SPACECRAFT SYSTEMS

Brij. N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The goal of this project is to develop and operate four spacecraft laboratories: Fltsatcom Laboratory, Spacecraft Test Laboratory, Spacecraft Dynamics and Control Laboratory, and Spacecraft Design Laboratory to support the Space Systems Engineering Curriculum in instruction and experimental research. This is a continuing project.

SUMMARY: During 2000, the major effort has been to make these laboratories operational and upgrade the Spacecraft Design Center with GENSAT software. The progress in making these laboratories operational has been exceptional. Fltsatcom Satellite and TT&C system have become operational. In the Spacecraft Attitude Dynamics Laboratory, the two-link manipulator has become fully operational and the Flexible Spacecraft Simulator is partially operational. In the Smart Structures Laboratory, piezoelectric shape control, piezoelectric active damping, shape memory shape control, and positioning hexapod experiment are operational. In the Spacecraft Design Center, GENSAT is integrated into eight seats and under an MOU between NRO/Aerospace/NPS; Aerospace is providing support to the center in terms of lectures, mentorship, and CDC software. Under AA 4871, students did preliminary design of Relay Mirror Spacecraft.

PUBLICATIONS:

Song, G., Schmidt, S.P., and Agrawal, B., "Active Vibration Suppression of a Flexible Structure Using Smart Material and a Modular Control Patch," *Proceedings of Institution of Mechanical Engineers,* Vol. 214, Part G, 2000, pp. 217-229.

Song, G., Kelly, B., and Agrawal, B., "Active Position Control of a Shape Memory Alloy Wire Actuated Composite Beam," *Journal of Smart Materials and Structures*, Vol. 9, 2000, pp. 711-716.

PRESENTATIONS:

Agrawal, B. and Chen, H. J., "Active Vibration Isolation on Spacecraft Using Smart Struts," IAF-00.I.4.05, 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Tillier, C. and Agrawal, B., "Yaw Steering for LEO Satellite Using Any Two of Three Reaction Wheels," IAF-00-A.2.01, 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Bernelli-Zazzera, F., Romano, M., and Agrawal, B., "Experiments on Tracking Control of a Flexible Space Manipulator," IAF-00-A.3.05, International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

THESES DIRECTED:

Ham, W., "Telemetry Systems Analysis and Design," Masters Thesis, Naval Postgraduate School, December 2000.

Bailey, B., "Performance and Space Borne Application Analysis of the Higher Order Cyclostationary Based Classifier," Masters Thesis, Naval Postgraduate School, December 2000.

Whittinghill, C., "A Study of the Feasibility and Applicability of Shape Controlled Space Based Inflatable Membrane Structures," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spacecraft Design, Spacecraft Attitude Control, Space Manipulator

ELECTRIC PROPULSION

Oscar Biblarz, Professor
Department of Aeronautics and Astronautics
Sponsor: Unfunded

OBJECTIVE: The goal of this project is to arrive at a specific procedure suitable for preliminary design of space missions where electric propulsion is more attractive than chemical propulsion.

SUMMARY: Electric propulsion has shown to be advantageous over chemical propulsion in a majority of space missions of interest. We extended the Langmuir-Irving payload mass-fraction formulation to a "dual optimum" condition to yield a minimum overall mass for a specified mission/payload which is consistent with minimum propulsion time. This dual optimum allows for the unambiguous selection of one or more electric engines based on their advertised specific impulse, efficiency and a specific power parameter (α in Watts/kg), which represents the power plant. Values of α are tabulated for the present inventory of engines. Examples are worked out for various missions of interest.

PUBLICATION:

Sutton, G. P. and Biblarz, O., *Rocket Propulsion Elements*, 7th Edition, John Wiley and Sons, New York, 2001.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Space Propulsion, Electric Propulsion, Ion Engines, Hall Thrusters, Optimum Specific Impulse, Minimum Thrusting Time

PULSE DETONATION ENGINE (PDE)

Christopher Brophy, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsors: Office of Naval Research and General Electric Aircraft Engines

SUMMARY: The past year at the laboratory has included an increase in the diversity of sponsors and associated sponsored projects. The Rocket Propulsion and Combustion Laboratory (RPCL) has continued to be active in two primary areas: Pulse Detonation Engine (PDE) and liquid rocket engine technology. Both the Office of Naval Research (ONR) and General Electric Aircraft Engines currently sponsor the PDE research. The ONR related work involves the identification and characterization of two-phase JP10 detonations as well as the investigation of initiator development and detonation wave diffraction issues. The ultimate application of the ONR work is the possible development of a high-speed tactical missile engine system slated for flight Mach numbers between 2 and 5. The results from the past year have agreed well with computational efforts at NRL. I have maintained a strong working relationship between the NRL team so that our collaboration considers the same geometries and conditions. This has been extremely insightful and has aided them in improving the detonation wave propagation predictions. Notable PDE research results over the past year include detonation of a JP10/air aerosol, simultaneous imaging of detonation wave leading shock and heat release region, and initial performance measurements.

A parallel research effort is also underway and sponsored by General Electric Aircraft Engines. They are interested in JP8 as the liquid fuel candidate and would like to address many of the same issues our JP10 research is investigating. The difference in the research programs is that GEAE wants to apply this research to a conventional military jet engine where the afterburner is replaced by a PDE augmenter. The NPS results will be used to aid GE in developing the prototype system proposed by GEAE on the NASA "REVCON" project which they has won last year.

The liquid fuel rocket engine work has progressed and we are now evaluating various film-cooling geometries. These geometries are designed to imitate real-world systems and allow us to characterize the plumes using multi-wavelength transmission (MWT), IR imagers, and FTIR spectrometers. The MWT apparatus was improved by utilizing diode lasers and shifting the transmission lines to slightly higher wavelengths for better S/N ratios and to minimize molecular absorption concerns. The signature characterization work is sponsored by the Air Force Research Lab at Edwards Air Force base.

Since the liquid rocket engine is design to run in a film-cooled mode, a company called Sierra Engineering is co-sponsoring the lab to investigate the performance of transpiration cooled motor segments. These segments transpire fuel through 30-micron holes in the wall to keep the walls below material limits. This work is of interest to the Air Force as well as NASA, both of which also support this work. This work could allow future liquid rocket engines to be designed with a more optimum wall-cooling concept than is currently used.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Pulse Detonation Engine, Liquid Rocket Engine

THE EFFECTS OF ROCKET MOTOR OPERATING CONDITIONS ON EXHAUST PLUME SOOT CONCENTRATIONS AND IR SIGNATURE

Christopher Brophy, Research Assistant Professor
David Netzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Air Force Research Lab

OBJECTIVE: To experimentally determine the effects of motor operating conditions, fuel composition and fuel additives on the exhaust plume soot characteristics and plume signature of gaseous oxygen/liquid-fuel rocket motors.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Rocket Motors, Plumes, Soot

FLUID MECHANICS OF COMPRESSIBLE DYNAMIC STALL CONTROL USING DYNAMICALLY DEFORMING AIRFOILS

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Research Office

OBJECTIVE: To develop flow control schemes through management of the unsteady vorticity field by dynamically deforming an airfoil for prevention of flow separation.

SUMMARY: This year the research effort was focused on testing the 6-inch chord NACA 0012 airfoil instrumented with 148 surface hot-film gages to identify the surface shear stress behavior in this flow. The surface flow was documented for a range of flow conditions representative of that encountered by a helicopter retreating blade. For the first time, the upstream movement of the transition point in unsteady compressible flow was quantified. Also, the onset of the laminar separation bubble and the effects of shock formation on the surface flow were captured. Considerable new information has been generated, which it is hoped will provide new insight into the dynamic stall mechanism onset. Presently, the use of digital filtering is being explored to extract only the low frequency content of the surface shear stress signature to identify possible new mechanisms. Also, tests with a three-sensor approach, with varying overheat ratios, for detecting local flow reversals are being planned. In these, voltages from a set of three closely spaced

sensors will be obtained and the output from the outer two compared with that from the central sensor to record instantaneous flow details.

PUBLICATIONS:

Chandrasekhara, M.S., Wilder, M.C., and Carr, L.W., "Compressible Dynamic Stall Control: A Comparison of Different Approaches," AIAA-99-3122, to appear in *AIAA Journal of Aircraft.*

Sahin, M., Sankar, L.N., Chandrasekhara, M.S., and Tung, C., "Dynamic Stall Alleviation Using a Deformable Leading Edge Concept – A Numerical Study," AIAA Paper 00-0520, Reno, NV, January 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Smart Materials, Deforming Airfoils

USE OF OSCILLATORY BLOWING TO CONTROL COMPRESSIBLE DYNAMIC STALL BEHAVIOR OF AN OSCILLATING NACA 0015 AIRFOIL

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Aero Flight Dynamics Directorate,
National Aeronautics and Space Administration

OBJECTIVE: To investigate compressible dynamic stall control using the oscillatory blowing technique on a trailing edge stalling oscillating NACA 0015 airfoil.

SUMMARY: This effort aims to control compressible dynamic stall using oscillatory blowing. A 0.02-inch blowing slot at 20 deg to the upper surface of a 6-inch chord NACA 0015 airfoil, was connected to a Boeing Company supplied high frequency, high amplitude actuator powered by a two channel audio receiver, via a symmetric plenum housed inside the airfoil. A dynamic pressure transducer installed in the plenum chamber recorded the pressure fluctuations as the airfoil oscillated and blowing was activated. Point diffraction interferograms were obtained at different flow conditions along with unsteady pressure in the plenum chamber. Preliminary trials at controlling stall were found to be successful. However, the strong airfoil peak suction pressure caused the actuator diaphragm to be pushed to one end of its stroke, eliminating most of its pumping ability. This problem is being addressed by building a vacuum enclosure to balance the pressure on both sides of the diaphragm. A more powerful blowing system is also being supplied by The Boeing Company to enhance chances of success.

PUBLICATION:

Ekaterinaris, J.A. and Chandrasekhara, M.S., "Numerical Investigation of Passive and Active Control of Unsteady Compressible Flow," AIAA Paper 00-4417, Denver, CO, August 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Oscillatory Blowing

CONTROL COMPRESSIBLE DYNAMIC STALL USING A VARIABLE DROOP LEADING EDGE VR-12 AIRFOIL

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Aero Flight Dynamics Directorate,
National Aeronautics and Space Administration

OBJECTIVE: To investigate compressible dynamic stall control using a Variable Droop Leading Edge (VDLE) Concept.

SUMMARY: In an attempt to develop new ways of controlling dynamic stall that can exploit the progress in smart materials, a new concept of drooping the airfoil leading edge steadily as it pitches up is being tested in this project. The idea is to reduce maintain low leading edge incidence while the airfoil is at high angles of attack to avoid leading edge stall onset. The technique holds special promise for compressible dynamic stall control since it is a leading edge type of stall. During the first few months since initiation, a 6-inch chord VR-12 (Boeing Vertol) airfoil has been designed, and fabricated with 20 unsteady pressure transducers installed on it. The design incorporates features to bring out all the power and signal leads through the ¼-chord point, the only stationary point in the system. The leading 25% of the airfoil can droop to as large as –25deg relative to the main element dynamically and it can be preset to any desired value as well. The design is now ready for testing in the Compressible Dynamic Stall Facility. The pressure transducers will be calibrated in a specially designed chamber and will account for temperature changes in the system. Integrated force and moment loops will be calculated for rotor retreating blade conditions to demonstrate the success of the approach.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Variable Geometry Airfoils, Dynamic Stall, Rotor Blade Flow Control

VORTEX RING STATE WARNING SYSTEM RESEARCH AND VALIDATION

CDR Mark A. Couch, USN, Military Instructor
Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this proposal is to continue research into the vortex ring state and to promote and support flight testing, validation and transition efforts to field the vortex ring state warning system developed under previous NSAP funding (NSAP Task Number: CNAL-1.2.99-TSP).

SUMMARY: Under NSAP Task Number: CNAL-1.2.99-TSP, LCDR Dave Varnes, Dr. Russ Duren and Dr. E. R. Wood had previously completed research into the vortex ring state (VRS) leading to the development and demonstration of a pilot warning system targeted specifically for the CH-60 helicopter. During 2000 the previous research was extended in two areas. First, the warning systems was refined and expanded. A Windows program was developed to provide a demonstration version of the warning system. The user interface (GUI) was refined and the program was expanded to allow the user to select multiple helicopter and tiltrotor aircraft. The second area of research included a further analysis of flight data available concerning VRS. The analysis was based on flight test data for a NASA H-34 helicopter. Additional information was obtained through discussions with engineers from Boeing and Westland Helicopter and at several conferences and workshops. Recovery techniques were discussed with instructors at Great Britain's Empire Test Pilot School. This is the only flight school that teaches pilots how to recognize and recover from VRS with actual flight experiences. After the unfortunate crash of a MV-22 on April 8, 2000, the research took on the additional tasks of supporting the accident investigation and additional flight-testing of the MV-22. Research into VRS is continuing on a slower pace in 2001 as an unfunded project.

PUBLICATIONS:

Varnes, D., Duren, R., and Wood, E. R., "Detecting the Vortex Ring State," *Rotor & Wing*, Vol. 34, No. 1, pp. 60-65, January 2000.

Varnes, D., Duren, R., and Wood, E. R., "An Onboard Warning System to Prevent Hazardous 'Vortex Ring State' Encounters," *Proceedings of the 26th European Rotorcraft Forum*, pp. 88-122, The Hague, The Netherlands, 26-29 September 2000.

PRESENTATIONS:

Duren, R.W., Wood, E.R., and Couch, M.A., "NPS Vortex Ring State Definition and Safety Data Review," Rotorcraft Aeromechanics Workshop, Naval Air Systems Command, Patuxent River, MD, 18-19 July 2000.

Wood, E.R., Couch, M.A., and Duren, R.W., "NPS Research on Vortex Ring State," Rotorcraft Aeromechanics Workshop, Naval Air Systems Command, Patuxent River, MD, 18-19 July 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Other (Avionics, Safety)

KEYWORDS: Avionics, Pilot Aid, Safety, Vortex Ring State

AIR-GROUND RAPID RETARGETING SYSTEM

Russell W. Duren, Associate Professor
Isaac Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command

OBJECTIVE: Time Critical Strike has been identified as a high priority area of research by multiple studies. The goal of time critical strike is to rapidly target and attack enemy forces and systems that can move and hide frequently, also known as Time Sensitive Targets. This research examines the problems associated with attacking a moving target using low cost GPS-aided standoff weapons, without an integrated weapon seeker.

SUMMARY: Research during 2000 concentrated on investigating design requirements and technical problems related to the development of a closed system, which will generate and transmit targeting information using the existing/planned, C4I system to provide off-board retargeting information to a generic GPS-guided standoff weapon. A conceptual system was developed that used generic sensor platforms and a ground-based targeting processor to provide targeting data to a generic standoff weapon via a Link-16 data link. A simulation model was developed in order to investigate the response of the proposed system to various combinations of identified error sources. The preliminary design of a simulation model was completed. Initial coding of the simulation model was performed using Statemate MAGNUM from I-Logix, Inc. Final coding is continuing in 2001 using MATLAB® Simulink®. The simulation model is being developed in a modular fashion to allow future expansion. Initially generic modules are being used for the target behavior, the sensors, the targeting processor, the data link, the weapon flight characteristics, and the weapon effects on the target. Due to the modular nature of the simulation model each of these modules will be capable of being replaced by more sophisticated or less generic modules in the future.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Other (Time Critical Strike)

KEYWORDS: Time Critical Strike, Time Sensitive Targets, RTIC; Real-time Information in the Cockpit, Targeting GPS, Weapon, Modeling, CEP, Command, Control and Communications, Conventional Weapons, Stand-off Weapons, Sensors, Modeling and Simulation

EA-6B FOLLOW-ON PLATFORM CAPABILITIES STUDY

CAPT Jim Powell, USN, Military Instructor
Information Warfare Academic Group
Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Chief Naval Operations (N88)

OBJECTIVE: This study is tasked to support N88 requirements definition in the Airborne Electronic Attack (AEA) Analysis of Alternatives (AoA) process by outlining and prioritizing technical alternatives for future TACAIR Electronic Attack, and by developing a roadmap to use in the conduct of the EA-6B Follow-on Platform AOA.

SUMMARY: Research was completed providing surveys of available information and systems that could be used to support the AEA AoA. A report was completed that surveyed previous AEA studies. The report summarized classified and unclassified studies from the time period of 1992 through 1999. It concluded with recommendations for future research. A set of surveys was performed as part of a master's thesis. These surveys examined a wide range of existing and proposed systems for potential use in an AEA system of systems. Systems that were surveyed included UAV and UCAV platforms; avionics payloads for reconnaissance, SIGINT, and various forms of electronic attack; and smart weapon platforms for SEAD and DEAD missions.

OTHER:

Duren, R. W., "Report on Previous Studies Related to the EA-6B Follow-on Platform," paper provided to the AEA AoA Technical IPT, June 2000.

THESIS DIRECTED:

Nance, L., "EA-6B Follow-On Study: UAVS and UCAVS," Master's Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: EA-6B, Electronic Warfare, Prowler, SEAD, Shielding, Slot Antenna, Smart Weapons, Unmanned Combat Air Vehicles, UCAV, Unmanned Air Vehicles, UAV, Electronic Attack

F/A-18 C/D AVIONICS ARCHITECTURE STUDY

Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center- Weapons Division

OBJECTIVE: Work with F/A-18 Advanced Weapons Laboratory personnel to develop a system-wide assessment of the F/A-18 C/D avionics system. Identify growth requirements and factors limiting growth over the next 20 to 30 years. Develop a list of potential solutions identifying costs and benefits associated with each solution. Identify best solution(s) and develop a funding schedule for implementation.

SUMMARY: Research on this project started in the last month of 2000 and concentrated gathering information on the existing avionics architecture and its performance. This is the first phase of what is projected to be a multi-year project. Initial reporting dates for the first phase of the project are scheduled in March, April and August of 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Conventional Weapons, Electronics, Human Systems Interface, Sensors, Modeling and Simulation, Other (Avionics)

KEYWORDS: Avionics, Avionics Data Bus, Avionics Architecture, Computer Architecture, COTS, Displays, Fibre Channel, Legacy Upgrades, Microprocessor Emulators, MIL-STD-1553, Mission Systems, Software Translation, System-level Simulation

INCORPORATION OF ENHANCED GROUND PROXIMITY WARNING SYSTEM (EGPWS) IN THE NASA AMES RESEARCH CENTER CAE BOEING 747-400 FLIGHT SIMULATOR

Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration-Ames Research Center

OBJECTIVE: Perform a trade study to determine the best method of incorporating EGPWS functionality into the Crew Vehicle Systems Research Facility (CVSRF) 747-400 simulator, obtain approval and funding for the project, and begin the design.

SUMMARY: A trade study was performed to determine the best method of incorporating EGPWS functionality into the CVSRF 747-400 simulator. Options considered in the trade study included rehosting vendor supplied software, developing simulation code from scratch, and installing a commercial EGPWS unit. Based on the results of the study, a decision was made to install a commercial EGPWS box in the simulator. Funding was obtained and a work package was developed to allow the design task to proceed. The design task included defining the electrical and mechanical interface to the simulator. This task included interfacing with hardware and software simulations of the pilot displays that were unique to the flight simulator environment. The completed hardware design specified multiple control panels, all of the cables and mechanical hardware to install the system, and a system of four personal computers with special graphics cards to perform the display task. The software design was specified at a top level, but not completed as part of this research.

THESIS DIRECTED:

Degennaro, R.A., "Incorporation of an Enhanced Ground Proximity Warning System (EGPWS) in the NASA Ames Research Center CAE Boeing 747-400 Flight Simulator," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronics, Human Systems Interface, Modeling and Simulation

KEYWORDS: EGPWS, Flight Simulation, Full Flight Simulator, GPWS, Ground Proximity Warning System

ANALYSIS OF TRACKING CHARACTERISTICS AND ID CONTRIBUTIONS OF DIVERSE SYSTEMS AND DATA SOURCES FOR MULTIPLE SOURCE INTEGRATION (MSI)

LCDR Dean A. Wilson, USN, Student
Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: This research supports Multiple Source Integration/Data Fusion (MSI/DF) initiatives being developed by PMA-231, Northrop-Grumman Corporation, and the Office of Naval Research for the E-2C Hawkeye aircraft. The MSI/DF concept seeks to provide a single fused track for each contact of interest in the battlespace. A fused track will be representative of all available sources of data contributing to that track. The Combat Identification process will tie together all identifying attributes of these tracks to enable a CID decision based on the track identification parameters and other parameters.

SUMMARY: Research completed in 2000 included performing an analysis of previous work performed in the subject area. In addition, work was begun to develop a computer simulation using the MATLAB® programming environment. The goal of the simulation is to provide a test bed for multiple tracking, sensor fusion and combat identification algorithms.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control and Communications, Computing and Software, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Combat Identification, Data Fusion, Kalman Filtering, Multiple Source Integration, Tracking

EXPLORATION OF FIBRE CHANNEL AS AN AVIONICS INTERCONNECT FOR THE 21ST CENTURY MILITARY AIRCRAFT

LCDR Shawn P. Hendricks, USN, Student
Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: To gain insight into the applicability of Fibre Channel in a military aircraft infrastructure. Fibre Channel systems are being adopted as the successor to MIL-STD-1553 on many military aviation platforms. This research will allow service Program Managers to make better decisions about future procurement of avionics systems that use Fibre Channel as their primary interconnect topology.

SUMMARY: This research evaluated Fibre Channel as avionics interconnection standard. It began by defining the requirements and measures of performance for an interconnection system suitable for new avionics architectures. The requirements address technical performance, affordability, reliability, sustainability, and maintainability considerations. The Fibre Channel standard was then briefly compared to the requirements for the avionics interconnection system. In order to perform a technical performance evaluation of a switched fabric avionics interconnection system, a computer simulation model was developed. The OPNET Modeler® tool from OPNET, Inc. was used to model the components of an advanced avionics system. This tool allows multiple system configurations to be defined and examined quickly, showing both the advantages of one configuration over another as well as potential problem areas. The simulation model, simulation results and conclusions where documented in a conference presentation and a thesis.

PUBLICATION:

S. Hendricks, S. and Duren, R., "Using OPNET to Evaluate Fibre Channel as an Avionics Interconnection System," *Proceedings of the 19th Digital Avionics Systems Conference*, pp. 4.C.1-1-8, Philadelphia, PA, 7-13 October 2000.

THESIS DIRECTED:

Hendricks, S. P., "Exploration of Fibre Channel as an Avionics Interconnect for the 21st Century Military Aircraft," Masters Thesis, Naval Postgraduate School, September 2000.

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

KEYWORDS: Avionics, Communications, Data Bus, Digital Interconnect, Fibre Channel, MIL-STD-1553, Modeling, Serial Interface, Simulation

TURBINE TIP-LEAKAGE FLOWS

G. V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsors: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: This project entails non-intrusive, laser-Doppler-velocimetry (LDV) measurements, in the endwall region of a turbine. A paper was presented at the Aerospace Sciences Conference in Reno, NV in January 2001. The specific turbine test article is the turbine of the High Pressure Fuel TurboPump (HPFTP) of the Space Shuttle Main Engine (SSME) and the particular hardware was designed and manufactured by Pratt & Whitney for NASA.

SUMMARY: LCDR Anderson continued the project by first improving on the numerical predictions. He used a more advanced two-equation (k-□) turbulence model. Next he was able to obtain a complete set of LDV measurements over the tips of the turbine rotor blades, at three axial stations and at three radial depths. These measurements were taken through an aerodynamic window, which vented air from within the turbine to the outside. Failure of the quill shaft, which connected the turbine to the power absorbing dynamometer, halted further tests. The quill shaft and dynamometer have been repaired and a follow on student is needed to continue the measurements through a pressurized aerodynamic window.

PUBLICATION/PRESENTATION:

Hobson, G.V., Anderson, S.C., McKee, J. and Southward, J., "Experimental and Numerical Investigation of the Tip Leakage Flow in the Single Stage Turbine of the Space Shuttle Turbopump," AIAA 2001-0831, 39th Aerospace Sciences Conference, Reno, NV, January 2001.

THESIS DIRECTED:

Anderson, C.S., "Analysis of the Tip Leakage Flow Field in an Axial Turbine," Engineers Thesis, Naval Postgraduate School, June 1999.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Turbine, Laser, Velocimetry, Tip-leakage Flows

CONTINUED DEVELOPMENT OF THE AFFORDABLE GUIDED AIRDROP SYSTEM

Richard M. Howard, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: To continue efforts in the development of a low-cost guidance, navigation, and control system for airdrop leading to the demonstration of autonomous guidance of a flat-circular parachute; and to support this effort with simulation, hardware development, model development, instrumentation development, and assistance with data analysis, test planning, and system demonstration.

SUMMARY: This part of the project had two components: 1) the development of an aerodynamic model of a controlled flat-circular parachute, and 2) the development of an instrumentation package for personnel parachute application. The previous development of round parachute aerodynamic models was reviewed, and a five-degree-of-freedom model was proposed. An instrumentation package consisting of a datalogger, three low-cost rate sensors, three linear accelerometers, a pressure sensor and a GPS card was designed based on similar work at NASA Dryden Flight Research Center. Further parachute model development and instrumentation package development and testing will continue in 2001.

PUBLICATION:

Dellicker, S., Williams, T., Hewgley, C., Yakimenko, O., Howard, R., Kaminer, I., Benney, R., and Patel, S., "Performance, Control, and Simulation of the Affordable Guided Airdrop System," *Proceedings of the 2000 AIAA Conference on Guidance, Navigation and Control*, Denver, CO, August 2000.

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Modeling and Simulation

KEYWORDS: Parachute, Modeling, Datalogger, Instrumentation

SSAT TECHNOLOGY ASSESSMENT AND RISK REDUCTION STUDY-WET WING DESIGN STUDY FOR SUBSCALE AERIAL TARGETS

Richard M. Howard, Associate Professor
Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Aerial Target Systems

OBJECTIVE: To conduct a wet-wing design study for Subscale Subsonic Aerial Targets (SSATs). The tools developed may be used for the evaluation of the structural technologies for the Joint Subscale Aerial Target (JSAT).

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Aerial Target, Unmanned Aerial Vehicle, Wet-Wing

PASSIVE SENSOR-BASED CONTROL OF NONLINEAR AUTONOMOUS SYSTEMS

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this proposal is to investigate sensor fusion architectures and mathematical algorithms required to support autonomous vertical take off and landing (VTOL) of uninhabited combat air vehicles on ships using passive sensors. Preliminary results were obtained on the synthesis of time-varying and nonlinear filters that integrate vision, GPS and inertial sensors to provide an accurate estimate of ship's position with respect to the aircraft as well as of the ship's inertial velocity.

PUBLICATIONS:

Yakimenko, O.A., Kaminer, I.I., Lentz, W.J., and Ghyzel, P.A., "Unmanned Aircraft Navigation for Shipboard Landing Using Infrared Vision," *Proceedings 2000 American Control Conference,* June 2000, Chicago, IL.

Kaminer, I.I., Pascoal, A.M., Kang, W., and Yakimenko, O.A., "Integrated Vision/Inertial Navigation Systems Design Using Nonlinear Filtering," *Proceedings 2000 Conference on Decision and Control*, Sydney, Australia.

Pascoal, M., Kaminer, I.I., and Oliveira, P., "Design of the Complementary, Time-Varying Filters Using Linear Matrix Inequalities,'' *IEEE Transactions on Aerospace and Electronics,* Vol. 36, No. 4, pp. 1099-1114.

Kaminer, I., Pascoal, A.M., Kang, W., and Yakimenko, O., "Integrated Vision/Inertial Navigation Systems Design Using Nonlinear Filtering," to appear in *IEEE Transactions on Aerospace and Electronics.*

OTHER:

Kaminer, I., *Passive Sensor Based Control of Nonlinear Systems*, ONR Contractor Report, Contract No. N0001497AF00002.

THESIS DIRECTED:

Ghyzel, P.A., "Vision-Based Navigation for Autonomous Landing of Unmanned Aerial Vehicles," Engineers Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Unmanned Combat Air Vehicles, Sensor Fusion, Robust Sensor-Based Control, Multi-Spectral, Neural Sensor Processing

CONTINUED DEVELOPMENT OF THE AFFORDABLE GUIDED AIRDROP SYSTEM (AGAS)

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Continue efforts in the development of a low-cost guidance, navigation and control system for airdrop leading to the demonstration of autonomous guidance of a flat circular parachute, to support this effort with simulation, hardware development, model development, instrumentation development and assistance with data analysis, test planning and system demonstration.

PUBLICATION:

Dellicker, S., Williams, T., Hewgley, C., Yakimenko, O., Howard, R., Kaminer, I., Benney, R., and Patel, S., "Performance, Control, and Simulation of the Affordable Guided Airdrop System,'' *Proceedings 2000 AIAA Conference on Guidance, Navigation and Control,* August 2000, Denver, CO.

THESIS DIRECTED:

Williams, T., Optimal Parachute Guidance, Navigation, and Control for the Affordable Guided Airdrop Systems (AGAS), Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Airdrop, Parachutes, Autonomous Guidance, Modeling

INTEGRATION AND FLIGHT TEST OF UCLA'S NAVIGATION COMPUTER ON NPS UAV FROG

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration-Goddard

OBJECTIVE: The objective of this proposal is to integrate and flight test the navigation computer developed by UCLA and NASA Goddard on NPS's UAV Frog. Specifically formation flights that include the Frog and UCLA's UAV Mule will be conducted at Camp Roberts flight test range starting in May of 2000 and completing in September of 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Unmanned Air Vehicles, Flight Test

IMPROVED TARGET ACCURACY AND SENSOR AIMING FOR RAH-66 WEAPONS SYSTEM

Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Using the MSC/NASTRAN structural dynamic model of the RAH-66 helicopter, determine biases between sensors lose and weapon pointing to the target for specified conditions as a function of the flight envelope. Weapons of interest are three-barrel, nose mounted 20mm turreted Gatling gun. Sensors include FCR, TV, and FLIR. Actual measured gun loads will be used for the analysis.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft, Dynamics, Structures, NASTRAN

LONG ENDURANCE NAVAL SUPPORT UNINHABITED COMBAT AIR VEHICLES (UCAVs)

Conrad Newberry, Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The primary objective of this proposal is to define the system integration issues for a notional UCAV capable of performing long endurance naval support for the Littoral Battlespace.

DoD KEY TECHNOLOGY AREAS: Human-System Interfaces

KEYWORDS: Uninhabited Combat Air Vehicle, Long Endurance, Naval Support

COMPUTATIONAL AND EXPERIMENTAL INVESTIGATIONS OF VARIOUS AERODYNAMIC AND AEROELASTIC PROBLEMS

M.F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: Perform computational and experimental investigations of various steady and unsteady aerodynamic and aeroelastic problems.

SUMMARY: The dynamic stall characteristics and of the NLR 7301 airfoil and of the Buffum cascade was analyzed using a Navier-Stokes code. Also, the effect of wind tunnel interference on the transonic flutter characteristics of the NLR 7301 airfoil was analyzed using the same Navier-Stokes code. Furthermore, the effect of Reynolds number on the vortical flow over double-delta wings was investigated in water tunnel tests.

THESIS DIRECTED:

Gossett, D.H., "Investigation of Cross-Flow Fan Propulsion for Lightweight VTOL Aircraft," Masters Thesis, Naval Postgraduate School, December 2000.

PUBLICATIONS:

Weber, S. and Platzer, M.F., "Computational Simulation of Dynamic Stall on the NLR 7301 Airfoil," *Journal of Fluids and Structures*, Vol. 14, pp. 779-798, 2000.

Weber, S. and Platzer, M.F., "A Navier-Stokes Analysis of the Stall Flutter Characteristics of the Buffum Cascade," *Journal of Turbomachinery*, Vol. 122, pp. 769-776, October 2000.

Hebbar, S.K., Platzer, M.F., and Fritzelas, A.E., "Reynolds Number Effects on the Vortical-Flow Structure Generated by a Double-Delta Wing," *Experiments in Fluids*, Vol. 28, pp. 206-216, 2000.

PRESENTATIONS:

Castro, B.M., Ekaterinaris, J.A., and Platzer, M.F., "Transonic Flutter Computations for the NLR 7301 Airfoil Inside a Wind Tunnel," AIAA Paper 2000-0984, 38th Aerospace Sciences Meeting, Reno, NV, 10-13 January 2000.

Weber, S. and Platzer, M. F., "A Navier-Stokes Analysis of the Stall Flutter Characteristics of the Buffum Cascade," ASME Paper No. 2000-GT-385, International Gas Turbine Congress, Munich, Germany, 8-11 May 2000.

DoD KEY TECHNOLOGY AREAS: Other (Aerodynamics)

KEYWORDS: Separated Flow, Transonic Flow, Vortical Flow, Flutter

ASRAAM MISSILE LAUNCH LOAD ANALYSIS

M. F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: The objective of the proposed investigation is to provide support services for the ASRAAM Missile High G (tip off) Launch Load Analysis.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Unsteady Aerodynamics, Flapping Wing Propulsion, Unmanned Air Vehicles

DEVELOPMENT OF SMALL UNMANNED AIR VEHICLE

M. F. Platzer, Distinguished Professor
K.D. Jones, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of the proposed effort is the exploration and demonstration of flapping wing propulsion for small-unmanned air vehicles

SUMMARY: Several micro-air-vehicle models of varying scales and complexity were built and tested which use two airfoils that are flapping in counterphase with variable frequency and amplitude. The thrust was measured with a laser device and compared with the numerical results obtained with a previously developed inviscid unsteady panel code.

THESES DIRECTED:

Lund, T.C., "A Computational and Experimental Investigation of Flapping-Wing Propulsion," Masters Thesis, Naval Postgraduate School, March 2000.

Duggan, S., "An Experimental Investigation of Flapping Wing Propulsion for Micro Air Vehicles," Masters Thesis, Naval Postgraduate School, June 2000.

PUBLICATION:

Tuncer, I.H. and Platzer, M.F., "Computational Study of Flapping Airfoil Aerodynamics," *Journal of Aircraft*, Vol. 37, No. 3, pp. 514-520, May-June 2000.

PRESENTATIONS:

Jones, K.D. and Platzer, M.F., "Flapping Wing Propulsion for a Micro Air Vehicle," AIAA Paper No. 2000-0897, 38th Aerospace Sciences Meeting, Reno, NV, 10-13 January 2000.

Jones, K.D., Lund, T.C., and Platzer, M.F., "Experimental and Computational Investigation of Flapping-Wing Propulsion for Micro-Air Vehicles," presented at the Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers, University of Notre Dame, Notre Dame, IN, June 5-7, 2000.

Jones, K.D., Lai, J.C.S., Tuncer, I.H., and Platzer, M.F.,"Computational and Experimental Investigation of Flapping-Foil Propulsion," presented at First International Symposium on Aqua Bio-Mechanisms, Tokai University Pacific Center, Honolulu, HI, 27-30 August 2000.

Platzer, M.F. and Jones, K.D., "The Unsteady Aerodynamics of Flapping -Foil Propellers," presented at Ninth International Symposium on Unsteady Aerodynamics and Aeroelasticity of Turbomachines, Lyon, France, 5-8 September 2000.

DoD KEY TECHNOLOGY AREAS: Other (Aerodynamics/Hydrodynamics)

KEYWORDS: Unsteady Aerodynamics, Unmanned Air Vehicles, Flapping Wing Propulsion

AEROELASTIC STUDIES OF HYPERSONIC MISSILE FINS

M. F. Platzer, Distinguished Professor
Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: The objective of this work is to perform an exploratory flutter analysis of the fins on the proposed Navy Hypersonic Weapons Technology Missile.

SUMMARY: A report was delivered which summarizes the vibration and flutter analysis of a representative fin using the MSC-NASTRAN code.

DoD KEY TECHNOLOGY AREAS: Other (Design Automation)

KEYWORDS: Aeroelasticity, Missile Aerodynamics, Hypersonic Flow

COMPUTATIONAL STUDY OF ABRUPT WING STALL

M.F. Platzer, Distinguished Professor
K.D. Jones, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research and Naval Air Warfare Center-Patuxent River

OBJECTIVE: Computational prediction of abrupt transonic wing stall on modern fighter/attack aircraft configurations using advanced Navier-Stokes codes.

SUMMARY: Three-dimensional Navier-Stokes computations of the F-18 E/F configurations are performed to establish criteria for the onset of abrupt wing stall.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Aerodynamics, Transonic Flows, Separated Flows, Vortical Flows, Computational Fluid Dynamics

SABBATICAL RESEARCH AT DRAPER LABS

I.M. Ross, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Surface Warfare Center-Crane Division

OBJECTIVE: This proposal is for researching the design of optimal gimbal tumbling for INS error reduction during the boost and bus phases of the Trident Missile. The task will be performed as part of the PI's sabbatical at The Charles Stark Draper Laboratory in Cambridge, MA.

SUMMARY: This is a classified project and not much can be said about the work performed beyond what is stated in the objective.

PUBLICATIONS:

Fahroo, F. and Ross, I.M., "A Spectral Patching Method for Direct Trajectory Optimization," *The Journal of the Astronautical Sciences*, Vol. 48, No. 2/3, April-September 2000.

Fahroo, F. and Ross, I.M., "A Second Look at Approximations to Differential Inclusions," *Journal of Guidance, Control and Dynamics*, Vol. 24, No.1, 2001, pp.131-133.

Fahroo, F. and Ross, I.M., "Costate Estimation by a Legendre Pseudospectral Method," *Journal of Guidance, Control and Dynamics*, accepted for publication in FY 2000, appeared in Vol. 24, No. 2, 2001, pp. 270-277.

Fahroo, F. and Ross, I.M., "Direct Trajectory Optimization by a Chebyshev Pseudospectral Method," accepted for publication in the *Journal of Guidance, Control and Dynamics*.

Yan, H., Fahroo, F. and Ross, I.M., "Accuracy and Optimality of Direct Transcription Methods," *Advances in the Astronautical Sciences, Space Flight Mechanics 2000,* Vol. 105, Part II, pp.1601–1630, (Kluever, C. A. et al, eds.), AAS Paper No. 00-205.

Fahroo, F. and Ross, I.M., "A Spectral Patching Method for Direct Trajectory Optimization," to appear in a Special Issue of the *Advances in the Astronautical Sciences* (AAS 00-260).

PRESENTATIONS:

Fahroo, F. and Ross, I.M., "Spectral Collocation Approximations for Optimal Control Problems," AMS Southeastern Section Conference (Special Session, Invited Talk), Lafayette, LA, 14-16 April 2000.

Fahroo, F. and Ross, I.M., "Direct Trajectory Optimization by a Chebyshev Pseudospectral Method," *Proceedings of the American Control Conference*, June 2000, Chicago, IL, Paper ACC00-AIAA1004.

Fahroo, F. and Ross, I.M., "Trajectory Optimization by Indirect Spectral Collocation Methods," *Proceedings of the AIAA/AAS Astrodynamics Specialist Conference*, August 2000, Denver, CO.

THESIS DIRECTED:

Schlotman, B., "Feasibility of Two-Gimbal Platform Tumbling to Minimize Velocity Error," Masters Thesis, Naval Postgraduate School, June 2000.

ADVANCED FAN AND COMPRESSOR DEVELOPMENT STUDIES

R. P. Shreeve, Professor
G. V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: To develop or validate tools for the design of advanced compression systems for Navy engines. Four tasks are ongoing: (i) to obtain experimental measurements and observations of CD blade stall for CFD code validation; (ii) to develop a geometry package geared to the design (by CFD analysis) of swept transonic blading, and to facilitate design optimization; (iii) to install and test an advanced transonic axial stage, and thereby establish the means to evaluate more advanced designs economically; (iv) to develop advanced measurement capability.

SUMMARY: (i) Blade-to-blade five-hole pressure probe surveys were made at different span-wise locations, to obtain the loss behavior of second-generation CD blading, at four degrees above design incidence. LDV was used to map the velocity field, and three-dimensional viscous flow calculations were made of the complete (periodic) passage flow. (ii) A new Bezier-surface representation of axial transonic blading, requiring only 32 control points and two parameters, was developed in an earlier Ph.D. study. Forward and aft sweep were introduced into a rotor design without changing blade shape, and the effect on aerodynamic performance and rotational stresses were determined. The geometry package was used successfully by a second student to perform a (limited) airfoil design optimization. A (limited) rotor design optimization can now be attempted. (iii) The Sanger (code-validation) compressor stage was rebuilt, re-instrumented and retested using a UV-transparent case wall. The need to control tip-clearance gap, and a method to do it, were demonstrated in a very successful test program. (iv) Development of pressure sensitive paint techniques for rotor measurements required the construction of a bench-top apparatus, with which to calibrate for pressure and temperature dependence over the ranges of interest. Application to the Sanger rotor test will follow the construction of an aluminum and Plexiglas modular case wall. A tip-timing technique for measuring the vibrations of rotor blades using laser light probes, was set up and validated (vs. photo observations), on a three-stage low speed compressor. This 'NSMS' technique was also required for blade response measurements in the HCF/Spin Test Research program.

PUBLICATION:

Hobson, G.V., Hansen, D.J., Schnorenberg, D.G., and Grove, D.V., "Effect of Reynolds Number on Separation Bubbles on Controlled-Diffusion Compressor Blades in Cascade," *Journal of Propulsion and Power,* Vol. 40, No. 1, January-February 2001, pp. 154-162.

PRESENTATIONS:

Enomoto, S., Hah, C., and Hobson, G.V., "Numerical and Experimental Investigation of Low Reynolds Number Effects on Laminar Flow Separation and Transition in a Cascade of Compressor Blades," Paper 2000-GT-0276, presented at the ASME Turbo Expo 2000, Munich, Germany, 8-11 May 2000.

Hobson G.V. and Weber, S., "Prediction of a Laminar Separation Bubble Over a Controlled-Diffusion Compressor Blade," Paper 2000-GT-0277, presented at the ASME Turbo Expo 2000, Munich, Germany, 8-11 May 2000.

von Backstrom, T.W., Hobson, G.V., Grossman, B., and Shreeve, R.P., "Investigation of the Performance of a CFD Designed Compressor Stage," Paper AIAA 2000-3205, presented at the 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Huntsville, AL, 17-19 July 2000.

THESES DIRECTED:

Muller, J.A., "Calibration to Determine Pressure and Temperature Sensitivities of a Pressure-Sensitive Paint," Masters Thesis, Naval Postgraduate School, June 2000.

O'Brian, J.M., "Transonic Compressor Test Rig Rebuild and Initial Results with the Sanger Stage," Masters Thesis, Naval Postgraduate School, June 2000.

Osburn, N.G., "Implementation of a Two-Probe Tip-Timing Technique to Determine Compressor Blade Vibrations," Masters Thesis, Naval Postgraduate School, June 2000.

Carlson, J.R., "Experimental and Computational Investigation of the End-Wall Flow in a Cascade of Compressor Blades," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Controlled-Diffusion Blading, LDV Measurements, Compressor Cascade Stall, Transonic Compressor Design, Pressure-Sensitive Paint (PSP)

HCF/SPIN TEST RESEARCH

R. P. Shreeve, Professor
G. V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: To investigate techniques for producing controlled blade excitation and measuring blade response which are suitable for high cycle fatigue (HCF)-related spin-testing and, when appropriate, to help transition those techniques to the Navy's Rotary Spin Facility at NAWCAD; also, to explore other HCF research opportunities.

SUMMARY: The engine-scale spin pit at the Turbopropulsion Laboratory was refurbished to serve as a research facility for the development of HCF-related gas-turbine rotor test and evaluation techniques. After initial tests using a large M1 rocket motor turbine rotor, blade excitation methods were explored using two (low cost, low risk) eleven-inch diameter rotors. First, air-jet excitation (AJE) and eddy-current excitation (ECE) were used to excite resonant modes at 3E (engine order) and 12E in an aluminum research fan. Second, ECE and oil-jet excitation (OJE) were used at 6E (and OJE at 4E) in a cropped titanium fan rotor. Hardware, and software acquisition and analysis programs were progressively developed for a twelve-channel strain gauge system and a four-channel tip-timing ('NSMS') system using capacitive or eddy-current probes. (A two-channel NSMS system using laser-light probes was separately demonstrated on a low-speed compressor). In collaboration with NAVAIR and Pratt & Whitney, the first engine-scale spin pit

tests will evaluate internal dampers for JSF engine-type counter-rotating turbine rotors, and resonant behavior of an F119 engine fan blisk. The excitation work has been carried out in collaboration with Hood Technology Corporation, who is funded by the Air Force to evaluate ECE.

PRESENTATIONS:

Shreeve, R.P., "HCF/Spin Test Research Review," Navy/Air Force Joint Program Review, Monterey, CA 19 May 2000.

Warren, J. and Shreeve, R.P., "The Navy's HCF Spin Test Program," HCF Passive Damping Action Team Meeting, Duke University, Durham, NC, 8 August 2000.

THESIS DIRECTED:

Osburn, N.G., "Implementation of a Two-Probe Tip-Timing Technique to Determine Compressor Blade Vibrations," Master Thesis, Naval Postgraduate School, June 2000.

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DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Spin Testing, High Cycle Fatigue, Gas Turbine Blade Excitation

SATELLITE SERVICING LABORATORY

Michael G. Spencer, Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Postgraduate School Research Initiation Program

OBJECTIVE: The objective of this research is to develop an autonomous servicing spacecraft simulator and test-bed. The simulator will be used for the development and validation of autonomous, neural network based control algorithms as well as various hardware elements necessary for autonomous rendezvous and docking, space manipulator control, and satellite servicing operations.

SUMMARY: The background research and scope of the new effort was developed during the initial three months of employment (September – November 00). The research proposal was approved mid December therefore, the significant efforts of this research will continue into 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Satellite Servicing

RESEARCH IN THE STRUCTURAL DYNAMIC RESPONSE OF THE RAH-66 COMANCHE HELICOPTER

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Comanche Program Office

OBJECTIVE: Continued work in support of the ongoing development of the Army's RAH-66 Comanche Helicopter. Tasks include static and dynamic analyses. A dynamic NASTRAN model provides the basis for the analyses and is maintained at the Naval Postgraduate School to support the ongoing Comanche flight test development program. The objective of the analyses is the optimization of the airframe for dynamic response.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft, Dynamics, Structures, NASTRAN

IMPROVED TARGET ACCURACY AND SENSOR AIMING FOR RAH-66 WEAPONS SYSTEM

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Using the MSC/NASTRAN structural dynamic model of the RAH-66 helicopter, determine biases between sensor loss and weapon pointing to the target for specified conditions as a function of the flight envelope. Biases are to be applied as fire control corrections. Weapons of interest are 2.75-in., rockets, stinger air-to-air wing-mounted missiles and three-barrel, nose mounted 20-mm turreted Gatling gun. Sensors include FCR, TV, and FLIR.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft Dynamics, Structures, NASTRAN

RESEARCH IN DAMPER FREE ROTOR DESIGN BASED ON MAPLE GENERATED NONLINEAR SIMULATION

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Derive the full non-linear lead-lag equations of motion for a multiblade helicopter rotor. Incorporate MAPLE and SIMULINK in the derivation. Apply this new expanded analysis in two areas with high potential for eliminating reliance on mechanical damping in helicopters. These are by introduction of structural tailoring to provide non-linear hinge less rotor lead/lag characteristics; and by swash plate feedback for increased lead/lag stability.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Rotorcraft, Helicopter, Ground/Air Resonance, Damperless, VTOL/MAPLE/SIMULIN