's Flight Dynamics Division (FDD) began investigating how the Ada language might apply to their software development projects. Although they began cautiously using Ada on only a few pilot projects, they expected that, if the Ada pilots showed promising results, they would fully transition their entire development organization from FORTRAN to Ada within 10 years. However, nearly 9 years later, the FDD still produces 80 percent of its software in FORTRAN, despite positive results on Ada projects. This paper reports preliminary results of an ongoing study, commissioned by the FDD, to quantify the impact of Ada in the FDD, to determine why Ada has not flourished, and to recommend future directions regarding Ada. Project trends in both languages are examined as are external factors and cultural issues that affected the infusion of this technology. This paper is the first public report on the Ada assessment study, which will conclude with a comprehensive final report in mid 1994. Author (revised)

N94-36628# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Fakultaet fuer Luft-und Raumfahrttechnik.
TWO-AXIS CAMERA PLATFORM FOR MACHINE VISION
J. SCHIEHLEN and E. D. DICKMANNS *In* AGARD, Pointing and Tracking Systems 6 p May 1994
Copyright Avail: CASI HC A02/MF A02

Mobile robots operating autonomously have to perceive their environment; many advantages favor using a vision sensor. The concept of dynamic vision is an adequate solution to this problem. The ability to track moving objects is essential. Therefore, a two axis camera platform is described having several modes of operation, which can be mounted on a mobile robot. An active vision system is presented, including the design of the pan-tilt head and the controller. Problems arising due to image processing delays, robots' own motion and platform actuator disturbances, e.g. friction, are treated. An aircraft application for vision based autonomous landing is given. Author

N94-36633# British Aerospace Defence Ltd., Preston (England). Military Aircraft Div.

SENSOR DATA FUSION FOR AIR TO AIR SITUATION AWARENESS BEYOND VISUAL RANGE

C. A. NOONAN, M. E. EVERETT, and R. C. FREEMAN *In* AGARD, Pointing and Tracking Systems 8 p May 1994

Copyright Avail: CASI HC A02/MF A02

A modern tactical aircraft is faced with ever increasing threats and, to be effective against them, it needs to know what and where they are as early as possible during any encounter. It must do this day and night, in all weather, in hostile countermeasure environments and in the presence of clutter. Tactical aircraft receive large amounts of information from multiple sensors and data communications systems. To allow the crew to manage the aircraft and ensure its mission is fulfilled, the information must be aligned, correlated, consolidated and presented to them in a meaningful form. The paper introduces a model of tactical situation awareness processing which comprises sensors, data fusion, situation assessment and sensor management. The purpose of each component of the model and the relationships between them are discussed. The requirements placed on sensor data fusion by air to air sensing are discussed, and so is the way in which they are dominated by particular features of the tactical aircraft platform and its mission. The influence of these factors on the design of air to air situation awareness systems is considered. A computer test harness, developed by BAe Defence, Military Aircraft Division, is described, along with built-in tools which calculate test statistics. The harness was developed as part of a program of studies carried out by the Mission Systems group of the Design Quality and R&D team within the Systems Engineering Department at BAe's Warton unit in Lancashire, U.K. Examples of the results which were obtained when an air to air sensor data fusion model was evaluated are reproduced. These take the form of graphs and diagrams representing test statistics and offer a means by which different solutions to various data fusion problems may be compared under identical conditions. Author

N94-36914*# Computational Mechanics Co., Knoxville, TN.

AN ARBITRARY GRID CFD ALGORITHM FOR CONFIGURATION AERODYNAMICS ANALYSIS. VOLUME 1: THEORY AND VALIDATIONS Final Report

A. J. BAKER, G. S. IANNELLI, PAUL D. MANHARDT, and J. A. ORZECHOWSKI Dec. 1993 179 p

(Contract NAS2-12568; SBIR-02.07-5494)

(NASA-CR-195918; NAS 1.26:195918; CMC-TR2.1-94-VOL-1) Avail: CASI HC A09/MF A02

This report documents the user input and output data requirements for the FEMNAS finite element Navier-Stokes code for real-gas simulations of external aerodynamics flowfields. This code was developed for the configuration aerodynamics branch of NASA ARC, under SBIR Phase 2 contract NAS2-124568 by Computational Mechanics Corporation (COMCO). This report is in two volumes. Volume 1 contains the theory for the derived finite element algorithm and describes the test cases used to validate the computer program described in the Volume 2 user guide. Author (revised)

N94-36922*# Computational Mechanics Co., Knoxville, TN.

AN ARBITRARY GRID CFD ALGORITHM FOR CONFIGURATION AERODYNAMICS ANALYSIS. VOLUME 2: FEMNAS USER GUIDE Final Report

PAUL D. MANHARDT, J. A. ORZECHOWSKI, and A. J. BAKER Sep. 1992 63 p

(Contract NAS2-12568; SBIR-02.07-5494)

(NASA-CR-196135; NAS 1.26:196135; CMC-TR4.2-92-VOL-2) Avail: CASI HC A04/MF A01

This report documents the user input and output data requirements for the FEMNAS finite element Navier-Stokes code for real-gas simulations of external aerodynamics flowfields. This code was developed for the configuration aerodynamics branch of NASA ARC, under SBIR Phase 2 contract NAS2-124568 by Computational Mechanics Corporation (COMCO). This report is in two volumes. Volume 1 contains the theory for the derived finite element algorithm and describes the test cases used to validate the computer program described in the Volume 2 user guide. Author (revised)

N94-36962*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.

ADVANCED INFORMATION PROCESSING SYSTEM: THE ARMY FAULT-TOLERANT ARCHITECTURE DETAILED DESIGN OVERVIEW Final Report

RICHARD E. HARPER, CAROL A. BABIKYAN, BRYAN P. BUTLER, ROBERT J. CLASEN, CHRIS H. HARRIS, JAYNARAYAN H. LALA, THOMAS K. MASOTTO, GAIL A. NAGLE, MARK J. PRIZANT, and STEVEN TREADWELL Jun. 1994 138 p

(Contract NAS1-18565; RTOP 505-64-52-53)

(NASA-CR-194924; NAS 1.26:194924) Avail: CASI HC A07/MF A02

The Army Avionics Research and Development Activity (AVRADA) is pursuing programs that would enable effective and efficient management of large amounts of situational data that occurs during tactical rotorcraft missions. The Computer Aided Low Altitude Night Helicopter Flight Program has identified automated Terrain Following/Terrain Avoidance, Nap of the Earth (TF/TA, NOE) operation as key enabling technology for advanced tactical rotorcraft to enhance mission survivability and mission effectiveness. The processing of critical information at low altitudes with short reaction times is life-critical and mission-critical necessitating an ultra-reliable/high throughput computing platform for dependable service for flight control, fusion of sensor data, route planning, near-field/far-field navigation, and obstacle avoidance operations. To address these needs the Army Fault Tolerant Architecture (AFTA) is being designed and developed. This computer system is based upon the Fault Tolerant Parallel Processor (FTPP) developed by Charles Stark Draper Labs (CSDL). AFTA is hard real-time, Byzantine, fault-tolerant parallel processor which is programmed in the ADA language. This document describes the results of the Detailed Design (Phase 2 and 3 of a 3-year project) of the AFTA development. This document contains detailed descriptions of the program objectives, the TF/TA NOE application requirements, architecture, hardware design, operating systems design, systems performance measurements and analytical models. Author

N94-36970 Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

A MEAN VALUE ANALYSIS HEURISTIC FOR ANALYSIS OF AIRCRAFT SORTIE GENERATION M.S. Thesis

RICHARD C. JENKINS Mar. 1994 91 p *Limited Reproducibility: More than 20% of this document may be affected by microfiche quality*

(AD-A278578; AFIT/GOR/ENS/94M-07) Avail: CASI HC A05

The primary objective of this study was to develop an analytical methodology based on the Mean Value Analysis algorithm that approximates the performance characteristics of a queueing network model (QNM) containing a fork-join queue with probabilistic branching. These performance characteristics are response time, throughput and queue length at each station. The QNM solved contains the essential features of the aircraft sortie generation process. The sensitivity of the method's accuracy to increases in server utilization was determined. The comparisons of the results of the MVA heuristic to the outputs of the Logistics Composite Model (LCOM) simulation indicate that the heuristic's accuracy decreased as server utilization increases. When server utilization was kept in realistic ranges, the results of the heuristic for a single fork-join queue were very accurate. For non-maintenance stations, results were within 1 to 2 percent of the LCOM simulation output.

For stations on the fork-join queue paths, heuristic results were within 5 percent of the LCOM simulation's output for that portion of the network. DTIC

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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.

A94-61635

COMPUTATION OF SUPERSONIC JET MIXING NOISE FOR AN AXISYMMETRIC CONVERGENT-DIVERGENT NOZZLE

ABBAS KHAVARAN Sverdrup Technology, Inc., Cleveland, OH, EUGENE A. KREJSA, and CHAN M. KIM *Journal of Aircraft* (ISSN 0021-8669) vol. 31, no. 3 May-June 1994 p. 603-609 refs (BTN-94-EIX94401358979) Copyright

The turbulent mixing noise of a supersonic jet is calculated for an axisymmetric convergent-divergent nozzle at the design pressure ratio. Aerodynamic computations are performed using the PARC code with a k-epsilon turbulence model. Lighthill's acoustic analogy is adopted. The acoustics solution is based upon the methodology followed in the MGB code. The source correlation function is expressed as a linear combination of second-order tensors (Ribner's assumption). Assuming separable second-order correlations and incorporating Batchelor's isotropic turbulence model, the source term was calculated from the kinetic energy of turbulence. A Gaussian distribution for the time-delay of correlation was introduced. The CFD solution was used to obtain the source strength as well as the characteristic time-delay of correlation. The effect of sound/flow interaction was incorporated using the high frequency asymptotic solution to Lilley's equation for axisymmetric geometries. Acoustic results include sound pressure level directivity and spectra at different polar angles. The aerodynamic and acoustic results demonstrate favorable agreement with experimental data. Author (EI)

A94-61854

SOUND RADIATION AND CAUSTIC FORMATION FROM A POINT SOURCE IN A WALL SHEAR LAYER

I. DAVID ABRAHAMS Keele Univ, Staffordshire, United Kingdom, GREGORY A. KRIEGSMANN, and EDWARD L. REISS *AIAA Journal* (ISSN 0001-1452) vol. 32, no. 6 June 1994 p. 1135-1144 refs (BTN-94-EIX94421374956) Copyright

The propagation of acoustic waves from a high-frequency point source in a shear layer flowing over an infinite rigid plate is considered. Stationary and moving sources are analyzed. An infinite sequence of caustic surfaces are created reflection from the wall. The acoustic fields on and off the caustics are obtained. EI

N94-36622# GEC-Marconi Avionics Ltd., Basilon, Essex (England).

INFRARED SEARCH AND TRACK DEMONSTRATOR PROGRAMME

W. D. MCGINN, C. J. TUCKER, and S. NALLANTHIGHAL *In* AGARD, Pointing and Tracking Systems 10 p May 1994 Copyright Avail: CASI HC A02/MF A0 2

The objective of the infrared search and track (IRST) program is to develop demonstration hardware which will be capable of long range detection and tracking of air targets in an airborne environment. This paper describes each of the major subsystems of the IRST equipment, which comprises the pointing system, the thermal imaging systems and the signal processing system. The various modes of operation are outlined which provide the capability to search for, detect and track multiple targets; to display imagery of a selected target and to provide passive ranging information. The equipment will be flown in an experimental Tornado aircraft and the installation and proposed trials are also described. A description of the ground proving equipment is also included. Author

N94-37344# CAE Electronics Ltd., Saint Laurent (Quebec).

TRAINING AND OPERATIONS SUPPORT SYSTEM (TOPS)

GUY LANGLOIS and IAN GORDON *In* AGARD, International High Speed Networks for Scientific and Technical Information 3 p Feb. 1994 Copyright Avail: CASI HC A01/MF A02

This paper describes a potential training and operations support system and discusses the enabling technologies that make it possible - high speed global networks, powerful computers, and an object oriented data base management system (OODBMS). It illustrates a real world example of the system using a scenario involving an aircraft maintenance technician. Author

SUBJECT INDEX

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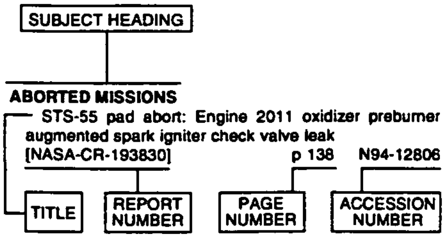

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ANDRISANI, DOMINICK, II
A feasibility study regarding the addition of a fifth control to a rotorcraft in-flight simulator
[NASA-CR-193240] p 112 N94-10895

TITLE | REPORT NUMBER | PAGE NUMBER | ACCESSION NUMBER

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Adaptive Research Corp., Huntsville, AL.
Structured finite volume modeling of US Navy aircraft engine test cells. Task 1: Turboshaft engine, volume 1
[AD-A268176] p 135 N94-17432

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CHINA
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p 153 A94-10101

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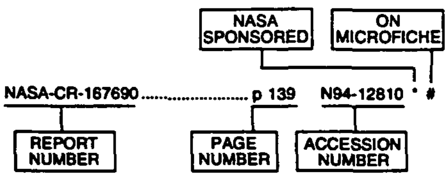

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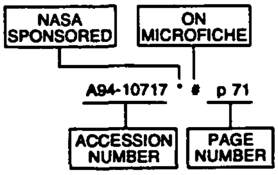

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1. Report No. NASA SP-7037 (309)	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Aeronautical Engineering A Continuing Bibliography (Supplement 309)		5. Report Date October 1994
		6. Performing Organization Code JTT
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address NASA Scientific and Technical Information Program		10. Work Unit No.
		11. Contract or Grant No.
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