SUPERSONIC FLOW PAST TWO OSCILLATING AIRFOILS

Georgios Alexandris-Major, Hellenic Air Force
B.S., Hellenic Air Force Academy, 1983
Master of Science in Applied Physics-June 1998
Advisors: M. F. Platzer, Department of Aeronautics and Astronautics
James Luscombe, Department of Physics
Kevin Jones, Department of Aeronautics and Astronautics

Supersonic flow past two oscillating airfoils with supersonic leading edge locus is analyzed using an elementary analytical theory valid for low frequencies of oscillation. The airfoils may have arbitrary stagger angle. This approach generalizes Sauer's solution for a single airfoil oscillating at small frequencies in an unbounded supersonic flow.

It is shown that this generalization can provide an elementary theory for supersonic flow past two slowly oscillating airfoils. This aerodynamic tool will facilitate the evaluation of pressure distributions and consequently the calculation of moment coefficient. Torsional flutter boundaries are computed. The results for the pitch-damping coefficient are the same when compared with previous analysis. For arbitrary frequencies a linearized method of characteristics was outlined.

The elementary theory that has been developed in the thesis can be used for flutter evaluation of aircraft carrying external stores. The result of the thesis is the derivation of the pitch-damping coefficient which is necessary to predict the flutter conditions.

DoD TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Flutter Analysis, Structures

INVESTIGATION OF THE PRESSURE AND TEMPERATURE SENSITIVITIES OF A PRESSURE SENSITIVE PAINT

Peter D. Baumann-Commander, United States Navy
B.A., University of California at Santa Cruz, 1979
Master of Science in Aeronautical Engineering-September 1998
Advisor: Raymond P. Shreeve, Department of Aeronautics and Astronautics
Second Reader: Garth V. Hobson, Department of Aeronautics and Astronautics

In the development of a surface pressure measurement system for transonic compressor rotors, it has been shown that Pressure Sensitive Paint (PSP) is also temperature dependent. In the present study, the sensitivities to pressure and temperature were examined experimentally using an electronically-gated, intensified Charged-Coupled-Device (CCD) video camera, frame-grabber software and an eight-inch diameter calibration chamber. Using a signal generator, in a procedure that matched the requirements of the rotor application, multiple low-intensity-level camera exposures were integrated and captured to produce a single usable image. Ten captured images were averaged to increase the image's signal-to-noise ratio and the result was used to produce an image ratio with respect to a static (ambient pressure/temperature) reference condition. Calibration tests of constant temperature/variable pressure and constant pressure/variable temperature were completed. The results were then compared with data obtained using the same paint and an automated, single-exposure calibration procedure at NASA Ames Research Center. It was shown that the calibration data could be used to derive the static pressure field produced over a high-speed test rotor using PSP and the same image-capture system used in the calibration. In preparation for a bench test of the procedure, a uniform-stress, high-speed test rotor disk, fitted with a shock generator was driven at speeds in excess of 30,000 RPM. Recommendations are made toward the goal of obtaining quantitative pressure measurements on transonic compressor rotors.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pressure Sensitive Paint, PSP, Charged Couple Device Camera, CCD, Photoluminescence, Imaging, Luminescence, PTOEP, UV Illumination, Detection, Emission, Aerodynamics, Measurements, Temperature and Pressure Calibration

COMPARATIVE ANALYSIS OF SELECTED RADIATION EFFECTS IN MEDIUM EARTH ORBITS

Jennifer A. Bolin-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Astronautical Engineering-December 1997
Advisors: Vicente C. Garcia, National Security Agency
Brij N. Agrawal, Department of Aeronautics and Astronautics

Satellite design is well developed for the common Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) and Highly Elliptical Orbits (HEO), i.e., Molniya, cases; Medium Earth Orbit (MEO) satellite design is a relatively new venture. MEO is roughly defined as being altitudes above LEO and below GEO. A primary concern, and a major reason for the delay in exploiting the MEO altitudes, has been the expected radiation environment and corresponding satellite degradation anticipated to occur at MEO altitudes. The presence of the Van Allen belts, a major source of radiation, along with the suitability of GEO and LEO orbits, has conventionally discouraged satellite placement in MEO. As conventional Earth orbits become increasingly crowded, MEO will become further populated.

This thesis investigates the major sources of radiation (geomagnetically trapped particles, solar particle events and galactic cosmic radiation) with respect to specific Naval Research Laboratory (NRL) designated MEO (altitudes between 3,000 nautical miles (nmi) and 9,000 nmi; inclination angle of 15 degrees). The contribution of each of these components to the total radiation experienced in MEO and the effects of the expected radiation on a representative spacecraft are analyzed in comparison to a baseline LEO orbit of 400 nmi and 70 degrees inclination. Dose depth curves are calculated for several configurations, and show that weight gains from necessary expected shielding are not extreme. The radiation effects considered include proton displacement dose and solar cell degradation.

KEYWORDS: Radiation, Medium Earth Orbit, Space

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Battlespace Environments

DESIGN OF AN ATTITUDE DYNAMICS AND CONTROL SUBSYSTEM FOR A MEDIUM EARTH ORBIT SATELLITE

Danny K. Busch-Lieutenant, United States Navy
B.S. in Mathematics, Belmont University, 1989
Master of Science in Astronautical Engineering-December 1997
Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics
Gangbing Song, Department of Aeronautics and Astronautics

The Department of Defense has a continuing need for satellite communications to satisfy the demand for information exchange for strategic, operational, and tactical warfighters. There is currently a Deputy Undersecretary of Defense for Space (DUSD (Space)) transition planning effort to develop a satellite communications architecture for the 2007-2010 time frame. During this time all three current satellite systems; UFO, DSCS, and MILSTAR, are expected to degrade rapidly. As part of the DUSD - Space effort the U.S. Navy was tasked to form a Mobile Users Study to establish a framework for completing the detailed requirements and engineering work needed to develop the UHF/Mobile User transition plan. Then, as part of the Navy effort, the Naval Postgraduate School's Astronautical Engineering class SE-61 under Professor Brij Agrawal's guidance designed a proposed medium Earth orbit communications satellite. This thesis is a design of the Attitude Dynamics and Control Subsystem for the subject medium Earth orbit MUS communications satellite. The thesis describes and explores the five major steps in designing an Attitude, Dynamics, and Control Subsystem. It also focuses on key ADCS related areas that are peculiar to a MEO satellite as compared to a GEO satellite.

KEYWORDS: Attitude Dynamics and Control Subsystem, ADCS, Medium Earth Orbit, MEO, Satellite Design, Spacecraft Design, Communications Satellite

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

INVESTIGATION INTO THE TUMBLING CHARACTERISTICS OF THE TIER III MINUS UNMANNED AIR VEHICLE (UAV)

Robert B Caldwell Jr.-Lieutenant Commander, United States Navy
B.S.A.E., Auburn University, 1986
Master of Science in Aeronautical Engineering-March 1998
Advisor: Richard M. Howard, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

A free-to-pitch wind tunnel analysis of a 1/25-scale model of the Tier III Minus DarkStar Unmanned Aerial Vehicle (UAV) was conducted to better quantify the susceptibility of the aircraft to entering a potentially catastrophic autorotative pitching motion known as tumbling. The objective of the experimental portion of the study was to determine total and dynamic moment coefficients as well as pitch damping coefficients for incorporation into a three-degree-of-freedom computer simulation. The simulation, based on the experimentally-obtained data, revealed that the Tier III Minus would tumble with the proper initial conditions of high angle of attack and/or pitch rate. Also investigated were the effects of uncommanded control surface deflection and wind shear. The simulation revealed a tendency to enter a tumble for control deflections of between -5 and -15 degrees. The results of the wind shear simulation revealed a resistance to tumbling for encountering FAR Part *25* design gusts of 38 and 66 ft/s.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Tier III Minus, Unmanned Aerial Vehicle, UAV, Tumbling

AN ANALYSIS OF LIMITATIONS IN ACTIVE CANCELLATION OF RADAR SIGNALS

Michael J. Dennis-Lieutenant, United States Navy
B.S.A.E., Massachusetts Institute of Technology, 1987
Master of Science in Aeronautical Engineering-September 1998
Master of Science in Electrical Engineering-September 1998
Advisor: Michael A. Morgan, Department of Electrical and Computer Engineering
Second Reader: Richard Howard, Department of Aeronautics and Astronautics Engineering

Acoustic noise suppression has been achieved by rebroadcasting a phase-inverted copy of an incident signal, such that the two signals cancel. The same effect applies in theory to electromagnetic signals, allowing the cancellation of radar signals. This effect would supplement existing "stealth" technologies. The electromagnetic equivalence theorem provides for a straightforward theoretical analysis, and several numerical analyses demonstrate cancellation on simple wire models. The limitations of the cancellation are covered with respect to bandwidth, canceler spacing, and two canceler unit failure (error) modes. Sucessful cancellation is demonstrated for two canceler densities up to approximately 50 MHz, and a significant reduction in canceler effectiveness results when the two failure modes are tested.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Sensors

KEYWORDS: Radar, Electromagnetic Field Cancellation, Radar Cancellation, Scattering Analysis

DESIGN AND BUILD OF EVA COMPATIBLE, BOLT/MOTOR BRACKET ASSEMBLIES FOR THE R-SLC SYSTEM AND ANALYSIS FOR FOLLOW-ON REDUCED GRAVITY TESTING

Damon E. Fields-Captain, United States Marine Corps
B.S., United States Naval Academy, 1988
Aeronautical and Astronautical Engineer-March 1998
Master of Science in Astronautical Engineering-March 1998
Advisors: Gerald H. Lindsey, Department of Aeronautics and Astronautics
Lois Scaglione, NASA Michael J. Smith Chair

The Robotic-Sidewall Logistics Carrier (R-SLC) is a design solution for putting small payloads (military and non-military) on orbit while meeting the requirement to transfer experiment and logistics equipment between the Space Shuttle and the International Space Station (ISS) by robotics rather than through the conduct of extra vehicular activities (EVA). The concept, design, and fabrication were all conducted by students and faculty at the Naval Postgraduate School (NPS) and the Boeing Defense and Space Group (Boeing).

Using as much off-the-shelf technology as practical for the design, the R-SLC will provide a lightweight, stand-alone means to more cost effectively carry small payloads aloft in the Shuttle cargo bay. This hardware will be fully Remote Manipulator System (RMS) compatible for on orbit removal and retrieval operations. Transferring or deploying payloads via the RMS reduces the requirement for astronauts to conduct EVA operations. EVA operations will only be required where system failure of power or robotics occurs.

This thesis project, specifically the bolt/motor bracket assemblies of the R-SLC, will integrate some off-the-shelf parts with three primary hardware elements specifically designed for this assembly. This innovation will provide the means to attach an EXPRESS pallet adapter to a side wall carrier so that it is removable and replaceable during EVA contingency operations. Special considerations were given to human factors engineering during the design process in order to accommodate the suited astronaut in a zero-gravity environment. Part two of this thesis encompasses the hazard and structural analyses of specifically designed flight support equipment and planning for a reduced gravity flight test aboard the NASA KC-135A aircraft in order to validate EVA compatibility.

DoD KEY TECHNOLOGY AREA: Other (Manned Space Flight)

KEYWORDS: Orbiter, Robotics, Logistics, Space Shuttle, ISS

DESIGN OF DIGITAL CONTROL ALGORITHMS FOR UNMANNED AIR VEHICLES

Steven J. Froncillo-Lieutenant Commander, United States Navy
B.S., University of Rhode Island, 1983
Master of Science in Aeronautical Engineering-March 1998
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

Recent advances in the design of high performance aircraft, such as fly-by-wire controls, complex autopilot systems, and unstable platforms for greater maneuverability, are all possible due to the use of digital control systems. With the aid of modern control tools and techniques based on state-space methods, the aerospace engineer has the ability to design a dynamic aircraft model, verify its accuracy, and design and implement the controller within a matter of a few months. This work examines the digital control design process utilizing a Rapid Prototyping System developed at the Naval Postgraduate School. The entire design process is presented, from design of the controller to implementation and flight test on an Unmanned Air Vehicle (UAV).

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Unmanned Aerial Vehicles, Rapid Prototyping Systems, Hardware-in-the-Loop Simulation, AROD, FROG, MATRIX, SystemBuild

A SECOND LAW APPROACH TO AIRCRAFT CONCEPTUAL DESIGN

David A. Gleeson-Lieutenant, United States Navy
B.S., University of Texas at Austin, 1990
Master of Science in Aeronautical Engineering, September 1998
Advisor: Conrad F. Newberry, Department of Aeronautics and Astronautics
Second Reader: Richard M. Howard, Department of Aeronautics and Astronautics

With advancements in the fields of propulsion, aerodynamics, structures, materials and controls, the routine exploration of hypersonic, atmospheric flight has become a more feasible concept. Thus, there is a need for efficient and effective hypersonic configurations. Current studies in configuration efficiency and effectiveness seem to be concentrated in aircraft subsystem design, especially propulsion systems, rather than at the conceptual aircraft system design level. This thesis attempts to initiate the process of incorporating the Second Law of Thermodynamics into the conceptual aircraft design process. The methodology for this process involves the use of the thermodynamic variable exergy, also known as availability. The ultimate goal of the process introduced by this thesis is to be able to define an aircraft configuration design space based upon both the First and Second Laws of Thermodynamics.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Conceptual Design, Configuration, Second Law of Thermodynamics, Exergy, Availability

AVIONICS SYSTEM DEVELOPMENT FOR A ROTARY WING UNMANNED AERIAL VEHICLE

Daniel S. Greer-Commander, United States Navy
B.S., University of Texas, 1981
Master of Science in Aeronautical Engineering-June 1998
Advisor: Russ W. Duren, Department of Aeronautics and Astronautics
Second Reader: Isaac I. Kaminer, Department of Aeronautics and Astronautics

The Naval Postgraduate School has developed a successful Rapid Flight Test Prototyping System (RLFTPS) for the development of software for remote computer control of fixed wing Unmanned Aerial Vehicles (UAV). This thesis reviews the work accomplished to mount sensors on a small remote controlled helicopter with instrumentation compatible with the RFTPS: an inertial measurement unit, a Global Positioning System (GPS) receiver, an altitude sensor and associated power supply and telemetry equipment. A helicopter with sufficient lift capability was selected and a lightweight aluminum structure was built to serve as both an avionics platform for the necessary equipment and also as a landing skid. Since the altitude sensors used for fixed wing UAVs, such as barometric sensors and GPS, do not provide sufficient accuracy for low altitude hover control, a lightweight, precision altimeter was developed using ultrasound technology. Circuitry was developed to drive a Polaroid 6500 Series Ranging Module and process the output data in a form compatible with the RFTPS avionics architecture. Flight testing revealed severe vibrations throughout the helicopter. An alternative avionics package of reduced size was constructed to house the sonic altimeter and a three-axis accelerometer. Subsequent test flight results and recommendations for further research are provided.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics, Sensors

KEYWORDS: Unmanned Aerial Vehicles, Avionics, Sonic Altimeter

A MILITARY UHF COMMUNICATIONS SATELLITE DESIGN FOR THE USER ON THE MOVE

Nicholas M. Homan-Lieutenant, United States Navy
B.S., University of Nebraska, Lincoln, 1992
Master of Science in Astronautical Engineering-December 1997
Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics
Vicente C. Garcia, National Security Agency

Initial proposals for commercial PCS at L/S band were based on LEO and MEO satellites; some more recent commercial initiatives have been based on GEO satellites with large deployable antennas to provide low data rate services to handheld units. This thesis addresses the feasibility of a UHF military satellite design capable of providing service to handheld units. More specifically, this thesis focuses on the key payload design aspects and technology considerations required to design a GEO satellite with a large deployable antenna that forms multiple beams, and employs on-board signal processing to demodulate and route signals between beams. Several design excursions based on cutting edge technologies in their final stages of R&D are discussed (e.g., Digital Beam Forming, and Turbo coding) along with their system impacts.

KEYWORDS: Satellite Personal Communications, Communications on the Move, Processing Payload, Digital Beam Forming, Waveform Coding, Spacecraft Design

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

PERFORMANCE ENHANCEMENTS TO JOINT ARMY/NAVY ROTORCRAFT ANALYSIS AND DESIGN (JANRAD) SOFTWARE AND GRAPHICAL USER INTERFACE (GUI)

William L. Hucke-Lieutenant Commander, United States Coast Guard
B.S.O.E., United States Coast Guard Academy, 1984
Master of Science in Aeronautical Engineering-June 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Robert L. King, Department of Aeronautics and Astronautics

The Joint Army/Navy Rotorcraft Analysis and Design (JANRAD) computer program was developed at the Naval Postgraduate School to perform performance, stability and control, and rotor dynamics analysis during preliminary helicopter design efforts. This thesis is the continuation of a previous work in which a Graphical User Interface (GUI) was developed and implemented as the front end to the JANRAD program. Due to the complexity of the GUI design, only the performance module of JANRAD was completed by the prior student. This thesis expands the capabilities of the performance module, and the JANRAD code, by adding graphical output of performance results, improved rotor sizing capabilities, resources for user defined blade elements and non-linear blade twist, airfoil meshing capabilities, and additional reference airfoil data corrected for compressibility effects. It also contains the basic architecture for the stability and control module GUI. Additionally, utilizing actual I.JH-60A Black Hawk airfoil and test flight data as inputs, JANRAD version 5.0 was run to validate its output with the test flight results, and those produced in a prior thesis by JANRAD version 3.1 (1995). Excellent agreement was demonstrated in all flight regimes. Utilizing airfoil data corrected for compressibility effects, high altitude runs resulted in much better correlation with test flight results than those experienced in 1995 using uncorrected airfoil data. A JANRAD Users Guide was updated and is included as Appendix A to this thesis.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Helicopter, Graphical User Interface, Performance, Preliminary Design, Stability and Control, UH-60A, JANRAD

A LABVIEW© BASED WIND TUNNEL DATA ACQUISITION PROGRAM

Michael R. Huff-Lieutenant, United States Navy
B.S., University of Illinois, 1989
Master of Science in Aeronautical Engineering-September 1998
Advisor: Conrad F. Newberry, Department of Aeronautics and Astronautics
Second Reader: Richard M. Howard, Department of Aeronautics and Astronautics

The Naval Postgraduate School (NPS) Aerolab® Low Speed Wind Tunnel located in Halligan Hall of the Naval Postgraduate School has been in operation since 1953. Although the tunnel is well maintained, its data acquisition system has not kept pace with modern technology. An effective but affordable solution for acquiring data was needed. It was determined that a software package known as LabVIEW© provides a low cost, data acquisition solution that will enhance the capabilities of the wind tunnel, while at the same time making it more user friendly to faculty and students. The focus of this thesis is the design of a VI that will collect and plot force and moment data from a six-component strain gauge balance and yield real time, non-dimensional, force and moment coefficients in six degrees of freedom. Wind tunnel tests consisting of a sweeps in the NPS Aerolab® low-speed wind tunnel were conducted to verify $(L/D)I_{sp}$ optimized, M• = 6, conical-flow waverider data obtained in 1994 using a different data acquisition system. Results of current testing substantiate the validity of the 1994 test data. Analysis of the current data set resolved pitching moment concerns related to the 1994 data.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Battlespace Environments, Computing and Software, Conventional Weapons, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Strain Gauge Balance, LabVIEW©, VI, Data Acquisition, Wind Tunnel, Waverider, Lift, Drag, Aeromoments

FUEL-OPTIMAL LOW-EARTH-ORBIT MAINTENANCE

Karl E. Jensen-Lieutenant, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Astronautical Engineering-June 1998
Aeronautical and Astronautical Engineer-June 1998
Advisors: I. Michael Ross, Department of Aeronautics and Astronautics
Fariba Fahroo, Department of Mathematics

First-order solutions indicate that a forced Keplerian trajectory (FKT) obtained by thrust-drag cancellation is as fuel-efficient as a Hohmann transfer. Further analysis has shown that the FKT is not Mayer-optimal. Therefore, there must exist another trajectory that matches or exceeds the efficiency of the Hohmann transfer. The application of this result to the fuel-optimal orbit maintenance problem implies that periodic reboosts must be more efficient than an FKT profile. This research begins with the formulation of an optimal periodic control (OPC) problem to determine the minimum fuel-reboost strategy. The problem is numerically solved by a spectral collocation method. The optimization code is further modified to increase accuracy and reduce sensitivity to initial guesses. The results of this effort identified a trajectory for a sample satellite that was 3.5% more efficient than an ideal impulsive Hohmann transfer over the same period of time. From the optimal code, a maximum thruster size is also identifiable for a set of initial conditions. The optimal trajectory can save as much as 10% of the propellant budget when compared to finite-bum Hohmann transfers.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Modeling and Simulation

KEYWORDS: Orbital Maintenance, Orbital Mechanics, Hohmann Transfer, Orbit Reboost, Orbit Transfer, Forced Keplerian Trajectory, Optimization, Periodic Control

UNMANNED AIR VEHICLES: A STUDY OF RECUPERATED-CYCLE GAS TURBINE APPLICATION

Michael Louis Jensen-Lieutenant, United States Navy
B.S.C.S., United States Naval Academy, 1990
Master of Science in Aeronautical Engineering-March 1998
Advisor: Raymond P. Shreeve, Department of Aeronautics and Astronautics Engineering
Second Reader: Garth V. Hobson, Department of Aeronautics and Astronautics Engineering

The DoD's Unmanned Air Vehicle (UAV) medium and high altitude/endurance programs require reliable and fuel-efficient propulsion systems, which suggests the use of turboprop technology. Operational UAVs use commercial reciprocating engines or high-bypass turbofan engines. Current engine types were reviewed and the potential performance of the gas-turbine cycle with recuperation, which would improve thermal efficiency and specific fuel consumption, was examined. The recuperated cycle was noted to have particular advantages for smaller engines. A study was performed using the GasTurb and GECAT engine codes, using component level efficiencies appropriate for small-scale turbomachinery and heat exchangers, to estimate the potential performance of a recuperated turboshaft/turboprop-powered UAV system in comparison to the present reciprocating engine system. It was shown that the use of a recuperated turboprop in a *Predator-type* UAV would result in extended range, increased power availability, and an altitude capability in excess of those attainable currently with spark-ignition engines. Such a recuperative gas-turbine engine would also provide better reliability than the reciprocating engines currently used by UAV platforms.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: UAV, Propulsion, Gasturb, GECAT, NEPP, Turboprop, Turboshaft, Recuperation

ACOUSTICAL EMISSION SOURCE LOCATION IN THIN RODS THROUGH WAVELET DETAIL CROSS CORRELATION

Joseph G. Jerauld-Lieutenant Commander, United States Navy
B.S., California Polytechnic State University at San Luis Obispo, 1986
Master of Science in Aeronautical Engineering, Naval Postgraduate School, 1997
Aeronautical and Astronautical Engineer-March 1998
Advisor: Edward M. Wu, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

Flaws in structural elements release strain energy in the form of stress waves that can be detected through acoustical emission techniques. The transient nature of a stress wave is analytically inconsistent to Fourier Transforms, and the wave characteristics under the effects of dispersion and attenuation deviate from the formal basis of the Windowed Fourier Transform. The transient solid body elastic waves contain multiple wave types and frequency components which lend themselves to the time and frequency characteristics of Wavelet Analysis. Software implementation now enables the exploration of the Wavelet Transform to identify the time of arrival of stress wave signals for source location in homogeneous and composite materials. This investigation quantifies the accuracy and resolution of two existing source location methods and develops a third technique using the Discrete Wavelet Transform on a windowed portion of the stress wave signal. A refined method for the spatial location of material damage induced stress waves can be used to directly monitor the safe-life of structures and provide a quantitative measure for the risk assessment of critical and aging structures.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Materials, Processes, and Structures

KEYWORDS: Acoustical Emission, Composites, Structures, Wavelet Analysis

ACOUSTICAL EMISSION SOURCE LOCATION IN THIN RODS THROUGH WAVELET DETAIL CROSS CORRELATION

Joseph G. Jerauld-Lieutenant Commander, United States Navy
B.S., California Polytechnic State University at San Luis Obispo, 1986
Master of Science in Aeronautical Engineering, Naval Postgraduate School, 1997
Aeronautical and Astronautical Engineer-March 1998
Advisor: Edward M. Wu, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

Flaws in structural elements release strain energy in the form of stress waves that can be detected through acoustical emission techniques. The transient nature of a stress wave is analytically inconsistent to Fourier Transforms, and the wave characteristics under the effects of dispersion and attenuation deviate from the formal basis of the Windowed Fourier Transform. The transient solid body elastic waves contain multiple wave types and frequency components which lend themselves to the time and frequency characteristics of Wavelet Analysis. Software implementation now enables the exploration of the Wavelet Transform to identify the time of arrival of stress wave signals for source location in homogeneous and composite materials. This investigation quantifies the accuracy and resolution of two existing source location methods and develops a third technique using the Discrete Wavelet Transform on a windowed portion of the stress wave signal. A refined method for the spatial location of material damage induced stress waves can be used to directly monitor the safe-life of structures and provide a quantitative measure for the risk assessment of critical and aging structures.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Materials, Processes, and Structures

KEYWORDS: Acoustical Emission, Composites, Structures, Wavelet Analysis

MODAL ANALYSIS AND ACTIVE VIBRATION CONTROL OF THE NAVAL POSTGRADUATE SCHOOL SPACE TRUSS

Scott E. Johnson-Lieutenant, United States Navy
B.S., Texas A&M University, 1991
Master of Science in Astronautical Engineering-June 1998
and
John Vlattas-Lieutenant, United States Navy
B.S.M.E., University of Pennsylvania, 1991
Master of Science in Astronautical Engineering-June 1998
Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics
Gangbing Song, Department of Aeronautics and Astronautics

This thesis examines active control of the Naval Postgraduate School (NPS) Space Truss using a piezoceramic stack actuator. Preceding the development of an active control mechanism for the NPS space truss, modal testing was performed to identify the modal properties of the truss. An impact hammer provided excitation to the truss and accelerometers measured the trussí response. Two data acquisition systems, dSPACE and an Hewlett Packard spectrum analyzer, were used independently to gather and analyze data. For active control, an active strut, consisting of a piezoceramic stack, a force transducer, and mechanical interfaces, was substituted in place of a critical diagonal strut and acted as a control actuator. The frequency response of the system was determined and an integral plus double-integral force feedback control law was designed and implemented. A linear proof mass actuator was employed to excite one of the trussí vibrational modes. The controller then suppressed the vibration along the length of the structure resulting in power attenuation on the order of 10-15 dB. Various combinations of velocity and position feedback gains were investigated in order to optimize the control action. Additional testing was also performed to determine the controllerís sensitivity over a frequency band.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Active Vibration Control, Piezoceramic Actuators, Modal Testing, Modal Analysis

VULNERABILITY REDUCTION TECHNOLOGY FOR ROTARY WING AIRCRAFT

Christopher A. Keane-Captain, United States Marine Corps
B.S., Marquette University, 1989
Master of Science in Aeronautical Engineering-June 1998
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics
Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

Aircraft Survivability is made up of two elements, aircraft susceptibility and aircraft vulnerability. Susceptibility is the inability of an aircraft to avoid being damaged by the elements of an enemy's air defense, and vulnerability is the inability of an aircraft to withstand the damage caused by the enemy's air defense. This thesis is written as a tool for the designer of future military helicopters and tiltrotor aircraft. The vulnerability of modem rotary wing aircraft, the vulnerability reduction concepts, and the technologies used to reduce vulnerability are examined. This thesis describes the threats that may be encountered by modern aircraft, the damage that those threats can cause, the aircraft component/system kill modes, the Loss of essential functions, and concludes with a vulnerability reduction checklist for the designer of rotary wing aircraft.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Rotary Wing Aircraft, Vulnerability, Reduction Concepts, Aircraft Survivability

ALUMINUM 7075-T6 FATIGUE DATA GENERATION AND PROBABILISTIC LIFE PREDICTION FORMULATION

John G. Kemna-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Aeronautical Engineering-September 1998
Advisor: Edward M. Wu, Department of Aeronautics and Astronautics
Second Reader: Gerald H. Lindsey, Department of Aeronautics and Astronautics

The life extension of aging fleet aircraft requires an assessment of the safe-life remaining after refurbishment. Risk can be estimated by conventional deterministic fatigue analysis coupled with a subjective factor of safety. Alternatively, risk can be quantitatively and objectively predicted by probabilistic analysis. In this investigation, a general probabilistic life formulation is specialized for constant amplitude, fully reversed fatigue loading utilizing conventional breakdown laws applied to the general probability damage function. Experimental data was collected both as a benchmark database, as well as an example of the implementation of probabilistic fatigue life prediction. Fully reversed, sinusoidal fatigue testing under load control was carried out at load levels giving high cycle fatigue lives from 1×10^4 to 5×10^6 cycles. The life range is longer than currently available in the literature, thereby increasing the confidence of predictions in the long-life domain, as well as the number of replications at each load level thereby extending the statistics. The load level data sets are interpreted by the probabilistic damage function for life location as well as life shape parameters using maximum likelihood analysis. Homologous life ranking and the minimum entropy hypothesis are investigated as well.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Processes, and Structures

KEYWORDS: Aluminum 7075-T6, Fatigue Life Prediction, Fatigue Database, Probability, Reliability, Damage Accumulation, Maximum Likelihood Analysis

APPLICATIONS OF RAPID PROTOTYPING TO THE DESIGN AND TESTING OF UNMANNED AIR VEHICLE (UAV) FLIGHT CONTROL SYSTEMS

John A. Komlosy Ill-Lieutenant Commander, United States Navy
B.A.E., Georgia Institute of Technology, 1985
Master of Science in Aeronautical Engineering-March 1998
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

The modern engineer has a myriad of new tools to assist in the design and implementation of ever increasingly complex control systems. A promising emerging technology is rapid prototyping. By totally integrating the development process, a Rapid Prototyping System (RPS) takes the designer from initial concept to testing on actual hardware in a systematic, logical sequence. At the Naval Postgraduate School (NPS), the concept of rapid prototyping has been applied to the discipline of flight control.

The NPS RPS consists of a commercially available rapid prototyping software suite and open architecture hardware to permit the greatest possible range of control and navigation projects. The RPS is crucial in that it allows students to participate in projects from the initial concept to the flight-testing phase of the design process. This thesis describes in detail two of these projects: the development of an Airspeed Controller using the RPS tools and the integration of a Voice Control System developed by ViA, Inc., of Northfield, Minnesota. Both projects demonstrate the inherent flexibility and risk reduction of the rapid prototyping approach to system design.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Rapid Prototyping, Unmanned Air Vehicles, Flight Control Systems

DEVELOPMENT OF GRAPHICAL USER INTERFACE (GUI) FOR JOINT ARMY/NAVY ROTORCRAFT ANALYSIS AND DESIGN (JANRAD) SOFTWARE

Chris F. Lapacik-Lieutenant Commander, United States Navy
B.S.A.E, West Virginia University, 1984
Master of Science in Aeronautical Engineering-March 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Robert L. King, Department of Aeronautics and Astronautics

A Graphical User Interface (GUI) was developed and implemented as the front end of the NPS software Joint Army/Navy Rotorcraft Analysis and Design (JANRAD). The original JANRAD computer program was developed to aid in the analysis of helicopter rotor performance, stability and control, and rotor dynamics. An interactive program, JANRAD was capable of accurately and quickly solving helicopter design problems at the preliminary design level. The addition of the GUI greatly simplified the use of the program but added considerable complexity to the original MATLAB® M-File code. Because of the increased complexity, only the Performance Analysis module of the program was modified. The use of several new features of MATLAB® version 5.1, such as the GUIDE® and Structure functions, simplified the construction of the GUI environment and enhanced the tie between the user interface and performance calculation routines. Although initiated from the MATLAB® command line, the program can now be worked entirely from the "Windows" environment. The performance routines were modified extensively to connect the user input with the existing analysis routines. However, the fundamental method of analysis remains unchanged. Several cases of Sikorsky UH-60A Black Hawk input data were run and results compared with those from JANRAD version 3.1 (1995). The results correlated exactly. A Users Guide was developed and is included in Appendix A.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software

KEYWORDS: Helicopter, Graphical User Interface, Performance, Preliminary Design

SOLID MODELING FOR ROTARY WING DESIGN AT NPS WITH AUTOCAD R13

Jeffrey S. Lincoln-Lieutenant, United States Navy
B.S.M.E., Boston University, 1988
Master of Science in Aeronautical Engineering-December 1997
Advisor: E. Roberts Wood, Department of Aeronautics and Astronautics
Second Reader: Conrad F. Newberry, Department of Aeronautics and Astronautics

This thesis is intended to be a reference for solid modeling and Computer Aided Design (CAD) tailored specifically for the Naval Postgraduate School's capstone helicopter design course, AA 4306. The goal is to present the use of AutoCAD R13 software as a central design tool throughout the conceptual design phase of the American Helicopter Society (AHS) Graduate Design Competition project. The specifics of AutoCAD that are essential to performing the design project are explored through examples of model construction and lessons learned from the 1997 VIPER design effort. The usage of solid modeling as a design tool for design team integration is investigated. It is intended for this work to allow future classes to acquire sufficient proficiency with CAD and solid modeling. Maximizing the practical usage of CAD techniques in a single quarter will provide for an improved learning experience in a more realistic design environment.

KEYWORDS: AutoCAD, Design, Solid Modeling, Helicopter, Rotary Wing

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Modeling and Simulation

IDENTIFICATION OF RANDOM LOADS IMPINGING ON THE RAH-66 COMANCHE HELICOPTER EMPENNAGE USING SPECTRAL ANALYSIS

Patrick H. Mason-Major, United States Army
B.S., Georgia Institute of Technology, 1986
Master of Science in Aeronautical Engineering-June 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Donald A. Danielson, Department of Mathematics
Joshua H. Gordis, Department of Mechanical Engineering

The Army RAH-66 Comanche Helicopter is currently undergoing developmental flight testing. The empennage of the aircraft is experiencing buffeting where the horizontal and vertical tail vibrate at resonant frequencies. These high buffet loads are manifested in higher than anticipated fitting loads, particularly on the tail, and vibrations in the crew stations and at the nose cone where the targeting sensors are located. Significant effort has been devoted to identifying the sources of excitation and the nature of the structural response. This thesis determines the location and magnitude of empennage vibratory airloads. Because the nature of the excitation is a random function, spectral analysis is used. To obtain the loads, a three-step process was utilized. First, from aircraft differential pressure transducers and accelerometers, the spectral content of the response and excitation was determined Then, using a NASTRAN model modified to replicate the flight test aircraft, frequency response functions were determined between selected points on the aircraft's tail and the accelerometers. Finally, using this information, a solution was obtained for the vibratory airloads. Having provided information on the nature of the driving forces, structural modifications can be made that move the natural frequencies away from the frequencies of the applied airloads.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: RAH-66 Comanche Helicopter, Random Vibrations, Comanche Tail Section, Structural Analysis, Spectral Analysis, NASTRAN Analysis

DYNAMIC SYSTEM IDENTIFICATION AND MODELING OF A ROTARY WING UAV FOR STABILITY AND CONTROL ANALYSIS

Matthew D. McEwen-Major, United States Marine Corps
B. S., San Diego State University, 1985
Master of Science in Aeronautical Engineering-June 1998
Advisor: Russ Duren, Department of Aeronautics and Astronautics
Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

This thesis presents a method for the dynamic system identification and simulation model development of a small rotary wing Unmanned Aerial Vehicle (UAV). Using aerodynamic parameterization and linear state-space modeling techniques, the Bergen Industrial UAV was modeled for computer simulation to analyze its inherent stability and control characteristics. The NIPS designed JANRAD software was utilized to determine the stability and control derivatives used in the simulation model. The identification of the UAV dynamic model will aid in the development of closed-loop controllers capable of autonomous UAV control. The fidelity of the simulation model was verified by comparing the simulation responses with data collected from on-board sensors during test flights.

DoD KEY TECHNICAL AREA: Air Vehicles

KEYWORDS: Unmanned Aerial Vehicles, Stability and Control, Modeling, Simulation, System Identification, Helicopter, JANRAD

DEVELOPMENT OF GRAPHICAL USER INTERFACE (GUI) FOR JOINT ARMY/NAVY ROTORCRAFT ANALYSIS AND DESIGN (JANRAD) SOFTWARE

Chris F. Lapacik-Lieutenant Commander, United States Navy
B.S.A.E, West Virginia University, 1984
Master of Science in Aeronautical Engineering-March 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Robert L. King, Department of Aeronautics and Astronautics

A Graphical User Interface (GUI) was developed and implemented as the front end of the NPS software Joint Army/Navy Rotorcraft Analysis and Design (JANRAD). The original JANRAD computer program was developed to aid in the analysis of helicopter rotor performance, stability and control, and rotor dynamics. An interactive program, JANRAD was capable of accurately and quickly solving helicopter design problems at the preliminary design level. The addition of the GUI greatly simplified the use of the program but added considerable complexity to the original MATLAB® M-File code. Because of the increased complexity, only the Performance Analysis module of the program was modified. The use of several new features of MATLAB® version 5.1, such as the GUIDE® and Structure functions, simplified the construction of the GUI environment and enhanced the tie between the user interface and performance calculation routines. Although initiated from the MATLAB® command line, the program can now be worked entirely from the "Windows" environment. The performance routines were modified extensively to connect the user input with the existing analysis routines. However, the fundamental method of analysis remains unchanged. Several cases of Sikorsky UH-60A Black Hawk input data were run and results compared with those from JANRAD version 3.1 (1995). The results correlated exactly. A Users Guide was developed and is included in Appendix A.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software

KEYWORDS: Helicopter, Graphical User Interface, Performance, Preliminary Design

FLIGHT TESTING AND REAL-TIME SYSTEM IDENTIFICATION ANALYSIS OF A UH-60A BLACK HAWK HELICOPTER WITH AN INSTRUMENTED EXTERNAL SLING LOAD

Allen H. McCoy-Lieutenant, United States Navy
B.S. Aerospace Engineering, Georgia Institute of Technology, 1989
Master of Science in Aeronautical Engineering-December 1997
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Mark B. Tischler, Rotorcraft Division, NASA-Ames Research Center

Helicopter external air transportation plays an important role in today's world for both military and civilian helicopters, external sling load operations offer an efficient and expedient method of handling heavy, oversized cargo. With the ability to reach areas otherwise inaccessible by ground transportation, helicopter external load operations are conducted in industries such as logging, construction, and fire fighting, as well as in support of military tactical transport missions. Historically, helicopter and load combinations have been qualified through flight testing, requiring considerable time and cost. With advancements in simulation and flight test techniques, there is potential to substantially reduce costs and increase the safety of helicopter sling load certification. Validated simulation tools make possible accurate prediction of operational flight characteristics before initial flight tests. Real-time analysis of test data improves the safety and efficiency of the testing programs. To advance these concepts, the U.S. Army and NASA, in cooperation with the Israeli Air Force and Technion, under a Memorandum of Agreement, seek to develop and validate a numerical model of the UH-60 with sling load and demonstrate a method of near real-time flight test analysis. This thesis presents results from flight tests of a U.S. Army Black Hawk helicopter with various external loads. Tests were conducted as the U.S. first phase of this MOA task. The primary load was a container express box (CONEX), which contained a compact instrumentation package. The flights covered the airspeed range from hover to 70 knots. Primary maneuvers were pitch and roll frequency sweeps, steps, and doublets. Results of the test determined the effect of the suspended load on both the aircraft's handling qualities and its control system's stability margins. Included were calculations of the stability characteristics of the load's pendular motion. Utilizing CIFER® software, a method for near real-time system identification was also demonstrated during the flight test program.

KEYWORDS: Helicopter, External Loads, Sling Loads, Flight Testing, CIFER, Real-time Data Analysis, Helicopter Handling Qualities, Helicopter Stability Margins, UH-60A, Black Hawk

DoD TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF COLD-FLOWTHROUGH THE TURBINE OF THE SPACE-SHUTTLE MAIN ENGINE HIGH-PRESSURE FUEL TURBOPUMP

Joseph R. McKee-Lieutenant Commander, United States Navy
B.S., University of Maryland, 1986
Master of Science in Aeronautical Engineering-September 1998
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

Computational predictions and experimental measurements were made on the Naval Postgraduate School's cold-flow turbine test rig. The test turbine was the Space-Shuttle Main Engine, high-pressure Fuel Turbopump, Alternate Development Model, designed and manufactured by Pratt & Whitney. The flow-field around the first-stage rotor end-wall region was measured using a laser-Doppler velocimetry (LDV) system. Measurements were taken at two axial locations over the rotor blade tip and at three radial locations from the end-wall casing. Three circumferential velocity profile measurements were taken downstream of the first-stage using a three-hole pressure probe. All measurements were taken at a referred rotational speed between 4781 and 4904 rpm. A computational fluid dynamics model of the combined first-stage stator and rotor was developed. Predicted velocity data from this model were extracted for comparison to the rotor exit plane probe measurements.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Computational Fluid Dynamics, Laser-Doppler Velocimetry, High-Pressure Fuel Turbopump Turbine, Space-Shuttle Main Engine

ANALYSIS AND AUTOMATION OF AN AIRCRAFT TAIL-SIZING DESIGN TOOL

Philip W. Meade-Lieutenant Commander, United States Navy
B.S., University of Illinois, Urbana, 1985
Master of Science in Aeronautical Engineering-September 1998
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

The numerical input/output behavior of a previously developed tail-sizing design tool for the High Speed Civil Transport (HSCT) aircraft is described and analyzed. HSCT, under development by NASA with industry partners, is an engineering design model of a future supersonic transport aircraft intended for the commercial passenger aviation market. Tail sizing, in the context of HSCT design, constitutes determining the maximum aft center-of-gravity that the aircraft can accept, given fixed limits on horizontal tail volume, maximum horizontal tail actuator deflection, and maximum actuator deflection rate, while remaining controllable in response to disturbances. Considerations regarding application of the tail-sizing design tool to the problem of FAR gust recovery for this longitudinally unstable aircraft, and limitations thereof are identified and discussed. An algorithm to automate the tool to produce specified outputs is developed and is implemented in MATLAB‰. The automated tool is then applied to the problem of recovery from a series of gust profiles. A set of tests is conducted to verify and validate the features of the tool. The tool is shown to be valid and accurate over a limited range of flight conditions and gust inputs. The limitations of the tool are identified and methods for extending its capabilities in the future, if necessary, are proposed. Features of previously developed graphical user interface (GUI) and data analysis software are extended, and new GUI and analysis software is developed.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: High Speed Civil Transport (HSCT), Automatic Flight Control, Linear Matrix Inequalities (LMI)

AN EXPERIMENTAL INVESTIGATION OF VORTEX BREAKDOWN IN TUBES AT HIGH REYNOLDS NUMBERS

Francis G. Novak-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1985
M.S., Naval Postgraduate School, 1992
M.E., Naval Postgraduate School, 1992
Doctor of Philosophy in Mechanical Engineering-September 1998
Advisor: T. Sarpkaya, Department of Mechanical Engineering
Committee: Matthew Kelleher, Department of Mechanical Engineering
F. Kevin Owen, Department of Mechanical Engineering
David Netzer, Department of Aeronautics and Astronautics
Richard Franke, Department of Mathematics

This thesis deals with non-cavitating swirling flows with vortex breakdown in various tubes. Phenomenological and quantitative investigations were carried out at Reynolds numbers ($Re_D = U_0D_0/n$) as high as 300,000. It was shown that a high Re_D vortex transitions to its new state (breaks down) via a rapidly spinning spiral form, as demonstrated with 4,000 frame per second video, short exposure time (6 ns) imaging, and Digital Particle Image Velocimetry. Of the known types, the spiral emerges as the fundamental breakdown form, and the axisymmetric bubble may now be regarded as a relatively low Re_D occurrence that is bypassed at sufficiently high Re_D. Some new phenomena were observed at high Re_D: Extremely

rapid spiral rotation (over 1,000 revolutions per second), core bifurcation, and reversals in the sense of the spiral windings. Familiar features of breakdowns, such as the transition from jet-like to wake-like axial velocity profiles and the rapidly expanding vortex core, were observed in extensive time averaged velocity and turbulence profiles ascertained with Laser Doppler Velocimetry. However, a mean stagnation point and recirculation were absent in the highest Re_D flow. The core meandering and stagnation point darting in the turbulent flow field were quantified and discussed in detail.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Vortex Breakdown, Turbulence, Laser Doppler Velocimetry, Particle Image Velocimetry, Swirling Flow, Spectra

ENVIRONMETAL TESTING OF THE PETITE AMATEUR NAVY SATELLITE (PANSAT)

Paul J. Overstreet-Lieutenant Commander, United States Navy
B.S., United States Merchant Marine Academy, 1985
Master of Science in Astronautical Engineering-December 1997
Advisors: Daniel Sakoda, Space Systems Academic Group
I. Michael Ross, Department of Aeronautics and Astronautics

Any complex and expensive system requires testing to ensure adequate performance. Communications satellites require extensive testing for two additional reasons: they operate in an environment considerably different from that in which they were built and, after launch, they are inaccessible to routine maintenance and repair. The objectives of testing is not necessarily to duplicate the space environment but to approach it sufficiently so that any spacecraft that passes the tests will operate successfully in its designed space environment. The major features of the space environment that are difficult to simulate exactly are zero gravity, high vacuum, solar radiation, particle radiation and extreme temperatures. This document describes the environmental test program and the test results for the PANSAT program. PANSAT is the acronym for the Petite Amateur Navy Satellite, which is a small communications satellite under development by the Space Systems Academic Group at the Naval Postgraduate School. PANSAT subsystems were subjected to thermal vacuum and random vibration testing as part of the overall environmental test program. Satellite launch, as a Shuttle secondary payload via the Space Transportation System (STS) Small Self-contained Payload (SSCP) program, is planned for October 1998.

KEYWORDS: Environmental Testing, PANSAT, Spacecraft Testing

DoD KEY TECHNOLOGY AREA: Space Vehicles

INTEGRATION OF A MULTI-RATE POSITION FILTER IN THE NAVIGATION SYSTEM OF AN UNMANNED AERIAL VEHICLE (UAV) FOR PRECISE NAVIGATION IN THE LOCAL TANGENT PLANE (LTP)

Robert C. Perry-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1985
Master of Science in Aeronautical Engineering-March 1998
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Russell W. Duren, Department of Aeronautics and Astronautics

Differential Global Positioning System (DGPS) provides highly accurate position information but at update rates of one Hz which is inadequate for precise aircraft terminal maneuvering such as take-off and landing. During this period between updates an accurate position estimate in Local Tangent Plane (LTP) can be made using complementary filtering of the DGPS position and indicated airspeed. Use of indicated airspeed as the filter velocity input necessitates the transformation from body to inertial (LTP) reference frame using Euler angle information available from the Inertial Measuring Unit (IMU) or DGPS. This filter provides accurate estimates of both vehicle position and existing wind. These filter outputs of

position and wind can then be used as inputs to a trajectory controller to ultimately enable autonomous launch and recovery of an Unmanned Aerial Vehicle.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Differential Global Positioning System, Unmanned Aerial Vehicles, Inertial Measuring Unit, Euler Angles,Complementary Filter

DEVELOPMENT AND VERIFICATION OF AN AERODYNAMIC MODEL FOR THE NPS FROG UAV USING THE CMARC PANEL CODE SOFTWARE SUITE

Stephen J. Pollard-Commander, United States Navy
M.S., Naval Postgraduate School, 1997
Aeronautical and Astronautical Engineer-September 1998
Advisor: Max F. Platzer, Department of Aeronautics and Astronautics
Second Reader: Kevin D. Jones, Department of Aeronautics and Astronautics

The CMARC panel-code is evaluated for the development of an aerodynamic model of the Naval Postgraduate School FROG Unmanned Air Vehicle (UAV). CMARC is a personal computer hosted panel-code software suite for solving inviscid, incompressible flow over complex three-dimensional bodies. A panel model of the NPS FROG UAV is developed to obtain stability derivative data at the cruise flight condition. Emphasis is placed on comparing the CMARC data to aerodynamic models obtained from classical design techniques and parameter estimation. Linearized longitudinal and lateral-directional state-equation models are used to compare the dynamic response of each data set. In addition, CMARC is used to generate static-source and angle-of-attack sensor position corrections. Position corrections are provided in look-up table and curve-fit formats. The aerodynamic model obtained with CMARC demonstrated higher fidelity dynamic longitudinal response than the classical design model. Dynamic lateral-directional response is similar to that obtained from classical design techniques. Adjustment through comparison with flight-test data is still required to optimize the CMARC model. Future studies should concentrate on improving CMARC modeling of fuselage side force through the addition of wake separation lines. Additionally, the propeller disk should be modeled in an attempt to capture the effects of increased dynamic pressure over the horizontal and vertical tail surfaces.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Unmanned Aerial Vehicles, UAV, CMARC Panel Method, Ames Research Center, PMARC, Panel Code, Stability Derivatives, Boundary Layer Code, Aircraft Dynamic Response

A PATCHED-CONIC ANALYSIS FOR OPTIMALLY DEFLECTING EARTH-CROSSING ASTEROIDS

Scott D.V. Porter-Lieutenant, United States Navy
B.S. United States Naval Academy, 1989
Master of Science in Astronautical Engineering-December 1997
Advisor: I. Michael Ross, Department of Aeronautics and Astronautics
Second Reader: Soon-Young Park, National Research Council Post-Doctoral Associate

The threat of collision between an asteroid or a comet and the Earth has been well documented. Mitigation of such a threat can be accomplished by destruction of the threat or by perturbing the threat object into a safe orbit. Following a summary of proposed mitigation techniques, this thesis investigates the impulse required to safely perturb a threatening Earth-Crossing Asteroid (ECA). While previously published analysis included only two-body approximations to the impact geometry, this thesis adds the effect of the Earth's gravitational field to more closely approximate reality. The results indicate that third-body effects are strongest on ECA's in a nearly circular heliocentric orbit, where the minimum required DV can be several times larger than that calculated using two-body approximations. To determine the minimum DV required for mitigation,

MATLAB,'s sequential quadratic programming (SQP) algorithm is applied to a constrained optimization problem. Third-body effects were added to a previously published two-body optimization by modifying the boundary conditions. With knowledge of the minimum DV requirements, the capability of current impulsive mitigation technology is analyzed. For asteroids of median density in co-planar orbits, a single 24 Mt nuclear explosive impulse applied earlier than 3 years before impact can effectively mitigate a threat with diameter of 6 km. The capability significantly decreases with shorter warning times.

KEYWORDS: Earth-Crossing Asteroid, Near-Earth Object, NEO Hazard Mitigation, Deflection, Asteroid, Comet, Impact Hazard, Optimum

DoD KEY TECHNOLOGY AREA: Space Vehicles

QUANTITATIVE STRUCTURAL RELIABILITY ASSURANCE THROUGH FINITE ELEMENT ANALYSIS

Christopher W. Rice-Commander (Select), United States Navy
B.S., United States Naval Academy, 1983
M.S., Naval Postgraduate School, 1998
Aeronautical and Astronautical Engineer-September 1998
Advisor: Edward M. Wu, Department of Aeronautics and Astronautics
Second Reader: Gerald H. Lindsey, Department of Aeronautics and Astronautics

Risk assessment of aging aircraft components can be achieved by operational de-rating using a safety factor subjectively selected from experience and heuristics. This investigation involves synthesizing currently available, maturing computer-aided methods into a format of objective quantitative risk assessment. The methodology is applied to quantify the effect of corrosion on P-3C main landing gear lower drag struts. This kind of synthesis is appropriate wherever structural operational risk is a concern. The P-3 has undergone many modifications since the 1950s and the lower drag struts are being scrapped due to internal surface corrosion. The corrosion process is random, resulting in pits varied spatially and in severity. These corrosion attributes are merged into a one random variable probability model. The casual relation of the corrosion to structural load is analyzed by finite elements. The structural configuration model input is provided by computer-aided drafting, verified by physical measurement. The effect of corrosion on current strut population reliability, as well as the future, is computed. The conclusion is that even under severe corrosion, compressive buckling is not an issue. All the other failure modes (compressive yielding, tensile yielding, and fracture by fatigue) can be assured by one cold temperature proof test.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Column Buckling, Corrosion, Finite Element Analysis, Probability, Reliability Assurance, Risk Assessment

SPACE-BASED RADAR AND ITS IMPACT ON AIRCRAFT SUSCEPTIBILITY

W. Alan Ricks-Civilian
Master of Science in Aeronautical Engineering-December 1997
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics
Second Reader: I. Michael Ross, Department of Aeronautics and Astronautics

Since the U.S. does not have the largest military force in the world, it relies on force multipliers to achieve victory. One of these force multipliers is stealth technology. However, when stealth technology is used in modern military aircraft, usually only the forward sector of the aircraft is treated and/or shaped. This forward sector treatment is effective against static, ground-based radars. However, the aircraft may be very susceptible to a look-down type of radar. This thesis addresses the viability of using space-based radar to detect stealth aircraft.

Many papers have been written on how to use space-based radar to detect and track targets. However, these papers neglect to develop the satellite constellation that would be necessary to provide continuous radar coverage. These papers also do not address how susceptible stealth aircraft would be to space-based radar. The approach of this thesis was to select a target area, in the case Iraq, and develop two satellite constellations that could provide the required radar coverage. The next step was to determine if the system would be able to detect and track stealth targets.

Based on the analysis, one satellite in geosynchronous orbit can detect stealth aircraft. However, because the satellite is 35,786 km away, the power requirements, as well as the spot size are too large to track stealth aircraft. On the other hand, a constellation of 32 satellites in low earth orbit (1000 km) can both detect and track stealth aircraft. In conclusion, if the U.S. does not start applying stealth technology to the upper surface of stealth aircraft, they will be susceptible to space-based radar.

KEYWORDS: Space, Radar, Satellite

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors

HYPERSPECTRAL POLARIMETRY FOR SATELLITE REMOTE SENSING

Michael J. Rigo-Lieutenant, United States Navy
B.S., United States Naval Academy, 1991
Master of Science in Astronautical Engineering-December 1997
Master of Science in Applied Physics-December 1997
Advisors: David D. Cleary, Department of Physics
Oscar Biblarz, Department of Aeronautics and Astronautics

The study of polarization of reflected light and its angular dependence is well documented. However, most measurements have been panchromatic in nature, i.e., they were taken over a broad wavelength region. A few polarization measurements have examined polarization at several specific narrow wavelength bands. These measurements can be classified as multi-spectral. Thus, previous efforts to characterize an object using polarization have not investigated a hyperspectral polarization signature.

This thesis determines the hyperspectral polarization signature of several common materials that are significant to the military. A range of materials was examined including camouflage fabrics, military paints, rubber, plastic, taggant, and glass. It is shown that a hyperspectral polarization signature, when combined with a hyperspectral reflectance signature may enhance present capabilities to detect, classify, and identify objects of military significance. This technique appears especially promising for dark objects, shiny surfaces, synthetic fabrics, and unpainted metal.

This combined approach could be realized in a hyperspectral polarimetric imaging satellite. The utility of designing such a sensor and many key design considerations are examined. Preliminary analysis suggests sensor designs for low earth and geosynchronous orbiting spacecraft may be feasible. Sensor data rate and signal-to-noise ratio will be the limiting factors in these designs.

KEYWORDS: Hyperspectral Imagery, Polarization, Polarimetry, Satellite Remote Sensing

DoD KEY TECHNOLOGY AREA: Sensors

TURBOCHARGERS TO SMALL TURBOJET ENGINES FOR UNINHABITED AERIAL VEHICLES

Gilbert D. Rivera, Jr.-Lieutenant, United States Navy
B.S.A.E., United States Naval Academy, 1991
M.S.A.E., Naval Postgraduate School, 1997
Aeronautical and Astronautical Engineer-June 1998
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics

Three test programs were conducted to provide the preliminary groundwork for the design of a small turbojet engine from turbocharger rotor components for possible Uninhabited Aerial Vehicle applications. The first program involved the performance mapping of the Garrett T2 turbocharger centrifugal compressor. The second program involved the bench testing of a small turbojet engine, the Sophia J450, at 115000 RPM, and comparing the results to another small turbojet, the JPX-240, from previously documented research. The compressor radii of the two engines were identical but greater than that of the Garrett compressor. The two engines, despite their physical similarities, had different fuel requirements. The J450 used heavy fuel (fuel pump required) while the IPX used liquid propane (pressurized fuel tank required). The third program involved the performance prediction of the J450 using GASTURB cycle analysis software. The compressor map generated from the Garrett T2 test was imported into GASTURB and used to predict the J450 performance at 94000, 105000, 115000, and 123000 RPM. The performance predictions agreed reasonably well with actual J450 performance.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Centrifugal Compressor, Turbomachinery, Uninhabited Aerial Vehicles (UAV), GASTURB, SMOOTHC, Turbojet, Turbocharger

THERMAL ANALYSIS OF PANSAT

Travis R. Smith-Lieutenant, United States Navy
B. S., Virginia Polytechnic Institute and State University, 1990
Master of Science in Astronautical Engineering-December 1997
Advisors: Oscar Biblarz, Department of Aeronautics and Astronautics
Ashok Gopinath, Department of Mechanical Engineering
Daniel Sakoda, Space Systems Academic Group

The thermal control system of a spacecraft is designed to maintain all spacecraft components within their specified operating temperature limits throughout all phases of a spacecraft's mission. In order to verify and aid in such a design process, a thermal analysis of the system must be conducted. A thermal model of the spacecraft is used to simulate its behavior under given thermal environments and boundary conditions so that temperature predictions can be made.

The focus of this thesis is to develop and analyze thermal models of PANSAT which describe its thermal behavior while it is in orbit and also prior to its insertion in its orbit (while it is still in the shuttle). The results of these analyses will serve to help in the thermal design and performance of PANSAT. This thesis completes the thermal model prerequisites of the STS 95 space shuttle mission hitchhiker program for PANSAT. The emphasis of this thesis is to develop a model that will allow the prediction of the temperatures of all the electrical components including the temperature sensitive electrical components of PANSAT such as batteries over a complete orbit of the satellite.

KEYWORDS: Thermal Analysis, Spacecraft Thermal Control

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

LASER DOPPLER VELOCIMETRY IN THE SPACE-SHUTTLE MAIN ENGINE HIGH-PRESSURE FUEL TURBOPUMP

James D. Southward-Commander, United States Navy
B.S., University of New Mexico, 1980
Master of Science in Aeronautical Engineering-March 1998
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

Modifications were made to the Naval Postgraduate School cold-flow turbine test rig to enable integration of a two-component laser-doppler velocimetry (LDV) system. The test turbine was the Space-Shuttle Main Engine, High-Pressure Fuel Turbopump, Alternate-Turbopump Development Model, manufactured by Pratt & Whitney. Flow field measurements were obtained, using the LDV system, in the first-stage rotor end-wall region of the test turbine, at three axial locations and at three depths from the end wall. For each survey location, velocity ratios, absolute flow angle, turbulence intensities, and correlation coefficients were examined. The laser data exhibited distinct trends with axial position, depth from the end wall, and with circumferential position. In addition to the laser data, velocity profiles were determined at the first-stage stator inlet and rotor exit planes, using a three-hole pressure probe. Both laser and probe data were taken at referred rotational speeds in the range 4815 to 4853 rpm. Phase-locked measurements were recorded using a once-per-revolution signal from a magnetic pick-up as a trigger. TSI Phase-resolved software version 2.06 was used for laser data acquisition and reduction.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles

KEYWORDS: Turbine, Data Acquisition, Laser Doppler Velocimetry, Space Shuttle Main Engine, High Pressure Fuel Turbopump

IDENTIFICATION OF CRITICAL COMPONENTS AND COMBAT KILL MODES OF NOTIONAL JOINT STRIKE FIGHTER AIRCRAFT DESIGNS

Nigel J. Sutton-Lieutenant Commander, United States Navy
B.S., Park College, 1987
M.S., University of Tennessee, 1995
Master of Science in Aeronautical Engineering-September 1998
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics
Second Reader: Conrad F. Newberry, Department of Aeronautics and Astronautics

The U.S. Navy is a partner with the U.S. Air Force in the new Joint Strike (JSF) program. In the JSF program, two conventional fixed wing versions, one land-based and one carrier-based, and a Short Take-Off and Vertical Landing (STOVL) version are being developed. Of interest to the Navy is the difference in the vulnerability of the carrier-based version and the STOVL version. An aircraft's vulnerability is the inability of the aircraft to withstand the damage caused by hits by enemy weapons. The first step in a vulnerability study of an aircraft is the identification of the critical components on the aircraft and the ways these components can be killed. The critical components on an aircraft are those components whose kill either individually or jointly, result in an aircraft kill. This thesis examines a notional design of a typical fighter/attack CV aircraft and two notional designs of a STOVL aircraft and identifies the critical components and their kill modes for each design. Comparing the set of critical components for each of the three designs reveals the potential differences in the vulnerability of the designs.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Other (Aircraft Survivability)

KEYWORDS: Vulnerability, Survivability, Kill Modes, Vulnerability Reduction, Vulnerability Reduction Technology, Joint Strike Fighter

INVESTIGATION OF THE EFFECTS OF VARIOUS NOZZLE CONFIGURATIONS ON SOLID-ROCKET-PLUME INTENSITIES AND SPECTRA

Sally A. Van Horn-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Applied Physics-March 1998
Master of Science in Astronautical Engineering-March 1998
Advisors: David D. Cleary, Department of Physics
Oscar Biblarz, Department of Aeronautics and Astronautics

Subscale rocket motors were fired and the plume signatures were measured in the infrared (IR) and ultraviolet (UV) wavelength regimes. Band-averaged and spectral data were recorded using an SR5000 IR spectrometer (2.5 to 5.5 μm range), an Agema 870 IR thermal imaging camera (3.5 to 5 μm range), and the Naval Postgraduate School UltraViolet Imaging Spectrometer (NUVIS) (325 to 405 nm range). Rocket motor nozzle geometries were varied to determine the effects of over- and under-expansion on the plume band-averaged intensity and spectra. Four different solid rocket propellants were used: X-61, NWC-278, AC-13, and AC-14. The enhanced mixing nozzle, used in conjunction with the X-61 propellant, reduced the plume signature in both the UV and IR regions. The total UV intensity of the plume decreased by about 30% and varied as function of distance from the rocket nozzle. The intensity difference was more pronounced at shorter wavelengths (325-385 nm) than at longer wavelengths (385-405 nm). The difference in power was not as large in the IR region (about 7%). Intensity results from the analysis of the NWC-278, AC-13, and AC-14 runs were inconclusive. Data from the NUVIS and Agema instruments were used to create spectra for each of the propellants. While distinct features were discernible in the UV spectra, they could not be identified with a specific atom or molecule. The IR spectra were characterized by several molecular bands attributed to a combination of CO_2, H_2O, and HCl.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Sensors

KEYWORDS: Solid Propellant Rocket, Rocket Plume Spectra, Rocket Plume Intensity, Plume Signature