MASTER OF SCIENCE
IN
AERONAUTICAL ENGINEERING

HELMET MOUNTED DISPLAY SYMBOLOGY FOR NIGHT AIRBORNE MINE COUNTERMEASURES IN THE MH-53E HELICOPTER

Juan Alvarez-Lieutenant, United States Navy
B.S., University of Miami, 1986
Master of Science in Aeronautical Engineering-December 1995
Advisor: Judith H. Lind, Operations Research

This study begins the process of developing and refining helmet mounted display (HMD) symbology appropriate for use by MH-53E helicopter pilots conducting night airborne mine countermeasures (AMCM) operations. The Navy is considering use of the Army Navy/Aviator Vision System (AN/AVS-7) HMD in the MH-53E to achieve a viable night AMCM capability. Needed is an initial design of appropriate night AMCM symbols to display on such an HMD system. Two new symbology elements critical to the tow segment of AMCM flight were designed and integrated into a preliminary HMD tow format for the MH-53E: tow boom skew angle and turn rate indicators. A fixed-based flight simulator was developed to evaluate the two proposed symbology elements. Seven fleet-experienced AMCM pilots qualified in the MH-53E flew simulated tow patterns while using the display to try to maintain AMCM tow parameters within specified limits. Both pilot performance data and subjective questionnaire results were collected and analyzed. Participants considered the proposed display easy to comprehend and use, and reported that such a display would be useful for night AMCM operations. Based on correlating performance and subjective data results, modifications to the evaluated tow symbology are recommended and a revised AMCM tow format is proposed.

APPLICATION OF MULTI-BLOCK CFD TECHNIQUES TO A MISSILE GEOMETRY

Bret S. Barton-Captain, Canadian Armed Forces
B.Eng., Technical University of Nova Scotia, 1989
Master of Science in Aeronautical Engineering-December 1995
Advisor: Garth Hobson, Department of Aeronautics and Astronautics

The aerodynamics of a missile body were modeled using computational fluid dynamics (CFD) techniques. A multi-block approach was used on a slender body and intersecting symmetric thin delta-wing. The CFD process and software were examined thoroughly including multi-block grid generation and interpolation, iblanking methods and flow-solver analysis. CFD results were compared with available wind tunnel data. Two Cartesian free-stream grids, a wing C-grid, a collar and body grid were used to model the body/wing geometry. The wing grid had a sharp tip and sharp leading and trailing edges. The body/wing intersection was represented with the collar grid. Both a hyperbolic grid generator, HYPGEN and an elliptic grid generator, GRIDGEN Vr 9, were evaluated. PEGSUS Vr 4.0 was used to compute the iblanking and interpolation stencil, based on the Chimera overlapping grid scheme. A single composite mesh was passed to the Navier-Stokes implicit flow-solver OVERFLOW Vr 1.6ag. Solutions were computed for inviscid and viscous flows at different Mach numbers and incidence angles. The Baldwin-Lomax shear and boundary layer turbulent models were used. Agreement was found between published wind tunnel data and the CFD solution thus validating the grid generation and flowfield solution procedure.

A HISTORICAL PERSPECTIVE OF AIRCREW SYSTEMS EFFECTS ON AIRCRAFT DESIGN

David O. Bauer-Lieutenant Commander, United States Navy
B.S., University of Kansas, 1981
Master of Science in Aeronautical Engineering-September 1996
Advisor: Conrad F. Newberry, Department of Aeronautics and Astronautics
Second Reader: Anthony P. Ciavarelli, School of Aviation Safety

The design of the aircrew workstation often has not been an orderly part of the overall aircraft design process but rather of much lower priority than the integration of the airframe and powerplant. However, the true test of the aircraft is how well the aircrew can use the aircraft for mission performance. NAVAIR has been seeking the establishment of an Aircrew Centered System Design discipline, to be addressed as an integral part of the global aircraft system design

process. A baseline, historical understanding of how the aircrew have been integrated into the aircraft and mission is needed. An analysis was conducted of several significant airplanes from the Wright Flyer to the present, seeking those design factors which affected how well the aircrew were able to perform the design mission. The physical and attentional resources of the aircrew must be understood and accommodated by those designing the cockpit and other workstations. Aircrew members who are knowledgeable of, and experienced in the intended mission must be involved in the design process from the very earliest phases of concept definition.

MACSAP 3.0: SURVIVABILITY ASSESSMENT SOFTWARE FOR AIRCRAFT CONCEPTUAL DESIGN

Gary G. Bishop-Lieutenant, United States Navy
B.S., Rensselaer Polytechnic Institute, 1989
Master of Science in Aeronautical Engineering-June 1996
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics
Second Reader: Conrad F. Newberry, Department of Aeronautics and Astronautics

The purpose of this thesis is to further develop the Macintosh Survivability Assessment Program (MACSAP) that was originally written in the multi-media programming language SuperCard® in September 1991. The program is designed to be autonomous and may be included in the second edition of *The Fundamentals of Aircraft Combat Survivability Analysis and Design*, by Robert E. Ball. The computer code is a training aid for the conceptual survivability design of three different combat aircraft: a long range strike aircraft, a close air support aircraft, and a fighter escort aircraft. MACSAP 3.0 modifies version 2.0 by improving on the design of the computer code. By writing more efficient code, the program runs 32% faster and has decreased in file size by 39%, so it can be contained on one 3.5 inch computer diskette. Additional improvements include the use of color coding to aid the student in using the software and supplementary graphics/screens with detailed descriptions of analysis procedures. MACSAP 3.0 is now a stand-alone, user-friendly computer program ready for the classroom.

FINAL MODIFICATIONS OF NPS *HUMMINGBIRD* REMOTELY PILOTED HELICOPTER IN PREPARATION FOR FLIGHT

Andrew J. Booth-Lieutenant, United States Navy
BME, Georgia Institute of Technology, 1988
Master of Science in Aeronautical Engineering-December 1995
Advisor: E. Roberts Wood, Department of Aeronautics and Astronautics

The goals of this thesis were to make final design modifications and perform static testing to prepare the *Hummingbird,* a 150 pound, remotely piloted helicopter (RPH), for untethered flight. The major elements involved were: (1) The adaptation of a suitable, permanently-dedicated test stand for use with large-scale RPH/RPV (remotely piloted vehicle) aircraft, (2) The rotor drivetrain improvements to the helicopter to enable it to safely operate in the event of an in-flight engine failure, thus avoiding the potential loss of aircraft due to crash, (3) Complete break-in and testing of a replacement engine for a mechanically-seized first engine, and (4) The actual flight testing while secured to the test stand.

The test stand modifications included the design and implementation of a compression spring to offset the weight of the newly designed mounting assembly and a restricting collar to confine the mobility of the stand's universal joint. The mechanical change to the drivetrain consisted of replacement of a conventional belt-driving sprocket with a one-way bearing inside the gear. This provides the *Hummingbird* with the critical capability to autorotate. The new engine, correctly broken in, and the subsequent static testing provide the Department of Aeronautics and Astronautics with a platform fully operational and ready to perform subsequent in-flight testing.

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

COMPUTATIONAL INVESTIGATION OF LOW SPEED FLOW OVER LOW ASPECT RATIO AIRCRAFT CONFIGURATIONS

Alain Carrier-Captain, Canadian Armed Forces
B.S., Ecole Polytechnique, University of Montreal, 1988
Master of Science in Aeronautical Engineering-December 1995
Advisor: Max F. Platzer, Department of Aeronautics and Astronautics

The objective of this thesis was to contribute to the development of a second-order approximation to the steady and oscillatory lifting flow past low aspect ratio wings by establishing the validity of a NASA-Ames developed incompressible three-dimensional flow panel code named PMARC, which would subsequently be used to test the range of validity of this second-order theory. The steady state configurations modeled in the validation process include swept back, delta and rectangular wings, an F5 wing and three equivalent bodies of revolution. Oscillatory cases were also run with one delta and the F5 wings and their respective equivalent bodies of revolution, as well as with one spindle. In steady state, comparison with experimental and theoretical data proved PMARC to be very accurate for lift and pressure calculations, but revealed a discrepancy in the velocity distribution calculation around delta wings. This finding was corroborated by applying the slender body/slender wing theory (Oswatitsch-Keune theory) to the delta wing. The unsteady state results are presented, but their validation is left for future work. As part of its primary objective, this thesis also presents a computer code that generates the F5 wing equivalent body of revolution from its chord-wise section definition. In order to be used as base software to the second-order theory, PMARC will have to be corrected, or a new software will have to be validated.

A STUDY ON THE EFFECTS OF THROTTLE CHANGES AND FLARE DECOYS IN AN ENGAGEMENT BETWEEN THE F-14B/D TOMCAT AND THE AA-11 ARCHER IR AAM

Ramon A. Collazo, Jr.,-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1984
Master of Science in Aeronautical Engineering-March 1996
Advisors: R. Ball, Department of Aeronautics and Astronautics
F. Levien, Information Warfare Academic Group

Technological advances coupled with extensive proliferation of infrared (IR) guided Surface-to-Air (SAM) and Air-to-Air (AAM) missiles arguably make them the most dangerous threat faced by tactical aircrews. The U. S. Navy has addressed this threat through aggressive IR countermeasures (IRCM) programs. One such program is the Electronic Warfare Advanced Technology (EWAT) Program sponsored by the CNO (N88). The Naval Postgraduate School and the EWAT Program are working together using modeling and simulation programs to evaluate proposed IRCMs.

This thesis uses the Modeling System for Advanced Investigation of Countermeasures (MOSAIC) software to simulate engagements between the Soviet-made AA-11 Archer IR AAM and the F-14B/D. Two scenarios, preemptive and defensive, are explored in which the F-14 uses flare decoys and/or reduction in power setting as recommended by the Navy Fighter Weapons School in an attempt to defeat the missile. A power modulation tactic, proposed by the Naval Air Warfare Center, Weapons Division, China Lake, is also examined. The results of the simulations are evaluated to determine the effectiveness of both current and proposed IRCM tactics.

POWER PLANT AND DRIVE TRAIN IMPROVEMENTS OF THE NPS *HUMMINGBIRD* REMOTELY PILOTED HELICOPTER
Robert E. Conway-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1985
Master of Science in Aeronautical Engineering-September 1996
Advisor: E. Roberts Wood, Department of Aeronautics and Astronautics
Second Reader: Richard M. Howard, Department of Aeronautics and Astronautics

Originally designed as a target drone for the U.S. Army, the NPS Hummingbird has undergone several modifications to convert it into a reliable research platform. The 165 pound remotely piloted helicopter (RPH) is powered by a Weslake Aeromarine Engines Limited (WAEL) 342 two stroke, twin cylinder, 25 hp, gasoline engine. An engine failure due to cylinder overheating halted research efforts until investigation as to the cause and subsequent corrections could be made. Costing approximately $3000 per engine, another failure is unacceptable. The tasks undertaken in this thesis were to investigate the cause of the overheat failure and improve the engine cooling system. Cooling system corrections required total redesigns of the engine cooling and engine start systems. Additionally, research of the RPH's history revealed a need for a torsional shock absorber to be incorporated in the drive train to increase component life. The changes made to Hummingbird provide a decrease in empty weight, minimal center of gravity change and, most importantly, an increase in user safety, providing the Department of Aeronautics and Astronautics with a dependable vehicle for rotary wing research.

A VALIDATION OF THE JOINT ARMY/NAVY ROTORCRAFT ANALYSIS AND DESIGN SOFTWARE BY COMPARISON WITH H-34 AND UH-60A FLIGHT TEST
David M. Eccles-Lieutenant, United States Navy
B.S.E.E., Tufts University, 1987
Master of Science in Aeronautical Engineering-December 1995
Advisor: E. Roberts Wood, Department of Aeronautics and Astronautics

A detailed comparison of the output from the NPS developed Joint Army/Navy Rotorcraft Analysis and Design (JANRAD) computer code with H-34 and UH-60A flight test data was made in an effort to determine the validity of the code's predictions. Airload distribution across the rotor disk, power required at various airspeeds ranging from hover to cruise, and thrust moment were used as measures of performance. Although a quantitative comparison of airload distribution is difficult to obtain, qualitatively, the predictions are good. JANRAD's power required estimations are correct to within two percent for altitudes below six thousand feet but accuracy suffers at higher altitudes, particularly above ten thousand feet. A correlation between the variation in kinematic viscosity from sea level to ten thousand feet and the accuracy of the power predictions is demonstrated. In the case of the UH-60A, the equivalent flat plate area of the helicopter is shown to be a function of airspeed, significantly impacting the accuracy of the power required prediction. Center of gravity offset from the main rotor's axis of rotation and unsteady inflow effects influence the accuracy of thrust moment predictions.

CONCEPTUAL DESIGN DEFINITION OF A JSOW UNITARY CATM
Gary Lee Formet, Jr.-Lieutenant, United States Navy
B.S., United States Naval Academy, 1988
Master of Science in Aeronautical Engineering-June 1996
Advisor: Gerald H. Lindsey, Department of Aeronautics and Astronautics
Second Reader: Sandra L. Scrivener, Department of Aeronautics and Astronautics

The AGM-154 Joint Stand Off Weapon (JSOW) Unitary missile is the next generation of smart weapons. This document seeks to provide insight into needed capabilities for the Captive Air Training Missile (CATM) which simulates the AGM-154 JSOW Unitary variant. This is done by presenting a proposed training program within the framework of aircraft carrier operations that justifies and delineates the CATM. From these, insights into the engineering conceptual

design goals that will apply to the CATM are extracted. Required capabilities and functions from these operations are discussed, which ultimately leads to the foundation for a draft Functional Requirements document and a revised Concept of Operations document for the CATM.

A WATER TUNNEL INVESTIGATION OF THE INFLUENCE OF REYNOLDS NUMBER ON THE HIGH-INCIDENCE FLOW OVER DOUBLE-DELTA WINGS

Anastasios E. Fritzelas-Lieutenant, Hellenic Navy
B.S., Hellenic Naval Academy, 1986
Master of Science in Aeronautical Engineering-March 1996
Advisor: M.F. Platzer, Department of Aeronautics and Astronautics

There are several disagreements in the published literature on vortex interaction and bursting data obtained in various wind and water tunnel tests of double-delta wings at high angle of attack (AOA).Therefore a test program was carried out in the Naval Postgraduate School water tunnel using a 76/40 deg. baseline double-delta wing model to investigate the effect of Reynolds number. The program consisted of: (i) Flow visualization studies at tunnel speeds of 0.2, 0.6 and 1.0 ft/sec in the 0-30 deg. AOA range to determine the influence of flow Reynolds number on vortex trajectory/ interaction and breakdown, and (ii) Laser Doppler Velocimetry studies of the flowfield to gain a better understanding of the vortex structure and verify the flow visualization results. Comparison of the test results at these tunnel speeds (corresponding to nominal flow Reynolds number of 15,000, 45,000, and 75,000) indicates a change in the vortical flowfield structure. The strake and wing vortices do not coil up and the breakdown occurs earlier as the tunnel speed is increased. The trends in the interaction and bursting data at higher tunnel speeds appear to be in better agreement with previous wind tunnel data.

NEURAL PREDICTION OF MISSILE DYNAMICS DURING HARDWARE-IN-THE-LOOP CAPTIVE-CARRY EXPERIMENTS

Charles W. Gill-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Aeronautical Engineering-September 1996
Advisor: Phillip E. Pace, Department of Electrical and Computer Engineering
Second Reader: Robert E. Ball, Department of Aeronautics and Astronautics

Systems using electronic attack (EA) are needed to defeat enemy active threat missiles. Many such systems exist, but difficulties arise when trying to measure their effectiveness. Two methods used are closed loop tests in an anechoic chamber and open loop tests conducted with a hardware-in-the-loop (HIL) threat simulator on board an aircraft. This thesis investigates the feasibility of using a particular class of neural networks (Levenburg-Marquardt) to predict the dynamics of an anti-ship cruise missile (ASCM) using only the seeker measured range-to-target and antenna azimuth and elevation angles. This technique accounts for seeker measured range and angles having a nonlinear relationship with the missile flight dynamics. Closed loop anechoic chamber simulations provide missile dynamics in an artificial environment while open loop captive-carry flight tests provide a true EA environment, but no dynamics. Closed loop and open loop results are combined to assess the effectiveness of the EA used by the Navy to defeat enemy missiles. The neural networks are trained using missile dynamics from closed loop simulations and are used to provide missile dynamics for open loop simulations. As an integral part of captive-carry signal processing tools, the prediction of the ASCM dynamics using neural networks considerably improves miss distance calculations.

LASER ANEMOMETRY AND PRESSURE MEASUREMENTS IN THE ENDWALL REGION OF AN ANNULAR TURBINE CASCADE UTILIZING A PRESSURIZED AERODYNAMIC WINDOW

Michael Hiro Guerrera-Lieutenant, United States Navy
B. S., United States Naval Academy, 1988
Master of Science in Aeronautical Engineering-September 1996
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

The purpose of this research was to compare previous laser-anemometry measurements obtained through an unpressurized laser window with the results from a pressurized laser window and to validate this innovative measuring technique in the endwall region of a confined annulus. Two-dimensional velocity, flow angle, and turbulence intensity measurements were obtained with a fiber-optics laser-Doppler velocimeter. The measurements were performed through a 1.09 mm opening in the endwall region of an annular turbine cascade at depths ranging from 0.01 mm to 0.89 mm with varying pressure applied to the chamber of the modified window. Cobra probe measurements were performed to validate the flow angles obtained by the laser anemometer. The cascade was modified to measure the inlet profile, which was performed with a three-hole probe.

PRELIMINARY VIBRATION SURVEY OF A SUSPENDED FULL-SCALE 0H-6A HELICOPTER FROM O TO 45 HZ

John H. Harris III-Lieutenant, United States Navy
B. S., The Pennsylvania State University, 1988
Master of Science in Aeronautical Engineering-March 1996
Advisor: E. Roberts Wood, Department of Aeronautics and Astronautics
Joshua H. Gordis, Department of Mechanical Engineering

Efforts to establish a helicopter research program in structural dynamics at NPS were greatly enhanced when the U. S. Army donated two OH-6A light observation helicopters. One of the helicopters is reserved for ground vibration testing and dynamics research. Vibration measurements are extremely important in predicting and understanding an aircraft's dynamic behavior and durability. A comparison of a helicopter's natural frequencies and those frequencies transmitted to the airframe through the rotor system can alert the designer/evaluator to possible dynamic problems. This thesis establishes a baseline vibration test program on the OH-6A helicopter for future testing and comparison to analytic models. The goal of the research is to establish natural frequencies (eigenvalues), principal mode shapes (eigenvectors), and damping characteristics of the OH-6A and to compare these values to test and analytical data obtained from the McDonnell Douglas Helicopter Company.

RADIATION PATTERN CALCULATION FOR MISSILE RADOMES IN THE NEAR FIELD OF AN ANTENNA

Scott M. Herzog-Lieutenant, United States Navy
B.S.A.A.E, The Ohio State University, 1988
Master of Science in Aeronautical Engineering-September 1996
Advisor: David C. Jenn, Department of Electrical and Computer Engineering
Second Reader: Robert E. Ball, Department of Aeronautics and Astronautics

An analytical model and computer simulation are presented for a radome located in the near field of an antenna. Using the computer code described here, design tradeoffs can be performed between electrical, structural, and aerodynamic properties of the radome. The code is based on a method of moments solution to the E-field integral equation for bodies of arbitrary shape. Measured radiation patterns for AGM-88 High Speed Antiradiation Missile (HARM) and AIM-SIC missile radomes are compared to computed data.

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A STUDY OF THE MEASURES OF EFFECTIVENESS FOR THE JMSDF AEGIS DESTROYER IN A LITTORAL, AIR DEFENSE ENVIRONMENT

Hideto Ito-Lieutenant Junior Grade, Japanese Maritime Self Defense Force
B.S., National Defense Academy Japan, 1990
Master of Science in Aeronautical Engineering-December 1995
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics

Maritime operations in a littoral area demand a fundamental change in the future defense build-up of the Japanese Maritime Self Defense Force (JMSDF). The anti-air warfare (AAW) capability of the JMSDF in the littoral area, especially against very low altitude anti-ship cruise missiles (ASCMs), should be improved. To achieve the required future air defense lethality, the JMSDF must optimize the resource allocation within a limited budget. Therefore, it is important to understand the essential elements of air defense lethality by the JMSDF Aegis destroyer in order to improve their operational effectiveness. In this study, a measure of effectiveness (MOE) for Aegis lethality against an ASCM attack is defined as "a denial area at an acceptable risk." Using this MOE, spread sheet lethality models based on Aegis weapons characteristics, target detection range, reaction time, and ASCM speed, are developed and used to study several alternative improvements to Aegis.

LOW-SPEED WATER TUNNEL FLOWFIELD VISUALIZATION STUDIES OF THE HYPERSONIC LOFTY WAVERIDER CONFIGURATION

Andrew M. Kenny, Jr.-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Aeronautical Engineering-September 1996
Advisor: C.F. Newberry, Department of Aeronautics and Astronautics
Second Reader: S.K. Hebbar, Department of Aeronautics and Astronautics

A flow visualization study of the vortical flow over a scale model LoFLYTE waverider configuration was conducted in the Naval Postgraduate School water tunnel facility using a dye-injection technique. The main focus of this investigation was to analyze vortex development, vortex core trajectories, and vortex bursting phenomena at high angles of attack (AOA) with and without sideslip. Still photographs and video frames were taken for pitch angles between 18° and 40° and yaw angles between 0° and 10°. At pitch angles lower than 18°, the vortex cores were not well developed and barely discernible. The LoFLYTE waverider vortical flowfield resembled that of sharp leading edge delta wings with similar leading edge sweep. As AOA increased, the longitudinal burst location of the vortices moved forward toward the model apex. The lateral position of the vortex cores remained constant with increasing AOA. In a sideslip condition vortex asymmetry was present, but as AOA was increased the vortex asymmetry was reduced. The secondary aspect of this investigation analyzed the behavior of the flow on the bottom surface of the waverider model, particularly in the vicinity of the engine inlet. As AOA was increased from -2° to 18°, the dye streaklines on the bottom surface were eventually drawn to the top surface due to the strong suction created by the development of well defined vortices originating at the sharp leading edges.

LINEAR MODELING OF TILTROTOR AIRCRAFT (IN HELICOPTER AND AIRPLANE MODES) FOR STABILITY ANALYSIS AND PRELIMINARY DESIGN

Gary D. Klein-Captain, United States Marine Corps
B.S., Aerospace Engineering, United States Naval Academy, 1985
Master of Science in Electrical Engineering-June 1996
Master of Science in Aeronautical Engineering-June 1996
Advisors: Robert G. Hutchins, Department of Electrical and Computer Engineering
E. Roberts Wood, Department of Aeronautics and Astronautics

This thesis investigates the linear state space modeling of a tiltrotor aircraft by modifying an existing MATLAB routine which is used for preliminary (helicopter) stability and control analysis. The modifications consist of changing existing

script files along with adding new ones. The modifications result in having a routine that allows the input of tiltrotor characteristics and subsequently generates a state space model along with other stability and control characteristics. The tiltrotor modeling is validated by the input of XV-15 characteristic data into the program and performing a eigenvalue comparison with a model of a similar tiltrotor, the V-22. A more extensive comparison is performed with another XV-15 model which has been extensively used and validated with wind tunnel and flight.

EVALUATION OF THE BOEING PAN AIR TECHNOLOGIES CODE (A502I) THROUGH PREDICTION OF SEPARATION FORCES ON THE GBU-24

Matthew Alan LeTourneau-Lieutenant, United States Navy
B.S., The George Washington University, 1988
Master of Science in Aeronautical Engineering-March 1996
Advisor: Max F. Platzer, Department of Aeronautics and Astronautics

The Boeing PAN AIR Technologies code (A502i) is investigated to explore its suitability for determination of separation forces on ordnance. To this end, A502i is first assessed by applying it to three problems for which other solutions and experimental data are available, i.e., steady flow past a rectangular, parabolic arc wing and a delta wing at both subsonic and supersonic conditions. Good agreement is found in all cases. A502i is then applied to the GBU-24's being in two configurations for a subsonic case and a supersonic case. Good agreement is found with data obtained from wind tunnel experiments for low angles of attack.

NUMERICAL SIMULATION OF THE FLOW FIELD ABOUT A MULTI- ELEMENT AIRFOIL WITH OSCILLATING FLAP

Miguel A. Ortiz-Lieutenant Commander, United States Navy
B.S., Embry-Riddle Aeronautical University, 1982
Master of Science in Aeronautical Engineering-March 1996
Advisor: Max F. Platzer, Department of Aeronautics and Astronautics

Investigation of steady and unsteady flowfields over airfoils is an active area of current computational and experimental research. In this study, the compressible, viscous, flow over a single and multi-element airfoil is numerically simulated by solving the Navier-Stokes equations. The motivation for this work includes interest in studying the effects of a stationary/flapping airfoil combination in tandem configuration. A single-block Navier-Stokes (NS) solver is employed to compute unsteady flowfields. Turbulence is treated using the Baldwin-Lomax turbulence model. A single C-grid is generated and it is partially distorted to simulate the flapping motion. Numerical solutions are obtained for flows at a fixed angle of attack and for unsteady flows over flapping airfoils. The numerical solutions agree well with the experimental data. The difficulties faced during the study are discussed and future improvements are suggested.

COMPARATIVE COMPUTATIONAL ANALYSIS OF AIRFOIL SECTIONS FOR USE ON SAILING CRAFT

Louis P. Partida-Lieutenant, United States Navy
B.S., United States Naval Academy, 1986
Master of Science in Aeronautical Engineering-March 1996
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Richard M. Howard, Department of Aeronautics and Astronautics

This thesis represents the results of a comparative analysis of current and proposed airfoil sections for use on sailing craft. The primary goal of this report is to develop a sail replacement that functions with the ease and durability of current sailboat sails, yet offers a marked improvement in overall performance, with minimum penalties of weight and construction complexity. State-of-the-art computational methods are utilized to determine the respective aerodynamic characteristics of a model of a current windsurfer sail section and models of a proposed semi-rigid wing-sail section.

Wing-sails offer the same promise of performance gains that modern airfoils have produced in comparison to early thin airfoils. An investigation into differences and possible benefits of the analyzed sections' aerodynamic loading and stall characteristics is made using fully viscous Navier-Stokes Computational Fluid Dynamic codes. Finally a full three-dimensional wing-sail computational model is constructed to identify further areas where sectional improvements would enhance the overall performance of the lifting shape.

PARAMETRIC (EWIR) DIFFERENCES IN HIL MISSILE SIMULATORS: IMPACT ON ELECTRONIC ATTACK SYSTEMS

Larry Alan Pugh-Lieutenant Commander, United States Navy
B.S., Southern Methodist University, 1983
Master of Science in Aeronautical Engineering-December 1995
Advisor: Phillip E. Pace, Department of Electrical and Computer Engineering

Failure to accurately simulate threat radar missile systems, in particular Anti-Ship Cruise Missiles, can have enormous ramifications in the training and evaluation of both personnel and electronic warfare equipment. In light of the current fiscal environment where defense dollars are extremely limited, a single generic simulator must be designed to represent several threat radar missile systems. This simulator must operate with a high degree of fidelity in order to provide an accurate and meaningful evaluation of the effectiveness of shipboard electronic attack systems designed to defeat these threat missile systems. This work examines the effect that parametric differences between the threat simulator and actual threat weapon systems will have on the operation of a variety of the most commonly used active electronic attack techniques. Specifically, does an error in the parameter influence how a particular technique is designed to function, and if so, in what manner is the technique affected by the parameter. The parameters of interest that are examined are taken from the Electronic Warfare Integrated Reprogramming database parameters.

BURNING RATES AND ATOMIZATION CHARACTERISTICS OF LIQUID HYDROCARBON FUELS

Kenneth L. Reber-Lieutenant, United States Navy
B.S., University of Colorado, 1989
Master of Science in Aeronautical Engineering-December 1995
Advisor: David W. Netzer, Department of Aeronautics and Astronautics

An investigation was conducted in which the burning characteristics of several liquid hydrocarbon fuels (JP-10, Escorez, Escorez-mixed with JP-10, RJ-7, Mobil E-5, and JP-8) were determined using a windowed combustion bomb at pressures from 1-10 atmospheres. A video camera was used to record the burning of the particles and a frame grabber and a computer were used to extract the data. Fuel atomization characteristics were measured using a standard poppet atomizer and Malvern particle sizer. The burning characteristics of several solvents (Koch 150,150nd,155) with high octane and high flash points were also measured. The burning rates of Escorez/JP-10 mixtures were found to be slightly higher than JP-10 and their volumetric heating values are also higher. Although they were found to have significantly poorer atomization characteristics, the measured particle sizes were small enough to be effectively utilized in ramjet combustors. Pumping characteristics were not measured. Mobil E-5 and RJ-7 were also found to have increased burning rates compared to JP-10. They also have higher volumetric heating values. JP-8 had higher burning rates than JP-10 but has a lower volumetric heating value. The Koch solvents had adequate droplet burning rates, but also significantly increased sooting characteristics.

UNITARY JOINT STANDOFF CAPTIVE AIR TRAINING MISSILE AVIONICS DESIGN THROUGH OPERATIONAL CONCEPTS AND FUNCTIONAL REQUIREMENTS ANALYSIS

Dennis J. Reilly III-Commander, United States Navy
B.S., United States Naval Academy, 1979
Master of Science in Aeronautical Engineering-March 1996
Advisor IsaacI. Kaminer, Department of Aeronautics and Astronautics

To accurately simulate the Unitary Joint Standoff (JSOW) weapon functions and provide pilots with the most realistic training, the captive air training missile (CATM) avionics design will fully implement well defined operational concepts and functional requirements in terms of flight simulation characteristics, operational functions, pilot feedback, and electronic interfaces. This would provide the Navy, Marines, and Air Force with a single, multi-capable, light weight CATM that consolidates CATM procurement, decreases aircraft turnaround time and increases aircrew training per flight hour.

JSOW CATM CONCEPTUAL WEIGHT AND AIRFRAME DESIGN

Michael T. Scarry-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Aeronautical Engineering-September 1996
Advisor: Gerald H. Lindsey, Department of Aeronautics and Astronautics
Second Reader: Sandra L. Scrivener, Department of Aeronautics and Astronautics

The Joint Stand Off Weapon (JSOW) is a new defense system consisting of a 1065 pound airframe, which includes a 500 pound warhead, to be carried on the F/A-18 Hornet. Training will be accomplished through use of a Captive Air Training Missile (CATM), which is a lighter mock-up of the actual weapon also carried on the wing of the aircraft but not released during training. The JSOW CATM, will need to have very few differences from the actual JSOW Unitary to be an effective training tool. Two main differences are that it will be lighter and have a longer service life. The threshold weight is to be less than 500 pounds, the objective weight is 300 pounds, and the threshold maximum service life is 1500 flight hours, 400 catapult launches and 400 arrested landings. Different CATM variations are considered followed by a strength analysis, using the I-DEAS software, of the most promising variation. This CATM design meets the stated weight objectives. To prepare the CATM for fatigue testing, a proposed service life needs to be defined. The usage of the current IR Maverick CATM over a three year period was examined and used to find the proposed service life of the JSOW CATM. Once the service life was defined, a preliminary fatigue analysis was performed using the I-DEAS software.

INVESTIGATION OF THE EFFECT OF REYNOLDS NUMBER ON LAMINAR SEPARATION BUBBLES ON CONTROLLED-DIFFUSION COMPRESSOR BLADES IN CASCADE

David G. Schnorenberg-Captain, United States Marine Corps
B.S.A.E., University of Minnesota, 1987
Master of Science in Aeronautical Engineering-June 1996
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

Detailed experimental investigation of second-generation, controlled-diffusion, compressor-stator blades at an off-design inlet flow-angle was performed in a low-speed cascade wind tunnel using various experimental procedures. The objective of the study was the characterization of the off-design flow and the detailed investigation of flow separation which occurred near mid-chord. When it was found that the flow separation behavior was strongly influenced by the Reynolds number, the effect of Reynolds number variation on flow separation was investigated. Surface flow visualization was performed to gain general insight into the flow behavior. Blade surface pressure measurements were obtained using instrumented blades, from which coefficients of pressure were calculated. Laser-Doppler velocimetry

(LDV) was used to characterize the off-design flow upstream, in the passage between two blades, in the boundary layer on the suction side of the blades, and in the wake region.

Overall, good comparisons between blade surface pressure measurements, LDV data and flow visualization were obtained for the separation region. At the highest Reynolds number, separation was turbulent and three-dimensional and at the low Reynolds number the separation was predominately laminar and two-dimensional.

APPLICATION OF PRESSURE-SENSITIVE PAINT IN SHOCK-BOUNDARY LAYER INTERACTION EXPERIMENTS

Douglas L. Seivwright-Lieutenant, United States Navy
B.S., Embry-Riddle Aeronautical University, 1985
Master of Science in Aeronautical Engineering-March 1996
Advisor: Raymond P. Shreeve, Department of Aeronautics and Astronautics

A new type of pressure transducer, pressure-sensitive paint, was used to obtain pressure distributions associated with shock-boundary layer interaction. Based on the principle of photoluminescence and the process of oxygen quenching, pressure-sensitive paint provides a continuous mapping of a pressure field over a surface of interest. The data measurement and acquisition system developed for use with the photoluminescence sensor was evaluated first using an underexpanded blowing jet over a flat plate. Once satisfactory results were obtained, the system was used to examine shock-boundary layer interaction in a blow-down supersonic wind tunnel at Mach numbers of 1.4 and 1.7. Details of the measurement technique, and discussion of the flow fields which were examined, are reported.

APPLICATION OF NEURAL NETWORKS TO PERISCOPE DISCRIMINATION

Robert N. Severinghaus-Lieutenant, United States Navy
B.S., University of Kansas, 1989
Master of Science in Aeronautical Engineering-March 1996
Advisor: Daniel J. Collins, Department of Aeronautics and Astronautics

The difficulty of detecting a periscope by radar is complicated by false targets. Radar range profiles are used in current correlation techniques to discriminate a periscope from false targets. Neural networks provide an alternative discrimination method that has good generalization and noise rejection features. This study applies neural networks to the periscope discrimination process using commercially available software. Four data input classes were used for training multiple neural networks. The first data input class was the radar range profile. The second data input class was the same as the first, but used a signal-to-noise improvement method to preprocess the radar range profiles. The third data input class used another noise reduction scheme, again on the same data. The discrete Fourier transform (DFT) of the radar range profile produced additional discrimination data. This frequency data was appended to the radar range profile to create a fourth data input class. The results of these neural networks in classification is presented and it is shown that neural networks can discriminate periscopes from false targets with high probability of detection (PD) and low probability of false alarm (PFA).

MOTION PLANNING AND DYNAMIC CONTROL OF THE NOMAD 200 MOBILE ROBOT IN A LABORATORY ENVIRONMENT

Ko-Cheng Tan-Lieutenant Commander, Republic of China Navy
B.S., Chinese Naval Academy, 1984
Master of Science in Aeronautical Engineering-June 1996
Advisor: Xiaoping Yun, Department of Electrical and Computer Engineering
Second Reader: Isaac Kaminer, Department of Aeronautics and Astronautics

Motion planning and control of a Nomad 200 mobile robot are studied in this thesis. The objective is to develop a motion planning and control algorithm that is able to move the robot from an initial configuration (position and orien-

tation) to a goal configuration in a typical laboratory environment. The robot must be able to avoid unknown static (e.g., walls and tables) and dynamic (e.g., people) obstacles. Dubin's algorithm finds the shortest path connecting two configurations in an obstacle-free environment, but it is not able to avoid obstacles present in the environment. The potential field algorithm is effective in avoiding unknown obstacles, but it has the local minimum problem and does not consider the orientation of a mobile robot. A modified potential field algorithm is first developed. The algorithm overcomes local minima in a typical laboratory environment. The modified potential field algorithm is then combined with Dubin's algorithm to incorporate orientation into motion planning. The combined algorithm is able to avoid static and dynamic obstacles and achieve position and orientation requirements. Simulation and physical experiment results are presented to demonstrate the effectiveness of the algorithm.

A SENSITIVITY STUDY OF NUMERICAL SOLUTIONS OF THE SOUTH CHINA SEA OCEAN MODEL TO VARIOUS GRIDS GENERATED BY GRID GENERATION TECHNIQUE

Vinh X. Tran-Lieutenant, United States Navy
B.S., University of Oklahoma, 1988
Master of Science in Aeronautical Engineering-December 1995
Advisor: Le N. Ly, Department of Oceanography

The sensitivity of numerical solutions of systems of nonlinear flow equations (Navier-Stokes equations) to the grid used is investigated through the use of the South China Sea (SCS) numerical ocean model. Traditionally, rectangular coordinate grids are used in environmental modeling. The advantage of rectangular coordinate grids is their simplicity in the generation process. However, rectangular coordinate grids are not well suited for regions with complex terrain (coastlines and topography) and occasionally lead to poor accuracy in numerical solutions. The grid generation techniques are being introduced to coastal ocean modeling to study the sensitivity of numerical solutions to the grid used and to investigate the enhancement of the modeling process. Grid generation techniques are broadly used in the aeronautical engineering community for solving CFD problems.

One orthogonal (121x191) and two curvilinear nearly-orthogonal grids (121x191 and 151x241) are designed to couple with the SCS numerical ocean model. The grids are designed using the EAGLEView grid generation code developed by the National Science Foundation (NSF) Engineering Research Center (ERC) of Mississippi State University. EAGLEView implements a grid generation technique using mainly elliptic and algebraic generation systems. The designed grids are processed with the SCS numerical ocean model for 200 days to study the sensitivity of numerical solutions to the grid used. The solutions of the temperature and salinity fields are presented and analyzed. The advantages of curvilinear nearly-orthogonal grids are also discussed.

UNITARY JOINT STANDOFF WEAPON CAPTIVE AIR TRAINING MISSILE FLIGHT SIMULATION

David R. Wagner-Commander, United States Navy
B.S., United States Naval Academy, 1981
Master of Science in Aeronautical Engineering-September 1996
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics

During the past year, a student/faculty team at the Naval Postgraduate School Aeronautics and Astronautics Department has been engaged in developing functional requirements for the Unitary Joint Standoff Weapon (JSOW) Captive Air Training Missile (CATM). One such requirement calls for pilot steering commands to be synthesized and displayed in the cockpit during JSOW training missions. A comprehensive understanding of the JSOW's guidance and control system's performance in free flight is critical to obtaining truly pilot-friendly steering commands and displays. To this end, this thesis models the JSOW guidance and control system using Matlab/Simulink software and offers the necessary framework for developing pilot-steering commands and displays.

UNIFORM SYSTEM FOR THE RAPID PROTOTYPING AND TESTING OF CONTROLLERS FOR UNMANNED AERIAL VEHICLES

James A. Zanino-Lieutenant, United States Navy
B.S., Boston University, 1988
Master of Science in Aeronautical Engineering-September 1996
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Richard M. Howard, Department of Aeronautics and Astronautics

The field of control systems has witnessed an explosion in state-space techniques addressing a variety of critical design issues facing control engineers today. Modern computational tools, such as the Matrix$_x$ Product Family developed by Integrated Systems Incorporated, allow the designer to quickly design, test and implement control systems based on these state-spaced techniques. These new computing advances shorten the time required to complete a control design from a few years to a few months. However, as the design process progressed new inputs and outputs were required, which usually resulted in a confusing mess of connections that were hard to follow. Therefore, a universal system was needed that could be used on any controller design to aid in the understanding and tracking of the controller's inputs and outputs. A description of this system is given along with a detailed step by step process on how it was implemented on a Unmanned Air Vehicle (UAV).