Aerospace Engineering Department

Professor Daryl G. Boden
Chair

The research and publication efforts of the Aerospace Engineering Department faculty and students covered a broad range of topics in aeronautics, astronautics, and engineering education. The research resulted in numerous presentations, papers in conference proceedings, workshops, and publications in archival journals.

The capstone courses highlighted this year's research in the Aerospace Engineering Department. All the midshipmen in the capstone design course for the Astronautical Engineering track continued work on the design of small satellites that we expect to launch in the future. The Aeronautical Engineering track students designed, built, and tested three unmanned aerospace vehicles (UAVs) for an external sponsor.

Students and faculty enjoyed outstanding support from the National Air and Space Administration (NASA), the Naval Network and Space Operations Command, the Naval Research Laboratory (NRL), the Air Force Research Laboratory (AFRL), Naval Air Systems Command, the U. S. Air Force Space Test Program, the Naval Air Warfare Center (NAWC), the National Center for Advanced Manufacturing, the Defense Intelligence Agency (DIA), Noesis Inc., National Space Biomedical Research Institute (NSBRI), the Aerospace Corporation, and the Boeing Corporation to accomplish their research and to support the capstone courses.

The department continued work in pedagogical research on engineering education as part of the Conceive-Design-Implement-Operate (CDIO) Initiative. This effort has resulted in presentations and workshops at CDIO meetings and engineering education conferences.

Sponsored Research

Wind Tunnel Testing of Ship Motion Effect on Airwake

Researcher: Assistant Professor David S. Miklosovic
Sponsor: Naval Air Warfare Center, Code 4.3.2.1

SAFEDI (Ship Aircraft Airwake Analysis for Enhanced Dynamic Interface) is an Office of Naval Research (ONR) sponsored initiative with a focus on developing computational fluid dynamics (CFD) airwake technology to enhance dynamic interface analysis, modeling, and simulation for all aircraft type and ship class combinations. One of the objectives of the program was to model the impact of ship motion on a ship's airwake using CFD. Validation data was required to provide confidence in the modeling capability. A wind tunnel test was proposed that will enable the flow over a ship moving with single degree-of-freedom motion to be examined in a controlled environment. CFD calculations, using the same flow conditions and geometry as the wind tunnel, were compared with the model-scale test results to determine the accuracy of the predictions.

Wind tunnel measurements of the airflow over a model of a typical ship moving with single degree-of-freedom, sinusoidal pitch motion, are required to validate CFD predictions. Airflow data was recorded over the flight deck and, where possible, over the bow and superstructure, aft of the ship and at points along a typical helicopter approach profile. Quantitative data consisted of 3-component velocity measurements (u, v, w) using Particle Image Velocimetry (PIV), and spectral data using hot wire anemometry. Qualitative assessments of the flow field may also be possible with smoke and/or helium bubble flow visualization techniques, using both video and still photography. Data was recorded for multiple motion frequencies, amplitudes and at different times within the motion period. Data was also recorded for a number of static trim cases.

This work was a continuation of efforts halted by tropical storm ISABEL and was completed at the end of FY05. This collaborative effort with NAVAIR 4.3.2.1 has forged close ties and a combined technical competence that is expected to inspire continued funding in subsequent years.

Unmanned Air Vehicle Project

Researcher: Professor Larry D. Birckelbaw, Research Professor
Sponsor: Defense Intelligence Agency (DIA)

This project was run as a two semester design class project at the United States Naval Academy Aerospace Engineering Department. Two to three student teams were asked to search open source information on Unmanned Air Vehicles (UAV's), low-observable materials, and advanced jam-proof autonomous guidance and control technologies and document what is available on the open market. Each student team was then tasked to design, fabricate and flight demonstrate an UAV that is capable of carrying a ten pound payload and accurately striking a fixed target located 20 miles from the takeoff point employing a jam-proof, autonomous flight control system. All funding necessary to purchase the materials and components required to design, fabricate, validate and flight demonstrate these UAV's was provided by the DIA, including all travel costs to the designated test site.

Enhanced Store Separation Simulation Capabilities for the U.S. Navy

Researcher: Assistant Professor Eric N. Hallberg
Sponsor: Naval Air Systems Command, Patuxent River, MD

The High Speed Anti-radiation Demonstrator (HSAD) Program was intended to demonstrate key enabling technologies for inclusion in the follow-on to the AGM-88E HARM missile during one captive carry and two free-flight tests. The HSAD missile was planned for release from an F/A-18C/D aircraft at a Mach number of 0.8 and an altitude of 30,000 feet. Improvements to the U.S. Navy's store separation prediction code (NAVSEP) are required by the U.S. Navy to analyze the separation of the missile and include the effects of the autopilot and moving control surfaces. A parametric analysis of the release needs to be conducted to account for uncertainty in the wind tunnel data, and certain malfunctions of the control surfaces with and without the autopilot engaged.

Midshipman Space Technology Applications Research Satellite-1 (MidSTAR-1)

Researcher: Visiting Professor Billy R. Smith, Jr.
Sponsor: Department of Defense (DOD) Space Test Program

MidSTAR is a general-purpose satellite bus capable of supporting a variety of space missions by easily accommodating a wide range of space experiments and instruments. The integration of the experiments with the satellite bus was accomplished with minimal changes to the satellite bus design. MidSTAR is intended to be a relatively low-cost, quick response platform accommodating small payloads approved by the DoD Space Experiments Review Board (SERB) and is awaiting launch through STP.

MidSTAR mod 1 was designed for use on the Expendable Secondary Payload Adaptor (ESPA) Ring developed by Air Force Research Laboratory (AFRL) for placement on Delta IV or Atlas V expendable launch vehicles. MidSTAR mod 2, still to be developed, will be designed for deployment from the Space Shuttle via the Canister All Payload Ejection (CAPE) system developed by AFRL.

Both mods are Class D spacecraft, produced at minimum cost with a correspondingly higher technical risk in production and operation. Both types of spacecraft are intentionally simple in design and rugged in construction, using commercial off-the-shelf "plug-and-play" components to the greatest extent possible. Component development and circuit-board level design are accomplished only when necessary.

The baseline MidSTAR mission includes a single spacecraft under the command and control of a single satellite ground (SGS) station located at the Naval Academy, Annapolis, MD. (Lat. 38.98 N, 76.49 W). The ground station forwards down linked data files to the Principal Investigators via the Internet. Secondary ground control will be available on an as-needed/space-available basis through the Naval Postgraduate School (NPS), Monterey, CA

(36.6 N, 121.89 W). Launch segment for MidSTAR mod 1 is either the Delta IV or Atlas V EELV. Launch segment for MidSTAR mod 2 is the Space Shuttle CAPE. The orbit will be tailored to payload requirements; where no requirements exist, the orbit of the primary payload or one of the other secondary payloads will be accepted. In order for the spacecraft to be seen from USNA SGS at an elevation greater than 30 degrees and range simultaneously less than 900 km, the orbit must be 500 +/- 200 km with inclination greater than 35 degrees.

MidSTAR-1 is the first implementation of the mod 1 design. It has been commissioned by STP to carry the Internet Communications Satellite (ICSat) Experiment for SSP (no. 39 on the 2002 SERB List) and the Configurable Fault Tolerant Processor (CFTP) Experiment for the Naval Postgraduate School (NPS) (no. 34 on the 2002 SERB List). MidSTAR-1 is scheduled for launch on a Lockheed-Martin Atlas V from Cape Canaveral on the STP-1 mission in December 2006.

Performance Calculation of Lunate Tails

Researcher: Professor Gabriel N. Karpouzian
Sponsor: Naval Research Laboratory (NRL)

This research extends the earlier work done in collaboration with Dr. William Sandberg of NRL in 2002-2003. The lifting-line theory of a high aspect ratio wing with a curved centerline was applied to a harmonically oscillating lifting surface similar to a caudal fin of fast, long-range swimming fish (e.g. tuna). The pressure distributions obtained from the asymptotic theory agreed fairly well with the doublet-lattice calculations at most span stations, thus lending support to the theory. Implicit in the results is the effect of curvature of the platform centerline, which can be evaluated by making a comparison with the results obtained for a straight-swept wing of equal (average) sweep. Using the results for the pressure distribution, the present work concerns the hydromechanical performance of lifting surfaces. In particular, thrust, power, and propulsive efficiency are computed for various modes of oscillations and morphological features. This enables us to obtain an optimum set of morphological and kinematics parameters that can enhance our understanding of the evolutionary convergence of swimming animals in carangiform mode. A parametric study can reveal the way in which certain parameters are combined to enhance the propulsive efficiency. Additional work will be required to validate the performance calculations by using the existing numerical codes developed by Dr. Sandberg and his colleagues at NRL. This work has a potential application to low-speed maneuvering submarines and Autonomous Underwater Vehicles (AUV).

Stochastic Analysis of Nonlinear Multidisciplinary Aerospace Systems

Researchers: Assistant Professor Chris L. Pettit
and Dr. Philip S. Peran (AFRL)
Sponsor: Air Force Research Laboratory (AFRL) Summer Faculty Fellowship Program

The performance and stability of nonlinear multidisciplinary aerospace systems is sensitive to variability in system parameters, initial conditions, and boundary conditions. Predictive quantification of the system's performance variability is computationally expensive to simulate but too time consuming and costly to achieve through physical tests. The objective of this project was to develop and test stochastic simulation methods that enable reasonably low order representations of variability in the response of high fidelity computational models. Current efforts are focused on the simulation of nonlinear aeroelasticity given uncertainty in the parameters of the nonlinear stiffness model. Research during the Summer 2005 intersession focused on the potential connection between spatial resolution in numerical models of distributed systems and the convergence of stochastic expansions based on these models. It was demonstrated that meshes or grids considered to be converged according to commonly used deterministic metrics should not be assumed to be converged when stochastic effects are modeled. Furthermore a simple approach was demonstrated for computing ad hoc Wiener chaos expansions of response processes in a post-processing manner even when the distribution of the input random variable is unknown.

Microdosimeter Instrument Suitable for Spaceflight

Researcher: Professor Vincent L. Pisacane
Sponsor: National Space Biomedical Research Institute (NSBRI)

The objective of this project was to develop a rugged, portable, low power, lightweight, solid-state radiation instrument MIDN (MIcroDosimeter iNstrument) to measure probability or frequency distributions of energy deposited in real time in cell-size structures from charged and neutral primary and secondary radiations. Assessment of the space radiation environment addresses the development of a countermeasure of the highest priority for space exploration. Determination of the magnitude of the average radiation quality, Qave, is necessary to calculate the dose equivalent, which is assumed to be proportional to risk and upon which regulatory limits in space are based. Microdosimetry spectra are the most accepted data for calculating Qave. Consequently, the observations are more reliable as a monitor of human cell damage than other macroscopic detectors that measure fluence.

Radar Fence Transponder Satellite (RAFT)

Researcher: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Space Test Program

The Radar Fence Transponder is one of a pair of Pico-satellites being developed under the U.S. Naval Academy Small Satellite Program. It was approved by the Department of Defense Space Experiments Review Board (SERB) and originally manifest on Space Shuttle missions STS-116 for flight in Spring 2005. Due to the space shuttle delays, the launch date has slid incrementally to December 2006. This year was the final design and build effort taking the students through the entire process culminating in flight ready hardware by the end of January 2006. The satellite will operate in the Amateur Satellite Service as a communications transponder but also carries a unique 216.98 MHz direct conversion receiver enabling the ground station at USNA to detect precisely when the spacecraft passes through the Naval Space Surveillance Radar beam across the southern US. The oscillator was also designed with a leaky local oscillator so that its 4 milliwatts can be detected by the Radar fence for independent calibration of the Radar's transmit and receive beams. This year 6 students over 2 semesters participated in the final test and delivery phases of this project.

MARScom Satellite

Researcher: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Space Test Program and HQ Navy Marine Corps MARS

MARScom satellite is the second of a pair of Picosatellites developed under the U.S. Naval Academy Small Satellite Program. It was approved by the Department of Defense Space Experiments Review Board (SERB) and originally manifest on Space Shuttle missions STS-116 for flight in 2005. Due to the space shuttle delays, the launch date has slid incrementally to December 2006. Its mission is also to experiment with the detection of picosat size spacecraft by the Navy Space Surveillance Radar but by passively augmenting the structure with a whip antenna resonant at the radar's 216.98 MHz frequency. This year was the final design and build effort taking the students through the entire process culminating in flight ready hardware by the end of January 2006. The satellite will operate using frequencies allocated to the Navy Marine Corps MARS program over the United States. It also carried a communications transponder for MARS network and also a unique UHF AM uplink for communications with the USNA's small boats. This year 6 students over 2 semesters were involved in the final stages of this project.

Atmospheric Neutral Density Experiment (ANDE)

Researcher: CDR Robert E. Bruninga, USN (Ret.)
(for all electronics systems)
Sponsor: Naval Research Laboratory (NRL) via the Space Test Program

The ANDE project was an experiment by the Naval Research Laboratory (NRL) to precisely measure the density of the atmosphere at orbital altitudes with a heavy but perfectly spherical 19" satellite. The satellite was to have passive laser reflectors for precise tracking by the Maui tracking station and no active electronics. U.S. Naval Academy proposed attaching a small Amateur Radio transponder, but with no change in external drag components by splitting the sphere with an insulating disk and using the spaceframe itself as the communications antenna.

Without solar panels, the spacecraft is designed to operate for over a year on 112 "D" cell lithium primary batteries using a special sleep-wake timer circuit. This year was the final test, debug, and build effort although most student design effort on the spacecraft ended in 2004. The project was delayed due to the Shuttle disaster in 2003. This semester culminated in completely developed, tested and integrated flight modules for integration at NRL in June 2005 and final testing through May 2006.

MISSE5/PCSAT2 Communications System

Researcher: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Naval Research Laboratory (NRL) via the Space Test Program

MISSE5 was the Materials on Space Station Experiment number 5 with the primary mission to fly the latest technology DOD solar cell technology for a one year exposure to the space environment. USNA proposed adding a communications transponder operating in the Amateur Satellite Service as a way to give student projects access to space and to also provide the MISSE5 passive experiment with a means for real-time telemetry during the mission. The experiment was launched on 26 July 2005 and activated by an astronaut on 3 August. Throughout this academic year students were involved wherever possible in operations, data collection and mission planning. Since emissions from PCSAT2 are considered a catastrophic hazard to astronauts during an EVA or during a docking evolution, our ground station is on the critical path for every EVA or docking evolution, having to plan and schedule our shut-down and re-activation with the controllers on console at JSC about once a month. Daily operations (6 passes a day) have to be monitored to be sure our ground station and telemetry system are collecting the necessary science data and periodically sending the needed maintenance uplink commands. The system will be retrieved by astronaut EVA and returned to Earth about 1 September 2006.

ParkinsonSAT

Researcher: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Aerospace Corporation

This project is a proposal to Aerospace Corporation to design and build a viable spacecraft to support remote data collection and communications. The project has a two path approach, one to fly a DOD sponsored transponder called ODTML (Ocean Data Transponder Microsat Link) and the other to provide a data collection and communications channel in the Amateur Satellite Service to encourage other universities to pool resources and built a population of satellites and sensors to further this mission. This year, students developed the design leading up to System Requirements Review, and built and tested a prototype environmental ocean buoy.

Communications Satellite (PCSAT-1)

Researcher: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Boeing Corporation

Although this U.S. Naval Academy Satellite was launched in 2001, it remains active and does require occasional ground station support. Typically, for the last few years, the satellite operates in a sleep mode to conserve power and we only access it during full sun periods (about 6 per year). During about half of these full sun periods (the winter ones), PCSAT-1 has a good geometry for a full recovery and we then try conducting experiments with this on-orbit USNA asset. During each of these full recovery periods, we have usually been successful in keeping the spacecraft in full operational status for up to a month before low power geometry forces a reset. This year we were fortunate to use both PCSAT-1 and PCSAT2 jointly to support experiments with our prototype communications system for ParkinsonSAT.

Chesapeake Bay Environmental Buoy

Researchers: CDR Robert E. Bruninga, USN (Ret.) and Professor Reza Malek-Madani (Mathematics Department)
Sponsor: National Oceanic Atmospheric Association (NOAA)

Several Naval Academy (USNA) personnel are involved in flow studies in the Chesapeake Bay. The research involves mathematical modeling of the flows in the bay, but they need ground-truth on actual currents to compare the NOAA models, and their models and then actual current data. The Satellite Lab was challenged to

design a GPS floating buoy package to be launched into the bay to give actual tracking data. This is the ideal remote sensing application using our USNA satellite communications technology. We were able to combine this effort into the ParkinsonSAT project. The objective is to build 10 buoys. This year, the ParkinsonSAT students were mentored through the design of the first buoy system for test deployment this summer.

Independent Research

Energy Dissipation Variability in Mechanical Joints

Researchers: Assistant Professor Chris L. Pettit, and
Oleg Shiryayev, Steven Page, and Joseph Slater, Wright State University

Dry friction and other energy dissipation mechanisms in the interfaces between structural components are the primary sources of damping in built-up structures. Accurate modeling of random variability in structural dynamics therefore requires the use of hysteretic joint models, which should be of sufficiently low order to permit efficient computational solutions. Several variants of Iwan models have appeared in the recent literature as promising models for this application. We have designed a bolted joint experiment for the purpose of identifying parametric variability of the adjusted Iwan beam element (AIBE). Impact hammer identification tests were performed to compare with published data and a new sinusoidal excitation algorithm was developed and implemented for comparison with the hammer tests. It was found that the two approaches select parameters AIBE parameters from different regions of the parameter space. This suggests that parameters identified with hammer tests should not be used to predict the dynamic response to more continuous excitation. It is hypothesized that the conflicting results are caused by the fact that the hammer tests do not properly elicit the memory effects responsible for hysteresis. Work this year was primarily focused on extending the previous year's efforts and completing related publications. This included acquiring new parameter identification results through the use of a mechanical shaker to enhance the observability of nonlinear effects in the response of the bolted specimen.

Random Set Theory for Reliability Estimation of Aerospace Structures

Researchers: Assistant Professor Chris L. Pettit,
Fulvio Tonon, University of Texas at Austin, and Ramana Grandhi, Wright State University

Uncertainty estimation in engineered systems often is sensitive to limited information about the statistical properties of inputs and system parameters. Dependable information for making decisions should reflect this epistemic uncertainty. A process based on random set theory was developed to calculate reliability bounds on net displacement at the tip of a representative wing structure subject to static aero elastic deformation. This process also included the use of proper orthogonal decomposition (POD) to reduce the aerodynamic load model to a function of three uncertain POD modal amplitudes, which were modeled via random set theory (RST) as imprecisely known random variables.

Academic Flight Simulator

Researcher: Assistant Professor Eric N. Hallberg

Current efforts involve reconstituting flight simulation capabilities (post Isabel), and developing HWITL avionics and control labs.

Midshipmen Research Course Projects

Design of an Autopilot for a Small UAV Using a Semi-Active Laser Guidance Sensor

Researchers: Various Midshipmen and Assistant Professor Eric N. Hallberg

During the past two years, teams of Naval Academy Aerospace Engineering Department students have worked in conjunction with other government agencies to assess the vulnerabilities and lethality of small unmanned air vehicles that might be used for terrorist actions. This project demonstrated in a high-fidelity simulation the terminal accuracy of a student-built UAV and laser seeker head using classical control methodologies.

ParkinsonSAT Satellite Design

Researchers: Midshipman 1/C David Koeppel, USN, Midshipman 1/C Kyle Vandegriff, USN, Midshipman 1/C James Paquette, USN, Midshipman 1/C Matthew Lovick, USN, Midshipman 1/C Jeffrey Robeson, USN and Midshipman 1/C Brian Piggrem, USN
Adviser: CDR Robert E. Bruninga, USN (Ret.)
Sponsor: Aerospace Corporation

Although these students formed the ParkinsonSAT Satellite development team, they also had additional responsibilities to follow up on some continuing requirements on the PCSAT2, ANDE, RAFT and MARScom projects that were in their final stages of test and integration and delivery to NRL and NASA. These experiences gave the students excellent experience with the type of work that will be required in the later stages of their own ParkinsonSAT project after they have graduated. In this sense, it was an excellent dovetailing of tasks and responsibilities. The ParkinsonSAT project is a new-start proposal this year to Aerospace Corporation to design and build a viable spacecraft to support remote data collection and communications. The project has a two path approach, one to fly a DOD sponsored transponder called ODTML (Ocean Data Transponder Microsat Link) and the other to provide a data collection and communications channel in the Amateur Satellite Service to encourage other universities to pool resources and built a population of satellites and sensors to further this mission. This year students developed the design leading up to System Requirements Review and built and tested a prototype environmental ocean buoy. The ParkinsonSAT design is detailed on the web page:
http://www.ew.usna.edu/~bruninga/buoy.html

Journal (Refereed) Manuscripts

KARPOUZIAN, Gabriel N., Professor, (co-author), "Text Mining the Global Abrupt-Wing-Stall Literature," *J. Aircraft*, Vol. 42, No. 3, June 2005, pp. 661-664.

> Database Tomography (DT) is a textual database analysis system consisting of two major components: 1) algorithms for extracting multi-word phrase frequencies and phrase proximities (physical closeness of the multi-word technical phrases) from any type of large textual database, to augment 2) interpretative capabilities of the expert human analyst. DT was used to derive technical intelligence from an Abrupt Wing Stall database derived from the Science Citation Index (SCI) database. Phrase frequency analysis by the technical domain experts provided the pervasive technical themes of the Abrupt Wing Stall database, and the phrase proximity analysis provided the relationships among the pervasive technical themes. Both concept and document clustering were used to provide the structural taxonomy of the Abrupt Wing Stall literature and the estimated levels of effort in the major sub-categories. Bibliometric analysis of the Abrupt Wing Stall literature supplemented the DT results with author/ journal/ institution publication and citation data.

NIEWOEHNER, R.J., CAPT, USN, (co-author), Introduction to Flight Test Engineering, 3e (Volume 1), Kendall-Hunt, Dubuque, IA, May 2006.

NIEWOEHNER, R.J., CAPT, USN (contributing author), 2nd edition of Phillips, Warren Mechanics of Flight, Wiley, forthcoming.

> Contributed approximately fifteen pages of content and homework problems on lateral-directional static stability and the minimum control airspeed problem.

NIEWOEHNER, R.J., CAPT, USN, (co-author), Engineering Reasoning, [Booklet- ~50 pages] Foundation for Critical Thinking, Sonoma, CA, June, 2006.

Authors contributed approximately half of the content using a previous booklet of Paul and Elder's as a template.

NIEWOEHNER, R.J., CAPT, USN, and FILBEY, Joshua (Trident Scholar 2000), "A Computational Study of F/A-18 E/F Abrupt Wing Stall in the Approach Configuration," *AIAA Journal of Aircraft*, Vol. 42, No. 6, pp. 1516-1522, November-December, 2005.

NIEWOEHNER, R.J., CAPT, USN, "True Airspeed Determination using GPS and Nonlinear Least Squares Data Reduction," *AIAA Journal of Aircraft*, accepted for publication.

This research improved an accuracy algorithm for the determination of air-data system errors using GPS.

NIEWOEHNER, R.J., CAPT, USN, (co-author), "Effect of Propeller Torque on Minimum-Control Airspeed," *AIAA Journal of Aircraft*, accepted for publication.

PETTIT, Chris L., Assistant Professor (co-author), "Using Random Set Theory to Calculate Reliability Bounds for a Wing Structure," *Structure and Infrastructure Engineering,* in press.

This paper shows how uncertainty can be propagated through a computer model when the input data consists of uncertainty affected by imprecision and randomness. The proper orthogonal decomposition (POD) is used to determine the dominant air pressure distributions on a wing, and the uncertainty in the POD modal amplitude variables is propagated through an FEM structural model to calculate the reliability bounds for the wing. It is shown that: (i) when working with imprecise input, the traditional probabilistic approach is inadequate because it would force the designer to add unavailable information; (ii) the proposed mathematical model of uncertainty is capable of capturing the incomplete knowledge upon which important conceptual and preliminary decisions must be made; (iii) this approach indicates if and where resources should be invested to acquire more information; (iv) the proposed techniques can be easily implemented using existing numerical codes; (v) a limited number of model runs is necessary to calculate bounds on the output distributions.

PETTIT, Chris L., Assistant Professor (co-author), "Nonlinear Plate Aeroelastic Response with Uncertain Stiffness and Boundary Conditions," *Structure and Infrastructure Engineering*, in press.

The probabilistic response of a nonlinear panel in supersonic flow is investigated using a new computational methodology. The aeroelastic system was modeled by coupling the von Karman plate equations for in-plane and out-of-plane deflections with piston theory aerodynamics. Baseline deterministic results are compared to published data to establish the validity of the aeroelastic model. Uncertainties in modulus of elasticity and boundary conditions (BC's) are considered, and the impact of these uncertainties on panel response is quantified in terms of limit-cycle oscillation (LCO) onset pressure and panel amplitude. The panel's uncertain BC's are modeled using rotational springs in place of ideally fixed boundary conditions. The panel's uncertain elastic modulus is modeled as a second-order, spatially homogeneous, isotropic, random field, while the boundary spring stiffness values are spatially constant for each random realization assuming either a uniform or Weibull distribution. Response probability distributions are obtained through Monte Carlo simulation (MCS) for selected values of freestream dynamic pressure. MCS is run for the case of random modulus only, as well as random modulus combined with boundary stiffness. It is observed that uncertainties have the greatest nonlinear influence on LCO amplitude near the deterministic point of LCO onset. Furthermore, panel response is much more sensitive

to location of the modulus field's extreme values than the correlation length used to generate the field. Interrogation of the random modulus fields using proper orthogonal de-composition (POD) yields insight into the local factors that govern the global response of the panel, permitting enhanced response prediction based on the nature of the random field realizations.

PETTIT, Chris L., Assistant Professor (co-author), "Spectral and Multiresolution Wiener Expansions of Oscillatory Stochastic Processes," *Journal of Sound and Vibration,* in press.

Wiener chaos expansions are being evaluated for the representation of stochastic variability in the response of nonlinear aeroelastic systems, which often exhibit limit cycles. Preliminary studies with a simple nonlinear aeroelastic computational model showed that the standard non-intrusive Wiener-Hermite expansion fails to maintain time accuracy as the simulation evolves. Wiener-Hermite expansions faithfully reproduce the short term characteristics of the process but consistently lose energy after several mean periods of oscillation. This energy loss remains even for very high order expansions. To uncover the cause of this energy loss and to explore potential remedies, the more elementary problem of a sinusoid with random frequency is used herein to simulate the periodic response of an uncertain system. As time progresses, coefficients of the higher order terms in both the Wiener-Hermite and Wiener-Legendre expansions successively gain and lose dominance over the lower order coefficients in a manner that causes any fixed-order expansion in terms of global basis functions to fail over a simulation time of sufficient duration. This characteristic behavior is attributed to the continually increasing frequency of the process in the random dimension. The recently developed Wiener-Haar expansion is found to almost entirely eliminate the loss of energy at large times. Details of the Wiener-Haar expansion of this process and a two degree-of-freedom nonlinear system are examined as a prelude to the stochastic simulation of aeroelastic limit cycles.

PETTIT, Chris L., Assistant Professor, "Uncertainty and Risk in Aerospace Vehicle Structures: Current Status and Recommended Directions," *International Journal of Materials and Product Technology,* Vol. 25, No. 1-3, 2006, pp. 211-230.

Widespread interest in uncertainty quantification methods for airframe design and certification is driven by the desire to realize acquisition and operational cost savings through increased reliance on analysis, the goal being to design and produce more robust airframes. General sources of uncertainty are described that complicate airframe design and testing, thereby contributing to the high cost of airframes. Recent applications of uncertainty quantification are reviewed with the objective of highlighting promising research and transition applications. Finally, several challenges and needs are explored to suggest future steps that must be completed to enable practical application of uncertainty quantification in airframe design and certification.

PISACANE, Vincent L., Professor (co-author), Thermoregulatory Models for Safety-for-Flight Issues for Space Operations, *Acta Astronautica*, accepted for publication.

This study investigates the use of a mathematical model for thermoregulation as a tool in safety-of-flight issues and proposed solutions for mission operations of the Space Shuttle and the International Space Station. Specifically, this study assesses the effects of elevated cabin temperature and metabolic loads on astronauts wearing the advanced crew escape suit (ACES) and the liquid cooled ventilation garment (LCVG). The 225-node Wissler model is validated by comparison with two ground-based human subject tests, firefighters and surrogate astronauts under anomalous conditions that show good agreement. Subsequent simulations indicate that the performance of the ACES/LCVG is marginal. Increases in either workload or cabin temperature from the nominal will increase rectal temperature, stored heat load, heart rate, and sweating leading to possible deficits in the ability of the astronauts to perform cognitive and motor tasks that could affect the safety of the mission, especially the safe landing of the Shuttle. Specific relationships are given between cabin temperature and metabolic rate that define the threshold for

decreased manual dexterity and loss of tracking skills. Model results indicate that the most effective mitigation strategy would be to decrease the LCVG inlet temperature. Methods of accomplishing this are also proposed.

PISACANE, Vincent L., Professor (co-author), "Use of Thermoregulatory Models for Space Shuttle and Space Station Operations and Review of Human Thermoregulatory Control," *Aviation, Space, and Environmental Medicine Journal of the Aerospace Medical Association*, accepted for publication.

Thermoregulation in the space environment is critical for survival, especially in off- nominal operations. In such cases, mathematical models of thermoregulation are frequently employed to evaluate safety-of-flight issues in various human mission scenarios. In this study, the 225-node Wissler model and the 41-Node Metabolic Man model are employed to evaluate the effects of such a scenario. Metabolic loads on astronauts wearing the advanced crew escape suit (ACES) and liquid cooled ventilation garment (LCVG) are imposed on astronauts exposed to elevated cabin temperatures resulting from a systems failure. The study indicates that the performance of the ACES/LCVG cooling system is marginal. Increases in workload and or cabin temperature above nominal will increase rectal temperature, stored heat load, heart rate, and sweating, which could lead to deficits in the performance of cognitive and motor tasks. This is of concern as the ACES/LCVG is employed during Shuttle decent when the likelihood of a safe landing may be compromised.

Conference Proceedings

PETTIT, Chris L., Assistant Professor (co-author), "Convergence Studies of Wiener Expansions for Computational Nonlinear Mechanics," *8th AIAA Non-Deterministic Approaches Conference*, Newport, RI, 1-4 May 2006.

Wiener chaos expansions are considered for simulating randomness in the response of nonlinear multidisciplinary systems. In contrast with deterministic computational models of these systems, there is a relative lack of published studies that illustrate the sensitivity of these expansions to numerical discretization and the representation of boundary conditions. Simulation-based, or non-intrusive, Wiener-Hermite and Wiener-Haar expansions are computed for nonlinear systems with assumed randomness in their spatially distributed properties. We demonstrate a method for estimating the expansion coefficients of the response that does not depend on explicit representation of the probability distribution of the uncertain parameters. Using this approach, we study the convergence of these stochastic expansions as a function of the spatial discretization of a geometrically nonlinear panel model under a uniform static pressure. Convergence of the resulting statistical moments is quantified as the grid is refined. For the nonlinear static panel problem described herein, some statistics are found to converge at noticeably different rates.

Technical Reports

BRUNINGA, Robert E., CDR, USN (Ret), APRS Technical Specification Addendum Version 1.2.:

Serving as technical chair of the APRS working group, I maintain and document proposed additions (1.2) to the APRS specification 1.01 initially published in November 2001. The draft of this new addendum version 1.2, updates some omissions or errors in the original document but also incorporates new features in this data communications standard. There are dozens of applications worldwide using this APRS protocol supporting over 30,000 end users. Many Universities and schools use this standard for telemetry from special projects such as Cubesats, High-altitude Ballooning, and remote data sensors. The version 1.2 is elaborated on the web page and is the single source for this technical data: http://www.ew.usna.edu/~bruninga/aprs/aprs12.html

BRUNINGA, Robert E., CDR, USN (Ret), ANDE Power System Report:

This report was an in-depth analysis of the ANDE power system for presentation to the Space Shuttle Safety Panel on 21 July 2006 as the final approval process for flight. The analysis looked at all possible battery failure modes and issues that could have an impact on the Space Shuttle and addressed the multiple redundancies and inhibits necessary to meet the NASA Manned safety requirements. The report is maintained on this web page: http://www.ew.usna.edu/~bruninga/ande/ANDE-laser-power-Decision-d.doc

BRUNINGA, Robert E., CDR USN (Ret), RAFT Acceptance Data Package:

This package contained the in-depth analysis of the RAFT spacecraft systems for delivery to the Space Test Program to meet the NASA requirements for spacecraft integration at Kennedy Space Center on 17-20 July 2006. This package and analysis addresses all the possible failure modes and issues that could have an impact on the Space Shuttle and addressed the multiple redundancies and inhibits necessary to meet the NASA Manned safety requirements. The report is maintained on this web page: http://www.ew.usna.edu/~bruninga/craft/RAFT-ADP-2006c.doc

Presentations at Professional Meetings and Conferences

BODEN, Daryl G., Professor, and GRAY, Peter J., "CDIO and its Adoption and Assessment at the U.S. Naval Academy," CDIO Seminar, Wismar University, Wismar, Germany, 16 June 2005.

BODEN, Daryl G., Professor and GRAY, Peter J., "CDIO and its Adoption and Assessment at the U.S. Naval Academy," UICEE 9th Baltic Region Conference, Gdynia, Poland, 17 – 19 June 2005.

BODEN, Daryl G., Professor (co-author), "CDIO, The Change Process," CDIO Workshop, University of Colorado, Boulder CO., 13 March, 2005.

BRUNINGA, Robert E., CDR, USN (Ret), "Space Communications – International Educational Network Classroom Experience - SCIENCE Project," Navy Space Experiments Review Board (SERB) Navy Research Laboratory, Washington, DC, 19 July 2005.

BRUNINGA, Robert E., CDR, USN (Ret), "S.C.I.E.N.C.E Project", Department of Defense (DOD) Space Experiments Review Board (SERB), A-Team SAFTAS Conference Facility, Arlington, VA, 3 November 2005.

BRUNINGA, Robert E., CDR, USN (Ret), "P-SAT - ParkinsonSAT Project" Navy Space Experiments Review Board (SERB) Naval Research Laboratory, Washington, DC, 11 July 2006.

HALLBERG, Eric N., Assistant Professor, "Store Separation Trajectory Simulation for the High Speed Anti-radiation Demonstrator (HSAD) Program," 44th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, 9-12 January 2006.

HALLBERG, Eric N., Assistant Professor, "Parametric Analysis of the Store Separation of a High Speed Anti-Radiation Demonstrator (HSAD) Missile," AIAA Atmospherics and Flight Mechanics Conference and Exhibit, Keystone, CO, 21 - 24 August 2006.

HALLBERG, Eric N., Assistant Professor, "CDIO Workspaces & Design-Build Experiences", CDIO North American Regional Meeting, Boulder, CO, 14-16 March 2006.

HALLBERG, Eric N., Assistant Professor, "MATLAB-based 6DoF Code for Store Separation with Autopilots," 2006 ITEA International Aircraft-Stores Compatibility Symposium XIV, Fort Walton Beach, FL, 11-13 April 2006.

MIKLOSOVIC, David S., Assistant Professor, and BOOKEY, Patrick B., LTjg, USN, "Aerodynamic Performance Enhancements of Multiple Winglet Configurations", 2005 ASME Fluids Engineering Division Summer Meeting and Exhibition, 19-23 June 2005, Houston, TX.

MIKLOSOVIC, David S., Assistant Professor, and BOOKEY, Patrick B., LTjg, USN, "An Historical and Applied Aerodynamic Study of the Wright Brothers' Wind Tunnel Test Program and Application to Successful Manned Flight", 2005 ASME Fluids Engineering Division Summer Meeting and Exhibition, 19-23 June 2005, Houston, TX.

NIEWOEHNER, R.J., Capt, USN, "Towards a Rational Foundation for Engineering Ethics," National Faculty Leadership Conference, Alexandria, VA, June 2006.

NIEWOEHNER, R.J., Capt, USN, "Engineering Reasoning", International Conference of the CDIO Consortium, Linkoping, Sweden, June 2006.

PETTIT, Chris L., Assistant Professor (co-author), "Convergence Studies of Wiener Expansions for Computational Nonlinear Mechanics," 8th AIAA Non-Deterministic Approaches Conference, Newport, RI, 1-4 May 2006.

PETTIT, Chris L., Assistant Professor (co-author), "Experimentally Quantifying the Dynamic Response of Bolted Lap Joints," 47th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Newport, RI, 1-4 May 2006.

PISACANE, Vincent L., Professor, ZIEGLER, J.F., Visiting Professor, NELSON, M. E., Professor (Mechanical Engineering Department), and DICELLO, J. F., (co-authors), "Microdosimetry Simulations of Solar Protons Within a Spacecraft," IEEE Nuclear and Space Radiation Effects Conference, Seattle, WA, 11-15 July 2005.

PISACANE, Vincent L., Professor, ZIEGLER, J.F., Visiting Professor, NELSON, M. E., Professor (Mechanical Engineering Department), and DICELLO, J. F., (co-authors), "Response of a SOI Microdosimeter to a 238 PuBe Neutron Source", IEEE Nuclear Science Symposium and Medical Imaging Conference, 23-29 October 2005, Puerto Rico; IEEE Nuclear Science Symposium Conference Record, 2005 IEEE, Vol.1, pp. 68-72.

PISACANE, Vincent L., Professor, ZIEGLER, J.F., Visiting Professor, NELSON, M. E., Professor (Mechanical Engineering Department), and DICELLO, J. F., (co-authors), "Solid-State Microdosimetric System for a Satellite Scheduled for Launch in 2006," 14th Symposium on Microdosimetry, Venezia, November 2005.

PISACANE, Vincent L., Professor, and DICELLO, J. F., (co-authors), "Comparisons of Integrated Radiation Transport Models with Microdosimetry Data in Spaceflight," 10th Symposium of Neutron Dosimetry, Uppsala, Sweden, 12-16 June 2006.

PISACANE, VINCENT L., Professor, ZIEGLER, J.F., Visiting Professor, NELSON, M. E., Professor (Mechanical Engineering Department), and DICELLO, J. F., (co-authors), "MIcroDosimeter iNstrument (MIDN) for Space Flight," NASA/NSBRI Bioastronautics Investigators Workshop, Houston, TX, February 2006. (Invited presentation)

PISACANE, Vincent L., Professor, ZIEGLER, J.F., Visiting Professor, NELSON, M. E., Professor (Mechanical Engineering Department), and DICELLO, J. F., (co-authors), "MIcrodosimeter iNstruemnt (MIDN) on MidSTAR-I," 36th International Conference on Environmental Systems, Norfolk, VA, 17-20 July 2006.

PISACANE, Vincent L., Professor, and DICELLO, J.F., (co-authors), "Thermoregulatory Models in the Management of Safety-For-Flight Issues for Space Shuttle and Space Station Operations," Status of Solid-State Microdosimetery for Future NASA Missions - NASA Workshop on Radiation Detection, USRA Division of Space Life Sciences, Center for Advanced Space Studies, Houston, TX, 6-7 April 2006. (Invited presentation)