PURDUE
UNIVERSITY

School of Aeronautics & Astronautics

2005-2006

Research Report

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OUR MISSION

Established as an independent school on July 1, 1945, the School of Aeronautics and Astronautics is committed to be a world-class leader in aerospace engineering education and fundamental and breakthrough research for aerospace vehicles and systems. Our mission of preparing men and women to be leaders in aerospace engineering by providing exceptional education and research programs for them is the focus of our life's work.

ACADEMIC HIGHLIGHTS

Undergraduate enrollment was 432 for the Fall of 2005 Graduate enrollment of 215 was the largest graduate enrollment in the School's history. During academic year 2005-06, 133 students earned their Bachelor of Science degree, 76 earned their Master of Science degree, and 14 earned their Doctor of Philosophy degrees. The *US News and World Report* ranked our graduate program 6th in the nation and our undergraduate program 4th amongst universities that award Ph.D.s. The School continues to appear on the list of "key schools" for the major US aerospace manufacturers.

Year	00-01	01-02	02-03	03-04	04-05	05-06
B.S.	60	65	90	116	142	133
M.S.	23	34	24	47	42	76
Ph.D.	17	14	10	11	12	15

Purdue University's Program for Study Abroad Office currently offers more than 200 programs in over 45 countries around the world. The School of Aeronautics and Astronautics currently has active student exchanges: Bristol University, United Kingdom; Royal Melbourne Institute of Technology, Melbourne, Australia; University of New South Wales, Sydney, Australia; Ecole Superieure des Techniques Aeronautiques et de Construction Automobile (ESTACA), Paris, France.

The School of Aeronautics and Astronautics, through Purdue University's Engineering Professional Education (EPE) Program, offers graduate level courses in aerospace engineering. This opportunity to reach students through distance education, along with our history of quality education, gives us confidence that our School's participation with EPE will be a benefit to all participants. The School is developing its first M.S. in Aeronautics and Astronautics through EPE.

DEVELOPMENT HIGHLIGHTS

Ducommun, The Boeing Company, Lockheed-Martin, Northrop Grumman, and Rolls-Royce supported the Industrial Affiliates Program (IAP) this year. The School's Industrial Advisory Council (IAC) continued its bi-annual meeting schedule, meeting both in April 2005 and September 2006. IAC members are: Mr. Frank Bauer, NASA Goddard Space Flight Center; Mr. Bradley Belcher, Rolls Royce; Dr. Paul Bevilaqua, Lockheed Corporation; Ms. Andrea Chavez, Ball Aerospace; Mr. Michael Corso, Henderson, Franklin, Starnes & Holt; Mr. Daniel Devitt, Vought Aircraft Industries, Inc; Mr. Darryl Davis, Boeing Integrated Defense Systems; Mr. Michael Dressen, Miltec Missiles & Space; Mr. John Gallman, Cessna Aircraft Co.; Dr. Carl Gran, The Aerospace Corp.; Mr. Joseph Gernand, Boeing; Dr. Andrew Kasowski, Cessna Aircraft Co.; Dr. Andrew King, Boeing; Mrs. Mary Kriebel, Northrop Grumman; Dr. Donald Lamberson, Major General, USAF (ret.); Mr. Thomas Maxwell, GE Aircraft; Mr. David McGrath, ATK Tactical Systems; Mr. G. Thomas McKane, A.M. Castle & Co.; Mr. James Renna, Sikorsky Aircraft; Mr. Charles Saff, Boeing; Mr. Randal Secor, Northrop Grumman Corp.; and Dr. Robert Strickler, Sangamon LLC.; Dr. Anthony Thornton, Sandia National Labs; and Mr. John Walsh, Ducommun Technologies.

As of June 30, 2006, the Campaign for Purdue has resulted in more than $16 million in gifts to AAE. We look forward to moving to Armstrong Hall during 2007.

ALUMNI HIGHLIGHTS

The following six Outstanding Aerospace Engineers (OAEs) were honored on October 9, 2006: Dr. Thomas C. Adamson, Jr... (B.S.A.E. 1949); Dr. Steven M. Ehlers (B.S.A.A.E. 1977, M.S.A.A.E. 1978, Ph.D. 1991); Mr. Jerry W. McElwee (B.S.E.S. 1968, M.S.I.A. 1970); Ms. Doris (Dodie) Hurt Powers (B.S.ATR 1949); Mr. Richard B. Rivir (B.S.A.E. 1960); and Mr. Norman V. Scurria, Jr. (M.S.A.S.E. 1980).

Dr. Allen S. Novick (B.S.A.E. 1965, M.S.A.E. 1967, Ph.D. 1967) was awarded the College of Engineering 2006 Distinguished Engineering Alumnus (DEA) Award and an OAE in February. Dr. Novick is currently Vice President, Marketing Intelligence and Support, Rolls-Royce Corporation**.**

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2005 are given in the "Faculty Summary" section of this report. Only documents that actually appeared in print during 2005 are listed. Note that 62 journal articles or book chapters, and 113 conference papers or technical reports, were presented or published. In addition to the published technical reports listed, many other technical progress reports were submitted directly to project sponsors.

CO-OP PROGRAM

During the 2005-06 academic year, 33 students were enrolled in the Cooperative Engineering Program with the companies listed on the following page. This popular program is limited only by the number of industry positions available. About 10 of 92 new applicants in Spring 2006 received appointments this year. Many other students gain industrial experience through internships.

During the past academic year several new certificate programs have been initiated under the umbrella of the Co-op program, which has been renamed "Professional Practice" to reflect its expanded role. The new programs are generally shorter than the traditional 5 term Co-op, typically expecting three work sessions from students after their sophomore year. We hope that these new programs will bring in more employers and greatly expand the professional practice opportunities open to AAE students.

Co-Op Companies
School of Aeronautics and Astronautics
July 1, 2005-June 30, 2006

Company	Location	Number of A&AE Co-op Students
Aerospace Corporation	Los Angeles, CA	0
American Trans Air	Indianapolis, IN	0
ATA Engineering Inc.	San Diego, CA	7
Atlantic Research Automotive Group	Knoxville, TN	0
BAE Systems Control	Ft. Wayne, IN	0
Ball Aerospace & Tech. Corp.	Boulder, CO	2
Boeing Satellite Systems	Long Beach, CA	0
Delta Air Lines	Atlanta, GA	0
General Electric GE Transportation/Aircraft Engines	Cincinnati, OH	10
International Truck and Engine Corp.	Fort Wayne, IN	0
Rockwell Collins	Cedar Rapids, IA	2
Rolls-Royce	Indianapolis, IN	0
Structural Analysis Engineering Corp.	Cincinnati, OH	2
U.S. Gov. Air Force Research Lab.	Edwards AFB, CA	0
U.S. Gov. NASA-Dryden Flight Research Center	Edwards, CA	1
U.S. Gov. NASA-Glenn Space Center	Cleveland, OH	0
U. S. Gov. NASA-Goddard Space Center	Greenbelt, MD	0
U.S. Gov. NASA-Johnson Space Center	Houston, TX	6
U.S. Gov. NASA-Kennedy Space Center	Kennedy Space Ctr., FL	0
U.S. NASA-Langley Research Center	Hampton, VA	0
U.S. Gov. National Air & Space Intelligence Center	Wright Patterson AFB, OH	0
U. S. Gov. Naval Research Laboratory	Washington, DC	0
U. S. Gov. Wright-Patterson AFB	Dayton, OH	1
United Parcel Service (Air Group)	Louisville, KY	1
United Technologies Pratt & Whitney	W. Palm Beach, FL	0
United Technologies Pratt & Whitney	East Hartford, CT	1

OVERVIEW OF RESEARCH AREAS AND FACILITIES

Purdue University has outstanding facilities, including several research facilities under construction in Purdue's Discovery Park, as a part of Purdue's strategic plan. Purdue has also excellent computing facilities. Purdue owns a 320-CPU IBM SP supercomputer and has just created a state-of-the-art visualization center.

The School of Aeronautics and Astronautics houses some of the nation's top research labs for the study of evolving aerospace industry technologies. Both computational and experimental facilities are available for graduate student use. With the recent support of the Boeing Company and the Intel Corporation, the School was able to enhance the Design/Build/Test (DBT) Laboratory, which prepares students for integrated product teams in industry. In addition, many workstations and personal computers are located throughout the School. The *High Performance Computing Cluster for Aerospace Applications* consists of a 57 quad node cluster (228 total processors) for distributed and parallel processing.

AERODYNAMICS

Aerodynamics research is directed toward a better understanding of the fundamental laws governing the flow of fluids in aerospace systems. Research topics of recent interest include aerodynamic noise, low-gravity fluid mechanics, computational methods in aerodynamics and fluid mechanics, experimental measurements using optical systems, and laminar-turbulent transition in hypersonic boundary layers.

Experimental facilities include four low-speed wind tunnels located at the **Aerospace Sciences Laboratory** (ASL). **The Boeing Wind Tunnel** is a large subsonic wind tunnel with two test sections: a closed 4-by-6 foot section with a maximum speed of 250 miles per hour, and a long test section adapted for high-lift research. The first test section is equipped with a six-component motorized pitch-and-yaw balance system.

Three smaller low-speed wind tunnels are also located at ASL. One has an 18 inch diameter test section, and the other two have test sections of 12 by 18 inches. Several small calibration tunnels are also available, along with a 20-by-20-inch water tunnel and a small water table.

Four high-speed facilities are located in the **Boeing Compressible-Flow Laboratory** at ASL. The **Boeing/AFOSR Mach-6 Quiet Tunnel** is a large Ludwieg tube with a 9.5-inch Mach-6 test section. It is the only hypersonic wind tunnel in the world with low noise levels comparable to flight, for unit Reynolds numbers up to about 3.5 million per foot. It can also be operated under conventional noise to a unit Reynolds number of 6 million per foot. Instrumentation is specialized for study of laminar-turbulent instability and transition, and includes high-speed hot wires, fast-response pressure transducers, hot-film arrays and anemometers, a high-sensitivity laser-differential interferometer, a glow-discharge perturber, and a pulsed laser perturber.

The Boeing Compressible-Flow Laboratory also includes a smaller Ludwieg tube with a 4-inch Mach-4 test section that remains quiet to a length Reynolds number of about 400,000. A 4-inch transonic test section, completed in 2004, can also be installed. A 3000-gal. air receiver supplies a 2-inch Mach-2.5 blowdown tunnel and a one-inch supersonic jet designed for nozzle-flow studies. Both can exhaust to a 500 cubic foot vacuum tank, and are used primarily for teaching. The jet apparatus also includes a heater and particle filter to enable supersonic hot-wire calibrations. A 4-inch shock tube is also available.

ASTRODYNAMICS AND SPACE APPLICATIONS

In the area of astrodynamics, the complex missions envisioned in the next few decades will demand innovative spacecraft trajectory concepts and efficient design tools for analysis and implementation. In support of such plans, current research efforts focus on spacecraft navigation and maneuver requirements, and mission planning, both in the neighborhood of the Earth and in interplanetary space. Some of the current research efforts focus on the following: 1) libration point orbits in the three- and four-body problems 2) trajectory design and optimization including optimal control strategies for out-of-plane motion in consideration of communication and other operational specifications 3) analyses of station-keeping requirements for such trajectories are also currently under study.

Current research efforts also include 1) analytic theory and control of spinning-up and thrusting vehicles, 2) mission design and trajectory design for interplanetary flight, 3) orbit decay and reentry problems, and 4) tethers in space 5) finding and developing new applications of the Global Positioning System (GPS). GPS has emerged as one of the most prevalent uses of satellite technology in people's everyday lives today. 6) Three dimensional reconstruction of biological structures obtained from serial electron microscope sections 7) computer applications to research and teaching of Microbiology 8) digital signal processing. 9) nonlinear dynamics and chaotic system analysis as applied to biological diversity. 10) satellite design 11) ground station design for acquisition satellite data.

AEROSPACE SYSTEMS DESIGN

The area of aerospace systems design involves the study of methods and techniques necessary for the design of aerospace systems and their components. The courses in this option provide opportunities to gain exposure to design methods and to gain experience through design projects. The topics addressed include requirements definition, functional decomposition, concept synthesis, application of design-oriented analysis methods, and optimization. Because aerospace systems are highly interdisciplinary, a systems perspective is encouraged to ensure that students are aware of how design decisions impact numerous features of the aerospace system.

DYNAMICS AND CONTROL

All modern aerospace vehicles rely upon an understanding of dynamics and control to improve system performance. Successful system design requires an understanding of the interactions of dynamic elements and the trade-offs between vehicle dynamic characteristics, control system properties, and system performance.

Current research is divided into the following areas: aircraft design for improved handling qualities, astrodynamics, robust and nonlinear control theory and applications, estimation theory and applications, dynamics and control of flexible spacecraft, mission design, modeling and control of aeroelastic aircraft, spacecraft maneuvers and trajectory analysis, and optimization.

Certain research projects and teaching activities require advanced and specialized laboratory facilities. The **Control Systems Laboratory** (CSL) contains high-end workstations. The mission of the CSL is to develop methods and tools (software) for the analysis and design of complex dynamical systems and to promote the availability and use of the methods by teaching relevant courses and interacting with industry. Experiments used for undergraduate instruction include a two-degree-of-freedom helicopter experiment, a three-degree-of freedom rotational system to emulate the attitude dynamics of a flexible spacecraft, and an inverted pendulum. The **Remotely Piloted Vehicle**, currently under development, represents a unique research facility upon which to perform many experiments in vehicle dynamics and control. Data communication with a computer based ground station is provided by a seven channel telemetry downlink.

PROPULSION

The Propulsion group has unique facilities, which are highly beneficial for the study of rocket propulsion and energy conversion. Laboratories are housed at two major remote campus facilities: the Maurice Zucrow Laboratory (MZL), and the Aerospace Sciences Laboratory (ASL).

The ***Advanced Propellants and Combustion Laboratory*** is housed at MZL, and is comprised of two test cells. The test cells are of poured, reinforced concrete design with containment steel doors and explosive rated viewing windows. These cells are classed for both Class 1.1 and 1.3 explosives and are equipped with a frangible blowout wall in case of major catastrophic events. Test Cell A currently contains a rocket thrust stand capable of handling thrust loads of up to 1000 lbf. Test Cell B is used for hybrid rocket combustion studies and vacuum ignition studies for a variety of new nontoxic hypergolic propellants. These cells are both equipped to handle advanced storable oxidizers with emphasis on high concentration hydrogen peroxide. In local proximity is a dedicated oxidizer storage building and a dedicated explosive/propellant storage bunker, rated for Class 1.1 materials.

The ***High Pressure Laboratory***, also located at MZL, is a major new facility shared with Mechanical Engineering. This facility has two 500 square-foot test cells rated for propulsion testing up to 10,000 lbf thrust levels. The airbreathing propulsion cell has a cyclic pulse detonation rig capable of simultaneous firing of up to four tubes. A 5 million sample-per-second high speed data system and associated pressure instrumentation is available in addition to a more standard suite of pressure/temperature/thrust instrumentation. A high-pressure gas turbine combustor experiment is also housed in this cell. The rocket propulsion cell has capabilities to test liquid oxygen/hydrocarbon thrust units at thrust levels up to 10,000 lbf and pressures up to 5,000 psi. Experiments in both the airbreathing and rocket propulsion cells are controlled remotely with a state-of-the-art data acquisition and control panel.

The ***Fuel Thermal Management Laboratory*** is housed at MZL, and includes a 15Kw power supply for electrically heating tubes containing flowing aviation fuels. The cell contains a fully temperature conditioned fuel tank, sparging system, nitrogen purging of test apparatus, and pressure/temperature/flow instrumentation for operation to roughly 1000 psi and 1200 deg. F operations. Data acquisition is achieved using LabView software and National Instruments acquisition cards in personal computers. Cameras are used for remote observation of the test cell.

The ***Laboratory for Electric and Advanced Propulsion*** is housed at the Aerospace Science Laboratory (ASL). There are two vacuum systems located at ASL to simulate operating conditions for electric propulsion devices. A smaller vacuum chamber (17-in diameter, 3-foot long cylindrical vessel) is primarily used for component testing. Depending on introduced gas flow, the vacuum system enables vacuum pressures between 10^{-2} to 10^{-6} Torr. A torsional thrust stand was designed and built capable of resolving forces below 1 mN. The recent addition of a large vacuum chamber substantially increases the testing capability of the Laboratory. The vacuum chamber features a 5–foot diameter, 9–foot long cylindrical vessel and various feedthroughs for power, diagnostics, and instrumentation. A 20,000–l diffusion pump in series with a 400–cfm mechanical pump establishes vacuum pressures below 10^{-6} Torr ($2 \cdot 10^{-8}$ psi). Both vacuum systems have their individual pumping systems, diagnostics, and propellant feed systems.

STRUCTURES AND MATERIALS

Structures and materials research includes work in composite materials, computational structural mechanics, damage tolerance analysis, experimental structural analysis, structural mechanics and aeroelasticity, dynamic behavior of advanced materials, tribology, manufacturing, wave propagation, smart materials and structures, and optimal design methods.

The **Fatigue and Fracture Laboratory** (http://roger.ecn.purdue.edu/~fslab/) is well-equipped to conduct structural integrity motivated research directed at evaluating the damage tolerant properties of materials and components. Two computer-controlled electro-hydraulic test machines (11 and 22 kip capacity), and associated equipment, are used to measure fracture loads and to study fatigue crack formation and propagation in test specimens subjected to simulated aircraft or spacecraft load histories. A scanning electron microscope is available to examine fracture surfaces.

The **Laboratory for Dynamic Response of Advanced Materials**, resided in Purdue's new Bowen Large-scale Testing Laboratory, contains unique equipment and facilities for the characterization of engineering materials under high-rate conditions. A variety of split Hopkinson bars (Kolsky bars) have been developed and modified for testing materials ranging from a single Kevlar fiber and soft tissues to metals and armor ceramics at strain rates from intermediate to impact level. A high-speed optical digital camera with the frame rate of up to 2,000,000 frames per second is used to record the high-rate deformation and failure processes. High-rate experiments are also conducted at different temperatures and different stress states, in addition to different strain rates.

The **McDonnell Douglas Composite Materials Laboratory** contains equipment and facilities for general material testing and for fabrication of composite laminates. An autoclave specially designed for curing epoxy-matrix composites is available for laminate fabrication. A hot press is used for forming thermoplastic composites, and an EnTec filament winding machine is available for making cylindrical composite structures. A water jet cutting machine is used for specimen preparation. Four complete MTS material and fatigue testing machines (55 kip, 22 kip, 11 kip, and 1 kip capacity) and associated equipment are used to perform ultimate strength, stiffness, and fatigue tests on various composite materials. An Applied Test Systems creep machine is available for constant load creep tests at room temperature or elevated temperatures. Dynamic material testing equipment includes a compressed air gun capable for launching a 33 gram projectile to about 500m/s, a drop tower for low velocity impact test, and a Hopkinson pressure bar for high strain rate test. Nondestructive inspection equipment includes an x-ray machine and an ultrasonic C-scan system. Additional facilities for preparing nanocomposites and microscopic observations of materials are also available.

The **Structural Dynamics Laboratory** has the latest equipment for recording ultra-dynamic events. Major equipment includes Norland and Nicolet digital recorders, a one-million-frame-per-second dynamic camera, impact gun, and various computer peripherals for data acquisition. The primary research interest is in the impact of structures and the analysis of consequent stress waves.

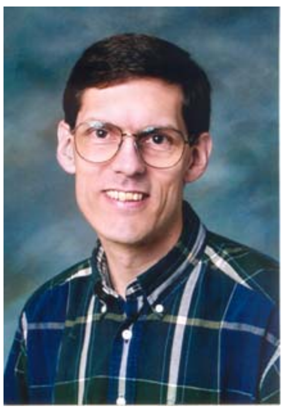
The **Tribology and Materials Processing Laboratory,** maintained jointly with the **Center for Materials Processing and Tribology** contains tribological instrumentation as well as up-to-date machines for manufacturing processes. Equipment includes a 22 kip computer-controlled electro-hydraulic test machine and associated equipment for fretting fatigue testing at room and elevated temperatures, infrared sensors for full-field temperature measurements, a friction apparatus for both low and high speed sliding indentation, lapping and polishing equipment, a vibration isolation table, micropositioning stages, a sliding wear experiment, Talysurf profilometers, phase shift interferometric profilometer, an atomic force microscope, a nanoindenter, a talysurf instrument for measurements of form, cylindricity cuts and taper, and an SEM and optical microscopes. A piezo-electric based load frame has been constructed to perform high frequency fretting fatigue experiments related to HCF of aircraft engines. Also, access is available to a variety of machine tools: a precision high speed surface grinder, a centerless grinder, and a super finishing machine, as well as associated piezoelectric force transducers.

School of Aeronautics and Astronautics

Faculty Summaries

Aerodynamics

Faculty Members



G. A. Blaisdell, Associate Professor, Ph.D. Stanford, 1991, computational fluid mechanics, transition, and turbulence

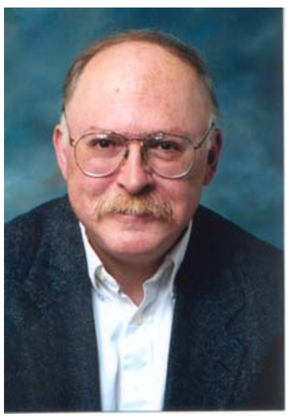
S. H. Collicott, Professor, Ph.D., Stanford, 1991, experimental and low-gravity fluid dynamics, optical diagnostics, and applied optics

M. C. Jischke, University President, Ph.D., Massachusetts Institute of Technology, 1968

A. S. Lyrintzis, Professor, Ph.D., Cornell, 1988, computational aeroacoustics, aerodynamics for rotorcraft and jet flows

S. P. Schneider, Professor, Ph.D. Caltech, 1989, experimental fluid mechanics, and high-speed laminar-turbulent transition

J. P. Sullivan, Professor, Sc.D., MIT, 1973, experimental aerodynamics, propellers, and laser-doppler velocimetry



M. H. Williams, Professor and Associate Head, Ph.D., Princeton, 1975, aerodynamics and computational fluid mechanics

GREGORY A. BLAISDELL
1991
Associate Professor

Degrees

B. S., California Institute of Technology, Applied Mathematics, 1980
M. S., California Institute of Technology, Applied Mathematics, 1982
Ph.D., Stanford University, Mechanical Engineering, 1991

Interests

Computational fluid mechanics
Transition and turbulence

Awards and Major Appointments

NASA-ASEE Summer Faculty Fellowship, 1995-1996
W. A. Gustafson Teaching Award, Fall 1997

Research Areas

Current research interests involve the study of transitional and turbulent fluid flows using computational fluid dynamics (CFD) as an investigative tool. Most flows of engineering interest are turbulent and turbulence has a significant impact on the performance of engineering systems. The drag on a body is generally much greater if the boundary layer is turbulent. Turbulence also increases heat transfer between a fluid and a surface. In addition, turbulent mixing is important to combustion.

The physics of basic turbulent flows are studied using direct numerical simulations (DNS) and large-eddy simulations (LES). With LES, the motion of the largest eddies are solved for directly while the effects of the unresolved small scale eddies are modeled. In contrast, with DNS all the relevant length scales within the turbulence are resolved and no modeling is needed. The results of the simulations are used to increase our understanding of turbulence and to test and improve turbulence models.

Current research projects are described below. Many of these investigations are being carried out using parallel processing computers. Parallel computing and advanced numerical methods is another area of interest.

Development of Large Eddy Simulation Methodology and Application to a Turbulent Axial Vortex (Sponsored by Purdue Research Foundation; Student: Brijesh Eshpuniyani; Computer resources: PUCC (IBM SP 2))

Axial vortices form in many engineering systems but are of particular importance to the wake hazard problem for commercial aircraft. A previous study used direct numerical simulation (DNS) to investigate an isolated turbulent axial vortex. However, the DNS are limited to low Reynolds numbers—the DNS are at a Reynolds number that is three orders of magnitude lower than that of the wake vortices behind a typical large commercial airliner. Although LES on currently available computers will not be able to achieve full scale Reynolds numbers, it will allow the trends with increasing Reynolds numbers to be determined. This is important because Reynolds number is believed to have a significant effect on the development of turbulence within a vortex.

Development of Low Jet Noise Aircraft Engines (Project Leader: Anastasios Lyrintzis, G. Blaisdell, L. Mongeau, S. Bolton, and (W. Dalton of Rolls-Royce), Sponsored by Indiana 21st Century Research and Technology Fund)

The regional and corporate aircraft engine market's rapid expansion will be severely compromised, unless jet noise is drastically reduced. Rolls-Royce, Indianapolis, with a commanding share of 37% in this sector of the world market, may lose business to out-of-state competitors if its engines fail to meet stringent airport noise regulations. In this project experts from Purdue University and Rolls-Royce will advance the science of jet noise reduction for turbofan engines by studying the noise of internally mixed engines, where the hot core flow is mixed with the cooler fan flow inside the exhaust nozzle by lobed mixers. The turbulent mixing of these two flows and their mixing with the atmosphere causes jet noise. Although empirical methods can be used to reduce noise, optimal engine design is not possible without deeper scientific understanding. Our team of experts will synthesize computational, theoretical, and experimental techniques to generate a new level of understanding of jet noise reduction. Rolls-Royce has a plan in place for the rapid commercialization of such scientific breakthroughs. Thus the accelerated technology transfer of our new science will impact about 1200 highly skilled employees at Rolls-Royce in Indiana and also its many local suppliers.

Conference Proceedings, Presentations, Invited Lectures

Garrison, L. A., **Lyrintzis, A. S**., **Blaisdell, G. A.**, and Dalton,W. N., "Computational Fluid Dynamics Analysis of Jets with Internal Forced Mixers," AIAA Paper 2005-2887, presented by L. A. Garrison at the 11th AIAA/CEAS Aeroacoustics Conference, Monterey, CA, May 2005.

Lew, P., **Blaisdell, G. A.**, and **Lyrintzis, A. S.**, "Recent Progress of Hot Jet Aeroacoustics Using 3-D Large Eddy Simulation," AIAA Paper 2005-3084, presented by P. Lew at the 11th AIAA/CEAS Aeroacoustics Conference, Monterey, CA, May 2005.

Tester, B. J., Fisher, M. J., Garrison, L. A., **Lyrintzis, A. S.**, and **Blaisdell, G. A.**, "Understanding and Prediction of Lobed Mixer Jet Noise," Final report for the Aeroacoustical Research Consortium / Ohio Space Institute, June 30, 2005, 161 pages.

STEVEN C. COLLICOTT
1991
Professor

Degrees

B. S., University of Michigan, Aerospace Engineering, magna cum laude, 1983
M. S., Stanford University, Aeronautics & Astronautics, 1984
Ph.D., Stanford University, Aeronautics & Astronautics, 1991

Interests

Experimental fluid mechanics
Low-gravity fluid dynamics
Optical diagnostics
Applied optics

Awards and Major Appointments

Presented the American Institute of Aeronautics and Astronautics “Special Service Citation,” March 1997

Research Areas

Four topics are being researched: high-bypass turbofan duct-strut flow, cavitation in spray orifices, low-gravity fluid dynamics, and optical methods for studying hypersonic boundary layer transition.

A source of total pressure loss and non-uniform back pressure on the fan in modern and proposed high bypass ratio turbofan engines is the strut-endwall flow in the bypass duct. NASA-funded experiments, coordinated with advanced concepts research at Pratt & Whitney, explore the flow structure at Reynolds numbers typical of full-scale cruise conditions. The experiment is designed to also provide valuable checkpoints for the integrated design codes being developed by Pratt & Whitney.

Spraying of a liquid is a common commercial operation, yet little attention has been paid to the flow inside the spray orifice. Particularly in diesel fuel injectors, small-scale non-equilibrium cavitation exists, the behavior of which cannot presently be predicted to any useful extent. This research, funded by the NSF-Career Award, probes the internal flow with specialized optics to uncover the physics of cavitation and turbulence in these flows. Coordination with Professor Heister's simulations with a pseudo-density model for non-equilibrium cavitating flows is crucial to the value of these experiments.

Design of fuel tanks to control sloshing liquids during weightless space flight requires incorporation of nonlinear contact-line dynamics into numerical models. Even the determination of equilibrium interface topology requires considerable numerical work in many situations. Validation and application of an existing model for determining equilibrium interface topologies in main liquid helium tank of the Gravity Probe-B spacecraft has been performed for Lockheed and the GP-B project. Incorporation of physically important stick-slip contact line motion as non-linear boundary conditions in a Boundary Element Method (BEM) code for low-g large-amplitude fluid slosh prediction is being pursued with Professor Heister.

Hypersonic boundary layer transition is a critical event on high speed flight vehicles, including the Space Shuttle during re-entry. Professor Schneider's experiments involve an optical perturber and optical diagnostics, both under the responsibility of Professor Collicott. The perturber has been developed and is in regular use. High-sensitivity, high bandwidth Laser Differential Interferometry is being applied to detect and measure instability waves in millimeter and thinner boundary layers in flows at speeds in excess of one-half of a kilometer per second.

Publications

Lindsley, W. G., **Collicott, S. H.,** Franz, G. N., Stolarik, B., McKinney, W., and Frazer, D.G., "Asymmetric and Axisymmetric Constant Curvature Liquid-Gas Interfaces in Pulmonary Airways," *Annals of Biomedical Engineering,* Vol. 33, No. 3, March 2005, pp. 365-375.

Kim, B.-D., **Heister, S. D.**, and **Collicott, S. H.**, "Three-Dimensional Flow Simulations in the Recessed Region of a Coaxial Injector," *Journal of Propulsion and Power,* Vol. 21, No. 4, July-August 2005, pp. 728-742.

Chen, Y., and **Collicott, S. H.**, "Experimental Study on the Capillary Flow in a Vane-Wall Gap Geometry," *AIAA Journal,* Vol. 43, No. 11, November, 2005, pp. 2395-2403.

Conference Proceedings, Presentations, Invited Lectures

Collicott, S. H., "Zero-Gravity Liquid-Vapor Interface Solutions and Stability in Circular Cylinders," *43rd AIAA Aerospace Sciences Meeting,* AIAA paper 2005-1147, Reno, NV, January 2005.

Collicott, S. H., invited presenter and panelist, *8th Annual Federal Aviation Administration Commercial Space Transportation Conference*, Washington, D. C., February 10-11, 2005.

ANASTASIOS S. LYRINTZIS
1994
Professor

Degrees

Diploma, National Technical University, Athens Greece, Mechanical Engineering, 1981
M.S., Cornell University, Aerospace Engineering, 1985
Ph.D., Cornell University, Aerospace Engineering, 1988

Interests

Computational Aeroacoustics
Aerodynamics for rotorcraft and jet flows

Awards and Major Appointments

AHS (American Helicopter Society), Acoustics Committee
AIAA Aeroacoustics, Technical Committee; Awards Subcommittee (Chairman 96-97)
ASME: coordinating group for CFD
Associate Fellow AIAA

Research Areas

Dr. Lyrintzis' current research interests can be divided mainly into three areas:

a. The Use of Integral Techniques in Computational Aeroacoustics

Dr. Lyrintzis has made significant contributions in the use of integral techniques Computational Aeroacoustics (CAA). CAA is concerned with the prediction of the aerodynamic sound source and the transmission of the generated sound starting from the time-dependent governing equations. The goal is to improve the state-of-the-art predictive techniques, so that aircraft and rotorcraft noise can be reduced. Dr. Lyrintzis has pioneered the use of integral techniques, (i.e. the Kirchhoff method and the porous Ffowcs Williams Hawkings [FWH] equation) for describing noise propagation. The methods are attractive because they utilize surface integrals (over a source region) to determine far-field acoustics, as opposed to the memory intensive volume integrals found in traditional acoustic analogy methods. Dr. Lyrintzis' research has demonstrated that a simple set of versatile portable Kirchhoff/Acoustic Analogy subroutines can be developed to analyze and reduce noise generation in a number of applications including fans, propellers, air-conditioning units etc. This work has been funded by NASA Langley Research Center, NASA Glenn Research Center, Sikorsky Aircraft Company and the Indiana 21st Research and Technology Fund, and the Aeroacoustics Research Consortium.

b. Aircraft Jet and Fan Noise for Supersonic Business Jet Engines (with Professor Blaisdell)

Operating behind a supersonic inlet the fan of an SSBJ engine will experience flow distortion characteristics quite different to those of a conventional turbofan installation. The effect of large inflow distortions will be addressed using a nonlinear CFD methodology. The study will investigate fan noise issues, including how inlet distortion may affect buzz saw noise from the fan, i.e. tones at multiples of fan rotation produced by non-uniform leading edge shock spacing on the fan leading edge. We are using the BASS code currently being developed at NASA Glenn as part of the QAT (Quiet Aircraft Technology) program. The code has been designed for aeroacoustic applications and has several high-order schemes.

The noise emissions of nozzles with internal mixers and ejectors employing geometry and conditions used for the new Rolls-Royce engine of the proposed supersonic business jet is being studied. The main objectives are to examine the effects of forced mixer and ejector design on the noise generation mechanisms, and to develop novel noise attenuation concepts. In our previous studies (in collaboration with Rolls-Royce and ISVR researchers), the noise from internal mixers was investigated based on a RANS approach coupled with semi-empirical models (i.e., the two-source model). We have analyzed experimental results obtained at NASA Glenn. We have also developed a high-order LES code for jet noise prediction and integral acoustics techniques for the computation of the noise signal. We are studying the flow with mixers and ejectors. The ejector will add additional dipolar noise sources; thus the existing two-source model will be extended to a multi-source model to capture the emissions from various nozzle components. This project is being funded by Rolls-Royce.

c. Shock Boundary Layer Interactions Modeling Enhancements (with Professor G. Blaisdell)

The purpose of this study is to evaluate current turbulence models and to test new turbulence modeling ideas for shock boundary layer interactions using the OVERFLOW code. The OVERFLOW code will be used because it is currently the dominant computational fluid dynamics (CFD) tool for Space Shuttle ascent aerodynamics and it is being considered for future use in aerothermal analyses. We are evaluating the standard turbulence models currently available within OVERFLOW to determine their performance on a variety of high-speed boundary layer flows by comparing results with experimental data. We will then determine the behavior of modifications to the near wall scaling and added compressibility corrections. The test cases to be considered will include simple boundary layer flows, shock-boundary layer interactions, and the Space Shuttle during ascent. This work has been funded by NASA Johnson Space Center.

Conference Proceedings, Presentations, Invited Lectures

Garrison L., **Lyrintzis A. S., Blaisdell, G. A.,** and Dalton, W., "Computational Fluid Dynamics Analysis of Flows with Internal Forced Mixers," AIAA paper 2005-2887 presented at the *11th AIAA/CEAS Aeroacoustics Conference*, Monterey, CA, May 2005.

Lew, P., **Blaisdell G. A.,** and **Lyrintzis, A. S**., "Recent Progress on Hot Jet Aeroacoustics Using 3-D Large Eddy Simulation," AIAA paper 2005-3084 presented at the *11th AIAA/CEAS Aeroacoustics Conference*, Monterey, CA, May 2005.

Tester, B., Fisher M., Garrison, L., **Lyrintzis, A. S.,** and **Blaisdell, G. A.,** “Understanding and Prediction of Lobed Mixer Noise,” Ohio Aerospace Institute (Aeroacoustics Research Consortium) Final Report, August 2005.

STEVEN P. SCHNEIDER
1989
Professor

Degrees

B. S., California Institute of Technology, Engineering & Applied Science, with Honors, 1981
M. S., California Institute of Technology, Aeronautics, 1984
Ph.D., California Institute of Technology, Aeronautics, 1989

Interests

Laminar-turbulent transition at hypersonic and supersonic speeds
Experimental fluid mechanics

Research Areas

High-speed laminar-turbulent transition is critical for applications including scramjet-powered cruise vehicles, gliding and ballistic re-entry vehicles, supersonic transports, and some types of interceptor missiles. Unfortunately, nearly all existing high-speed experimental results are contaminated by facility noise, such as that radiating from the turbulent boundary layers normally present on the test-section walls of supersonic and hypersonic tunnels. Just as at low speeds, reliable experimental progress requires low-turbulence wind tunnels with noise levels comparable to those in flight.

Sponsored Research Summaries

Quiet supersonic tunnels with low noise levels comparable to flight were developed at NASA Langley during the 1970's and 1980's to address problems such as laminar-turbulent transition that are strongly affected by noise level. Detailed measurements of the mechanisms of transition are needed, under low noise conditions, in order to develop computational models that are based on the correct flow physics. To perform these measurements, quiet Ludwieg tubes have been developed at Purdue, for operation at Mach 4 and Mach 6.

The Boeing/AFOSR Mach-6 Quiet Tunnel at Purdue is the only hypersonic quiet tunnel presently in operation. Quiet flow operation to a unit Reynolds number of 3.5 million per foot has been demonstrated in the 9.5-inch diameter nozzle. Modern digital and optical instrumentation enables efficient use of the 7-second run-time, and the short duration keeps operating costs low. Measurements are made on various models using hot wires, temperature-sensitive paints, high-sensitivity laser differential interferometry, high-frequency pressure transducers, and arrays of surface hot films. Instability waves can be generated in a controlled manner using a glow-discharge perturber at the model surface or using a laser-induced hot spot in the freestream.

Publications

Matsumura, S., **Schneider, S. P.**, and Berry, S. A., "Streamwise-Vortex Instability and Transition on the Hyper-2000 Scramjet Forebody," *Journal Spacecraft and Rockets*, Vol. 42, No. 1, January-February 2005, pp. 78–89.

Lyttle, I. J., Reed, H. L., Shipyluk, A. N., Maslov, A. A., Buntin, D. A., Burov, E. V., and **Schneider, S. P.**, "Numerical-Experimental Comparisons of Second-Mode Behavior for Blunted Cones," *AIAA Journal*, Vol. 43, No. 8, August 2005, pp. 1734–1743.

Conference Proceedings, Presentations and Invited Lectures

Taskinoglu, E., Knight, D. D., and **Schneider, S. P.,** "A Numerical Analysis for the Bleed-Slot Design of Purdue Mach-6 Wind Tunnel," AIAA paper 2005-0901, presented at the *Aerospace Sciences Meeting*, Reno, Nevada, January 2005.

Schneider, S. P., Skoch, C., Rufer, S., Swanson, E., and Borg, M. P., "Laminar-Turbulent Transition Research in the Boeing/AFOSR Mach-6 Quiet Tunnel," AIAA paper 2005-0888, presented at the *AIAA Aerospace Sciences Meeting*, Reno, Nevada, January 2005.

Schneider, S. P., "Laminar-Turbulent Transition on Reentry Capsules and Planetary Probes," AIAA paper 2005-4763, presented at the A*IAA Fluid Dynamics Meeting*, Toronto, Ontario, Canada. June 2005.

Skoch, C. R., and **Schneider, S. P.**, "Disturbances from Shock/Boundary Layer Interactions Affecting Upstream Hypersonic Flow," AIAA paper 2005-4897, presented at the *AIAA Fluid Dynamics Meeting*, Toronto, Ontario, Canada, June 2005.

Robarge, T. W., and **Schneider, S. P.**, "Laminar Boundary-layer Instabilities on Hypersonic Cones: Computations for Benchmark Experiments," AIAA paper 2005-5024, presented at the *AIAA Fluid Dynamics Meeting*, Toronto, Ontario, Canada, June 2005.

Rufer, S. J., and **Schneider, S. P.**, "Hot-wire Measurements of Instability Waves on a Blunt Cone at Mach 6," AIAA paper 2005-5137, presented at the *AIAA Fluid Dynamics Meeting*, Toronto, Ontario, Canada, June 2005.

Schneider, S. P., invited speaker, *Workshop on Hypersonics: Requirements, Current Capabilities, and Future Research Directions*, organized by AFOSR and the University of Minnesota, September 14-15, 2005.

JOHN P. SULLIVAN
1975
Professor

Degrees

B. S., University of Rochester, Mechanical & Aerospace Sciences (with honors), 1967

M. S., Massachusetts Institute of Technology, Aeronautical Engineering, 1969

Sc.D., Massachusetts Institute of Technology, Aeronautical Engineering, 1973

Interests

Experimental aerodynamics

Laser instrumentation

Luminescent sensors for temperature and pressure measurements

Research Areas

Current research interest is in the area of experimental aerodynamics with particular emphasis on comparison of experimental data with computational analysis. Current programs include:

1. High lift systems
2. Suction/blowing airfoils

In addition to the above programs, work also continues on developing laser instrumentation (laser Doppler velocimeter, particle image velocimeter, laser sheet concentration, etc.) and pressure and temperature paint for:

1. Wind tunnels - low speed to hypersonic
2. Gas turbine engines
3. Flight tests

Conference Proceedings, Presentations and Invited Lectures

Gregory, J. W, Gnanamanickam, E. P, **Sullivan, J. P.**, and Raghu, S, "Variable-Frequency Fluidic Oscillator Driven by Piezoelectric Devices,"AIAA paper 2005-0108, *43rd AIAA Aerospace Sciences Meeting*, Reno, NV, 2005.

MARC H. WILLIAMS
1981
Professor and Associate Head

Degrees

B. S., University of Pittsburgh, Aeronautical Engineering,
magna cum laude, 1969
M. A., Princeton University, Aerospace & Mechanical Sciences, 1971
Ph.D., Princeton University, Aerospace & Mechanical Sciences, 1975

Interests

Aerodynamics
Computational fluid Mechanics

Research Areas

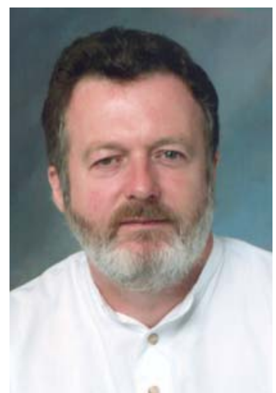
The determination of aeroelastic stability and forced response characteristics of flight vehicles requires methods for predicting the unsteady aerodynamic loads that are induced by structural deformation and/or free stream disturbances. Current research is directed at developing such methods for transonic flight and for rotating machinery.

Much of this work has been done for advanced propfan applications. These engines are intended for use on medium range commercial transports, which operate at low transonic Mach numbers. In order to maintain high operating efficiency and low noise, the blades are very thin and flexible. Therefore, they are subject to substantial static and dynamic deformations which alter the aerodynamic loads on the blades. Computational methods have been developed to predict these loads, both for single and counter rotating systems. Flutter boundaries and forced vibration amplitudes have been successfully predicted for a variety of current propfan designs. The most successful schemes developed so far have been based on linearized aerodynamic models. Work is under way on including nonlinear transonic effects through three-dimensional potential formulation with moving grids.

DYNAMICS AND CONTROL

Faculty Members

D. Andrisani II, Associate Professor, Ph.D., SUNY at Buffalo, 1979, estimation, control, and dynamics



M. J. Corless, Professor, Ph.D., Berkeley, 1984, dynamics, systems, and control

D. DeLaurentis, Assistant Professor, Ph.D., Georgia Institute of Technology, 1998, design methods, and aerospace systems and flight vehicles

A. E. Frazho, Professor, Ph.D., Michigan, 1977, control systems

J. L. Garrison, Associate Professor, Ph.D., University of Colorado, 1997, satellite navigation, GPS, and remote sensing

K. C. Howell, Hsu Lo Professor of Aeronautical and Astronautical Engineering, Ph.D., Stanford, 1983, orbit mechanics, spacecraft dynamics, control, and trajectory optimization

I. Hwang, Ph.D., Stanford, 2004, hybrid systems/nonlinear systems, applications to air traffic control

J. M. Longuski, Professor, Ph.D., Michigan, 1979, spacecraft dynamics, orbit mechanics, control, orbit decay, and reentry

M. A. Rotea, Professor, Ph.D., Minnesota 1990, robust and nonlinear multivariable control, optimization, and system identification

DOMINICK ANDRISANI II
1980
Associate Professor

Degrees

B. S., Rensselaer Polytechnic Institute, Aeronautical Engineering, 1970
M. S., State University of New York at Buffalo, Electrical Engineering, 1975
Ph.D., State University of New York at Buffalo, Electrical Engineering, 1979

Interests

Estimation
Control
Dynamics
Flight Aircraft Flying Qualities

Research Areas

Extensive experience in experimental methods in the study of vehicle dynamics and control has focused teaching and research on practical and important aerospace problems in four areas. First is the area of estimation theory, where new estimation algorithms have been developed using the partitioning approach. The second area involves the application of estimation theory to aerospace problems. Here estimation theory has been used to develop a new class of target trackers. These trackers incorporate knowledge of the aerodynamic and thrust vectors to help improve the trackers ability to estimate target acceleration. The third area involves research towards the development of design specifications for helicopter flight control systems, i.e., helicopter flying qualities. The fourth area involves analysis and detection of pilot-in-the-loop oscillations.

Conference Proceedings, Presentations, Invited Lectures

Krozel, J., and **Andrisani II, D.**, "Intent Inference and Strategic Path Prediction," AIAA Paper # 2005-6450, *AIAA Guidance, Navigation, and Control Conference and Exhibit*, Aug. 15-18, 2005, San Francisco, California.

Krozel, J., and **Andrisani II, D.**, "Independent ADS-B Verification and Validation," AIAA Paper # 2005-7351, *AIAA 5th ATIO and 16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences*, Sept. 26-28, 2005, Arlington, Virginia.

MARTIN CORLESS
1984
Professor

Degrees

B. E., University College, Dublin, Ireland, Mechanical Engineering, (1st honors), 1977

Ph.D., University of California, Berkeley, Mechanical Engineering, 1984

Interests

Dynamics
Systems
Control

Research Areas

Most of the research is concerned with obtaining tools, which are useful in the analysis and control of systems containing significant uncertainty. These uncertainties are characterized deterministically, rather than stochastically. The systems treated can be linear or nonlinear and continuous-time or discrete-time. The major application of the research is in the analysis and control of aerospace and mechanical systems. In these applications, some of the research focuses on the effect of flexible elements.

Publications

Bengea, S., DeCarlo, R., **Corless, M.**, and Rizzoni, G., “A Polytopic System Approach for the Hybrid Control of a Diesel Engine Using VGT/EGR," *ASME Journal of Dynamic Systems, Measurement and Control*, Vol. 127, No. 1, 2005, pp. 13-21.

Corless, M., “Discussion on Uniform Parametric Convergence in the Adaptive Control of Mechanical Systems," *European Journal of Control*, Vol. 11, No. 2, 2005, pp. 104-107.

Conference Proceedings, Presentations, Invited Lectures and Reports

Ackimese, A. B., and **Corless, M. J.**, “Observers for Systems with Non-linearities Satisfying an Incremental Quadratic Inequality," *2005 American Control Conference*, Portland, Oregon, 2005.

Corless, M., “Stabilization in the Presence of Actuator Lower Bounds," *13th International Workshop on Dynamics & Control, DaimlerChrysler Training Center*, Wiesensteig, Germany, 2005.

DANIEL DELAURENTIS
2004
Assistant Professor

Degrees

B.S., Aerospace Engineering, Florida Institute of Technology, Melbourne, FL, June 1992.

M.S., Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA, August 1993.

Ph.D., Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA, December, 1998.

Research Interests

Design Methods:

1. Mathematical modeling and object-oriented frameworks for the design of system-of-systems, especially those for which air vehicles are a main element (transportation and mobility networks, uninhabited air vehicle networks, etc.)
2. Approaches for robust design, including robust control analogies and uncertainty modeling/management in multidisciplinary design

Aerospace Systems and Flight Vehicles:

3. Sizing/Synthesis algorithms for design & performance estimation of revolutionary flight vehicles
4. Exploration of Personal Air Vehicle designs and concept of operations
5. Aircraft flight stability and control, especially as an integral part of conceptual design

Conference Proceedings, Presentations, Invited Lectures and Reports

DeLaurentis, D., "Understanding Transportation as a System-of-Systems Design Problem," AIAA paper 2005-0123, *43rd AIAA Aerospace Sciences Meeting and Exhibit*, Reno, Nevada, January 10-13, 2005.

DeLaurentis, D., "System-of-Systems Panel," *CEIAT 1st International Conference on Innovation and Integration in Aerospace Sciences*, Belfast, Northern Ireland, August, 2005. **(invited panelist)**

ARTHUR E. FRAZHO
Professor
1980

Degrees

B.S.E., The University of Michigan, Ann Arbor, Computer Engineering, 1973

M.S.E., The University of Michigan, Ann Arbor, Computer Information and Control Engineering, 1974

Ph.D., The University of Michigan, Ann Arbor, Computer Information and Control Engineering, 1977

Interests

Control systems

Research Areas

This research develops and applies operator theory to problems in deterministic and stochastic control systems. These techniques are used to design models for both linear and nonlinear control systems. We also obtain fast recursive algorithms for computing reduced order models. This also yields a theory of H^{∞} controller reduction and pole placement with applications to large space structure control. Finally, these techniques are used to solve problems in signal processing and inverse scattering theory.

Publications

Yagci, B., **Frazho, A. E.**, and Sumali, H., "Determining the Extension of a Hydraulic Cylinder using Spectral Estimation," *Journal of Sound and Vibration*, Vol. 279, 2005, pp. 487-496.

Biswas, A., Foias, C., and **Frazho, A. E.**, "An Intertwining Property of Positive Toeplitz Operators," *Journal of Operator Theory*, Vol. 54, No. 2, 2005, pp. 301-322.

JAMES L. GARRISON
Associate Professor
2000

Degrees

B.S. Rensselaer Polytechnic Institute, Troy, NY, Aeronautical Engineering, 1988
M.S. Stanford University, Stanford, CA, Aeronautics and Astronautics 1990
Ph.D. The University of Colorado, Aerospace Engineering Sciences, 1997

Interests

Satellite navigation
GPS
Remote sensing

Awards and Major Appointments

Institute of Navigation, Early Achievement Award, June 2002.

Publications

Thompson, D. R., Elfouhaily, T. M., and **Garrison, J. L.**, "An Improved Geometrical Optics Model for Bistatic GPS Scattering from the Ocean Surface," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 43, No. 12, December 2005.

Conference Proceedings, Presentations, Invited Lectures

Garrison, J. L., and Liang, L., "Numerical Simulation of GNSS Code Tracking Loops Using the Euler-Maruyama Method," *Electronics Letters*, Vol. 41, No. 15, July 21, 2005

Garrison, J. L., Heckler, G., Smajlovic, D. and Katzberg, S. J., "Airborne Ocean Wind Measurements from Reflected GPS Signals," presented at the *GNSS Reflection Workshop 2005,* The University of Surrey, Guildford, UK, June 9-10, 2005.

You, H., and **Garrison, J. L.**, "A Stochastic Model for the GNSS-R Signal from the Ocean Surface" presented at the *GNSS Reflection Workshop 2005,* The University of Surrey, Guildford, UK, June 9-10, 2005.

Garrison, J. L., and Liang, L."Numerical Simulation of GNSS Code Tracking Loops Using the Euler-Maruyama Method," *Electronics Letters,* July 21, 2005, Vol. 41, No. 15.

KATHLEEN C. HOWELL
1982
Hsu Lo Professor of Aeronautical & Astronautical Engineering

Degrees

B. S., Iowa State University, Aerospace Engineering, 1973
M. S., Stanford University, Aeronautical & Astronautical Engineering, 1977
Ph.D., Stanford University, Aeronautical & Astronautical Sciences, 1983

Interests

Orbit mechanics
Spacecraft dynamics, control
Trajectory optimization

Research Areas

In the area of astrodynamics, the complex missions envisioned in the next few decades will demand innovative spacecraft trajectory concepts and efficient design tools for analysis and implementation. In support of such plans, current research efforts focus on spacecraft navigation and maneuver requirements, and mission planning, both in the neighborhood of the Earth and in interplanetary space. Some sample projects are mentioned below.

Much recent research activity has involved libration point orbits in the three- and four-body problems. The *n*-body problem in orbital mechanics generally considers trajectory solutions when (*n*-1) gravity fields are significant. Spacecraft in the vicinity of libration points thus operate in an environment in which gravity forces due to two or three (or more) celestial bodies may result in trajectories that appear as three-dimensional, quasi-periodic Lissajous paths. Such three-dimensional trajectories are of considerable interest in connection with any future lunar operations. In the near term, missions involving libration point satellites are included in a number of programs that the U. S. is planning with international partners. Technical studies involve trajectory design and optimization including optimal control strategies for out-of-plane motion in consideration of communication and other operational specifications. Analyses of station-keeping requirements for such trajectories are also currently under study.

The subject of optimal transfer trajectories is of considerable importance and rapidly growing in complexity as well. New types of problems now facing mission designers render standard optimization strategies inadequate, particularly for application in the *n*-body problem. Nominal transfer trajectory determination and optimization is the focus of an expanding investigation. Various projects range from development of new computational techniques to application of geometric nonlinear dynamical systems theory to these problems.

A related problem of interest involves Earth orbiting vehicles that repeatedly pass close to the Moon. Such trajectories use lunar gravity to effect trajectory changes. Not only can such a swingby aid in minimizing mission fuel requirements, it also creates trajectory options that may otherwise be impossible. Analysis is complicated, however, by the strong solar perturbation. Multi-conic analysis has proven promising and work is continuing to develop tools to make optimal trajectory design efficient and accurate. Design strategies can also be extended to other multi-body systems. Such applications are under considerations as well.

Publications

Howell, K.C., and Marchand. B. G., "Natural and Non-Natural Spacecraft Formations Near the L_1 and L_2 Libration Points in the Sun-Earth/Moon Ephemeris System," *Dynamical Systems: an International Journal,* Special Issue: "Dynamical Systems in Dynamical Astronomy and Space Mission Design," Vol. 20, No. 1, March 2005, pp. 149-173. (Invited)

Howell, K. C., and Marchand, B. G., "Control Strategies for Formation Flight in the Vicinity of a Libration Point Orbit," *Journal of Guidance, Control, and Dynamics,* Vol. 28, No. 6, November-December 2005, pp. 1210-1219.

Conference Proceedings, Presentations, Invited Lectures

Marchand, B. G., **Howell, K. C.**, and Betts, J. T., "Discrete Optimal Control for S/C Formation Keeping Near the Libration Points," *AAS/AIAA Astrodynamics Conference*, Lake Tahoe, California, August 2005.

Howell, K. C., and Kakoi, M., "Transfers between the Earth-Moon and Sun-Earth Systems Using Manifolds and Transit Orbits," paper IAC-05-C1.6.01, *IAF 56th International Astronautical Congress*, Kukuoka, Japan, October 2005.

Howell, K. C., *2004 Brouwer Award Invited Lecture*, "Theory of Orbits: Epicycles to Chaos," *AAS/AIAA Spaceflight Mechanics Meeting,* Copper Mountain, Colorado, January 24, 2005.

Howell, K. C., "Spacecraft Mission Design within the Context of High Performance Computing and Visualization," SuperComputing/05, *International Conference for High Performance Computing Networking and Storage*, Seattle, Washington, November 2005.

Crassidis, J., Junkins, J. L., Markley, L., and **Howell, K. C.**, Proceedings, "The Malcolm Shuster Symposium," Vol. 106, *Advances in the Astronautical Sciences,* The State University of New York at Buffalo, Buffalo, New York, June 12-16, 2005.

D'Amario, L., Hoots, F., **Howell, K. C.**, and Williams, B., "*Proceedings of the 2005* AAS/AIAA Astrodynamics Specialist Conference, Vol. 103, *Advances in the Astronautical Sciences*, Lake Tahoe, California, August 2005.

INSEOK HWANG
2004
Assistant Professor

Degrees

B. S. - Department of Aerospace Engineering, Seoul National University, Seoul, Korea, February 1992.

M. S. - Department of Aerospace Engineering, Korea Advanced Institute of Science and Technology (KAIST), Taejeon, Korea, February 1994.

Ph.D. - Department of Aeronautics and Astronautics, Stanford University, January 8, 2004

Research Interests

Hybrid Systems/Nonlinear Systems
Applications to Air Traffic Control
Other applications

Book Chapter

Hwang, I., Stipanovic, D.M., and Tomlin, C., Polytopic Approximations of Researchable Sets applied to Linear Dynamic Games and to a Class of Nonlinear Systems, *Birkhauser,* 2005.

Conference Proceedings, Presentations, Invited Lectures and Reports

Yepes, J. L., **Hwang, I.,** and **Rotea, M.,** "An Intent-Based Trajectory Prediction Algorithm for Air Traffic Control", In the *Proceedings of the AIAA Guidance, Navigation, and Control Conference,* San Francisco, CA, August 2005.

Oh, S., **Hwang, I.,** Roy, K., and Sastry, S., "A Fully Automated Distributed Multiple-Target Tracking and Identity Management Algorithm", In the *Proceedings of the AIAA Guidance, Navigation, and Control Conference*, San Francisco, CA, August 2005.

Yepes, J. L., **Hwang, I.,** and **Rotea, M.,** Pilot's Intent Inference and Aircraft Trajectory Prediction with Applications to Air Traffic Control, *Proceedings of the UKC Aerospace Science and Technology Symposium*, Irvine, CA, August 2005

Hwang, I., Control in Information Rich World: Application to Air Traffic Control, *Korea Aerospace Research Institute (KARI),* Taejon, Korea, August 2005.

Hwang, I., Control in Information Rich World: Application to Air Traffic Control, *Division of Aerospace Engineering in the School of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST)*, Taejon, Korea, August 2005.

Hwang, I., Control in Information Rich World: Application to Air Traffic Control, *School of Mechanical and Aerospace Engineering, Seoul National University,* Seoul, Korea, July 2005.

JAMES M. LONGUSKI
1988
Professor

Degrees

B.S.E., The University of Michigan, Aerospace Engineering, cum laude, 1973
M.S.E., The University of Michigan, Aerospace Engineering, 1975
Ph.D., The University of Michigan, Aerospace Engineering, 1979

Interests

Spacecraft Dynamics
Orbit Mechanics
Control
Orbit decay and reentry

Awards and Major Appointments

NOVA (Notable Organizational Value-Added) Award from Jet Propulsion Laboratory

Research Areas

Current research efforts include 1) analytic theory and control of spinning-up and thrusting vehicles, 2) mission design and trajectory design for interplanetary flight, 3) orbit decay and reentry problems, and 4) tethers in space.

In 1) the current goal is to develop a general analytic theory (which provides solutions for angular velocity, the attitude, the angular momentum vector and the translational velocity of rigid and elastic bodies subject to arbitrary body-fixed torques and forces) and to develop control laws based on the analytic theory.

In 2) mission design tools developed at the Jet Propulsion Laboratory have been acquired for research use at Purdue. Both theoretical and computational techniques are being employed to analyze the gravity-assist problem in terms of identifying potential trajectories (such as the Voyager Grand Tour, the Galileo VEEGA, and the Europa Orbiter Tour) and optimizing the launch energy and propellant requirements for these missions.

In 3) analytic solutions have been obtained for the probability of immediate reentry and of orbit decay, as well as escape, in the event of misdirected interplanetary injection maneuvers occurring at low earth orbit. The solutions have relevance to safety issues involving nuclear power plants aboard deep space probes.

In 4) the feasibility of using tethers for aerobraking has been demonstrated. The basic idea is to connect an orbiter and a probe together by a long tether, for missions to planets with atmospheres. The probe enters the atmosphere and is used to reduce the hyperbolic speed of the orbiter to capture speed, thus eliminating the large retro maneuver normally required. New issues being addressed include analysis of the flexible tether, tether guidance and control, and spacecraft (endpoint) attitude control.

Publications

Landau, D. F., **Longuski, J. M.**, and Penzo, P. A., “Method for Parking-Orbit Reorientation for Human Missions to Mars,” *Journal of Spacecraft and Rockets*, Vol. 42, No. 3, May-June 2005, pp. 517–522.

Park, R. S., Scheeres, D. J., Giampieri, G., **Longuski, J. M.**, and Fischbach, E., “Estimating Parameterized Post-Newtonian Parameters from Spacecraft Radiometric Tracking Data,” *Journal of Spacecraft and Rockets*, Vol. 42, No. 3, May-June 2005, pp. 559–568.

McConaghy, T. T, Russell, R. P., and **Longuski, J. M.**, “Towards a Standard Nomenclature for Earth–Mars Cycler Trajectories,” *Journal of Spacecraft and Rockets*, Vol. 42, No. 4, July-August, 2005, pp.

Jokic, M. D. and **Longuski, J. M.**, “Artificial Gravity and Abort Scenarios via Tethers for Human Missions to Mars,” *Journal of Spacecraft and Rockets*, Vol. 42, No. 5, September-October 2005, pp. 883–889.

Chen, K. J., McConaghy, T. T., Landau, D. F., **Longuski, J. M.**, and Aldrin, B., “Powered Earth-Mars Cycler with Three-Synodic-Period Repeat Time,” *Journal of Spacecraft and Rockets*, Vol. 42, No. 5, September-October 2005, pp. 921–927.

Longuski, J. M., Gick, R. A., Ayoubi, M. A., and Randall, L., “Analytical Solutions for Thrusting, Spinning Spacecraft Subject to Constant Forces,” *Journal of Guidance, Control, and Dynamics*, Vol. 28, No. 6, pp. 1301-1308.

MARIO A. ROTEA
1990
Professor

Degrees

Electronic Engineering Degree, Universidad Nacional de Rosario, Argentina, 1983
M.S.E.E., University of Minnesota, Electrical Engineering, 1988
Ph.D., University of Minnesota, Control Science & Dynamical Systems, 1990

Interests

Algorithms for estimation and control under uncertainty
Algorithms for large-scale optimization and on-line optimization
Modeling, optimization, and control of mechanical and aerospace systems

Awards and Major Appointments

NSF Young Investigator Award
Center for Satellite Engineering, Co-Director

Publications

Lana, C., **Rotea, M. A.,** and Viassolo, D., "Robust Estimation Algorithm for Spectral Neugebauer Models," *Journal of Electronic Imaging, SPIE*, Vol. 14, No. 1, pp. 1-10, 2005.

D'Amato, F.J. and **Rotea, M. A.**, "LFTB: An Efficient Algorithm to Bound Linear Fractional Transformations," *Optimization and Engineering, Springer*, Vol. 6, No. 2, pp. 177-201, 2005.

Li, Y., **Rotea, M. A.**, Chiu, G., Mongeau, L., and Paek, I., "Extremum Seeking Control of Tunable Thermoacoustic Cooler," *IEEE Transactions on Control Systems Technology*, Vol. 13, No. 4, pp. 527-536, 2005.

Kothandaraman, G. and **Rotea, M. A.**, "SPSA Algorithm for Parachute Parameter Estimation," *AIAA Journal of Aircraft*, Vol. 42, No. 5, pp. 1229-1235, 2005.

Conference Proceedings, Presentations, Invited Lectures

Yepes, J. L., Hwang, I., and **Rotea, M. A.**, AIAA-2005-5824: "An Intent-Based Trajectory Prediction Algorithm for Air Traffic Control," *AIAA Guidance, Navigation, and Control Conference and Exhibit*, San Francisco, CA, 2005.

Yepes, J. L., **Hwang, I.,** and **Rotea, M.,** Pilot's Intent Inference and Aircraft Trajectory Prediction with Applications to Air Traffic Control, *Proceedings of the UKC Aerospace Science and Technology Symposium*, Irvine, CA, August 2005.

Rotea, M. A., and C. Lana, "State Estimation with Probability Constraints," *44th IEEE Conference on Decision and Control and European Control Conference*, Seville, Spain, 2005.

Rotea, M. A., "Changes and Opportunities in Dynamic Systems and Controls at NSF," Dynamic Systems and Controls Division of the ASME, Spring 2005 Newsletter.

Rotea, M. A., "Funding Opportunities in Mechatronics," Panel on Grand Challenges of Advanced Intelligent Mechatronics, *Advanced Intelligent Mechatronics*, Monterey, CA, 2005.

Rotea, M. A., IMECE2005-83017: "Funding opportunities in Control Systems," *ASME International Mechanical Engineering Congress and Exposition*, Orlando, FL, 2005.

PROPULSION

Faculty & Staff Member

W. E. Anderson, Assistant Professor, Ph.D., 1996, Pennsylvania State University, combustor design, combustion stability, atomization,& combined cycle propulsion

S. D. Heister, Professor, UCLA, 1988, rocket propulsion& liquid propellant injection systems

J. P. Gore,(by courtesy) Vincent P. Reilly Professor in Mechanical Engineering, Ph.D., 1986; Pennsylvania State University, 1986, Combustion, turbulent reacting flows & pollutant reduction, radiation heat transfer, biomedical heat transfer & fluid flows

I. Hrbud, Assistant Professor; Ph.D., Auburn University, 1997; Electric propulsion, space power, advanced in-space propulsion

C. L. Merkle, joint appointment with Mechanical Engineering, Reilly Professor of Engineering, Ph.D., Princeton Univ., 1969; Computational fluid dynamics & mechanics, two phase flows, propulsion components and systems

S. Meyer, Senior Engineer, MSAE 1991, Purdue Univ.

WILLIAM E. ANDERSON
2001
Assistant Professor

Degrees

B. S., Arizona State Univ., Chemistry, 1979
M. S., Univ. of Arizona, Chemical Engrg., 1984
Ph.D., The Pennsylvania State University, Mechanical Engrg., 1996

Interests

Combustor design
Combustion stability
Atomization
Combined cycle propulsion

Sponsored Research Summaries

Rocket Combustor Design – The a priori analysis of rocket combustor performance, heat transfer, and life are difficult because the extreme environments of the combustor make direct measurements and prediction difficult. Improved methodologies for preliminary injector design analysis and combustor life prediction are being developed using subscale approaches combined with relatively simple analysis. The injector design projects emphasize measurements in representative high-pressure rocket combustors (>1000 psia) and concurrent determination of one-dimensional energy release profiles. The life prediction work looks to develop innovative subscale test approaches for life cycle testing, including the acquisition of validation data for thermostructural models, life data on advanced materials in prototypical combustor configurations, identification of failure modes, and definition of long-life design concepts. This work is sponsored by NASA Marshall Space Flight Center.

Rocket-Based Combined Cycle Combustors – Combined cycle systems offer potential cost and performance benefits over all-rocket systems, yet they present design challenges due to added system complexities. Work is underway to develop a prototype thruster that will be used in a flight experiment to develop an operational baseline for future flight tests of RBCC systems. This work is sponsored by NASA Dryden Flight Center.

Non-Toxic Propellants – It is imperative to find safe replacements for highly toxic storable propellants. Before new propellant combinations can be used, reliable design databases must be developed. Experimental combustion data are being generated for hydrogen peroxide and dimethylethylamidoazide, two propellants that are significantly less toxic than storable propellants currently in use. The experiments include both realistic combustor conditions and geometries and measurements of propellant drop vaporization and chemical reaction in optically accessible chambers. Work is also underway to develop improved field test methods for the determination of the stability margin of hydrogen peroxide. Sponsors include NASA Marshall Space Flight Center and Stennis Space Center, and the Army Space and Missile Defense Command.

Publications

Sisco, J. C., Mok, J.-S., and **Anderson, W. E.,** "Autoignition of Kerosene by Decomposed Hydrogen Peroxide in a Dump Combustor Configuration," *Journal of Propulsion and Power*, Vol. 21, No. 3, 2005, pp. 450-459.

Austin, B.L., **Heister, S. D.**, and **Anderson, W. E.**, "Characterization of Pintle Engine Performance for Nontoxic Hypergolic Bipropellants," *Journal of Propulsion and Power*, Vol. 21, No 4, 2005, pp. 627-635.

Mok, J.-S., Helms, J.W., Sisco, J.C., and **Anderson, W. E.**, "On the Thermal Decomposition of Hydrogen Peroxide, Part I: Experimental Results," *Journal of Propulsion and Power*, Vol. 21, No. 5, 2005, pp. 942-953.

Conference Proceedings, Presentations, Invited Lectures

Miller, K., Sisco, J., Nugent, N., and **Anderson, W. E.**, "Experimental Study of Combustion Instabilities in a Single-Element Coaxial Swirl Injector," Paper 2005-4298, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Tucson, Arizona, July 10-13, 2005.

Jos, C., **Anderson, W. E.**, Sankaran, V., and Gujarathi, A., "Ducted Rocket Tests with a Fuel Rich Primary Thruster," paper no. 2005-4282, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-13, 2005, Tucson, AZ.

Sung, I. and **Anderson, W. E**., "A Subscale-Based Rocket Combustor Life Prediction Methodology," Paper 2005-3570, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-13, 2005, Tucson, AZ.

Pourpoint, T. and **Anderson, W. E.**, "Environmental Effects on Hypergolic Ignition," Paper 2005-3581, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-13, 2005, Tucson, AZ.

Wennerberg, J., **Anderson, W. E.**, Haberlen, P., Jung, H., **Merkle, C.**, "Supercritical Flows in High Aspect Ratio Cooling Channels," Paper 2005-4302, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-13, 2005, Tucson, AZ.

Ellis, M., Xia, G., Sankaran, V., **Anderson, W. E.**, and **Merkle, C.**, "Acoustic Mode Simulations in Experimental Rocket Combustors," Paper 2005-4300, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-13, 2005, Tucson, AZ.

Pourpoint, T. L., and **Anderson, W. E**., "Hypergolic Ignition of Catalytically Promoted Fuels with Rocket Hydrogen Peroxide," European Conference for Aerospace Sciences (EUCASS), July 4-7, 2005, Moscow, RUSSIA.

Sung, I.-K., and **Anderson, W.E.**, "Test and Evaluation of Rocket Combustor Life Prediction Methodologies," European Conference for Aerospace Sciences (EUCASS), July 4-7, 2005, Moscow, RUSSIA.

Wennerberg, J., Jung, H., **Anderson, W. E.**, and **Merkle, C.**, "Experiments and Computations of Heated Supercritical Flows in High Aspect Ratio Cooling Channels," 53rd JANNAF Propulsion Meeting, Dec, 5-8, 2005, Monterey, CA.

JAY P. GORE
2006 (by courtesy)
Vincent P. Reilly Professor in Mechanical Engineering

Degrees
Ph.D., Penn State, 1986
M.S., Penn State, 1982
B.E., University of Poona, 1978

Interests
- Combustion, Turbulent reacting flows and pollutant reduction
- Radiation Heat Transfer
- Biomedical heat transfer and fluid flows

Other Information
Dr. Jay P. Gore is the interim Director of the Energy Center in Discovery Park and the Associate Dean of Engineering for Research and Entrepreneurship in the College of Engineering. He is also the Vincent P. Reilly Professor in Mechanical Engineering. He served as a Research Fellow in Aerospace Engineering at the University of Michigan and as an Assistant Professor of Mechanical Engineering at the University of Maryland prior to joining Purdue as an Associate Professor. Dr. Gore received early promotions to the rank of Professor of Mechanical Engineering and to the Chair Professorship. Jay is a past Chairman of the Central States Section of the International Combustion Institute and the ASME K11 Committee on Heat Transfer in Fire and Combustion. He has served as an Associate Editor of the ASME Journal of Heat Transfer. He was the U.S. Editor of the 28th International Combustion Symposium. Dr. Gore currently serves as an Associate Editor of the AIAA Journal. He has received the Best Paper in Heat Transfer Literature Award from ASME and a Presidential Young Investigator Award. He has also received Faculty Fellowships from the Japanese Ministry of Education and the U. S. Department of Energy.

Jay's research is in the area of combustion and radiation heat transfer with applications to pollutant reduction, efficiency enhancements, fire safety, and improved fundamental understanding. He has received over $10M in research funding and is currently serving as the PI for grants over $1M in gas turbine combustion and radiation heat transfer applications. He is applying infrared radiation sensing knowledge to a wide range of problems including Bio Heat Transfer, Food Science, and Optical Biopsy in collaboration with a large group of multidisciplinary scientists and physicians. He has authored or coauthored over 100 archival papers, 4 book chapters, and 175 conference papers. Jay has developed/revised 2 courses (Combustion and Advanced Combustion) at Purdue University and three courses in heat transfer and thermodynamics at the University of Maryland.

STEPHEN D. HEISTER
1990
Professor

Degrees

B.S.E., The University of Michigan, Aerospace Engineering, 1981
M.S.E., The University of Michigan, Aerospace Engineering, 1983
Ph.D., University of California at Los Angeles, Aerospace Engineering, 1988

Interests

Rocket propulsion
Liquid propellant injection systems
Two-phase and capillary flows

Sponsored Research Summaries

1. Atomization modeling - Under **AFOSR** sponsorship, a number of atomization models have been developed to study the unsteady evolution of liquid jets and droplets. These simulations utilize boundary element methods to provide high-resolution of very large surface distortions and atomization processes. In fact, a number of the models can carry out calculations beyond atomization events. Currently, we are developing a more comprehensive model to treat the entire spray formed by a high-speed injection process. This model incorporates detailed drop dynamics including collisions and secondary atomization of droplets in the spray. Current models track upwards of 2,000,000 droplets simultaneously in a parallel-processing approach.

2. Rocket Combustion Experiments - This effort involves the use of the Purdue University Rocket Propulsion and Power Lab (PURPPL); a facility housed at the Maurice Zucrow Labs. Lab scale motors have been fired to assess basic combustion phenomena in hybrid rockets. Over 100 firings of a hydrogen peroxide/polyethylene propellant combination have been conducted during the past four years. Due to the high level of interest in the clean burning, safe handling aspects of hydrogen peroxide, numerous other opportunities are being investigated for potential application in the PURPPL facility. These efforts are heavily coupled with Professor Rusek's present research group.

3. Diesel Engine Injector Modeling - This project, funded by **Cummins Engine Company**, **NSF**, and **ARO** is aimed at developing computational tools for use in simulating internal flows in diesel injector passageways. Due to the high injection pressures, cavitation is a crucial feature, which must be incorporated in the modeling. To this end, we have developed a new cavitation treatment capable of addressing hydrodynamic nonequilibrium effects in a fully viscous calculation. Two-dimensional simulations have been compared to experimental measurements from Professor Collicott's research group with favorable results. A full 3-D model has recently been

developed making use of advanced parallel processing schemes in a LINUX computing environment. The model shows complex unsteady flow behavior under cavitating conditions. Presently, a turbulence model is being incorporated in the 2-D codes.

Publications

Corpening, J. H., **Heister, S. D,** and **Anderson, W.A.**, “On the Thermal Decomposition of Hydrogen Peroxide, Part II: Modeling Results,” *Journal Propulsion and Power*, 2005

Shimo, M., Canino, J. V., and **Heister, S. D.**, “Modeling Oil Flows in Engine Sumps: Seal Runners and Engine Wall Films,” *Intl. J. of Gas Turbine Research*, Vol. 127, 2005, pp. 827-834.

Austin, B., **Heister, S. D.,** and **Anderson, W. A.**, “Development of Pintle and Splashplate Injectors for Nontoxic, Storable, Hypergolic Bipropellants,” *J. Propulsion and Power*, Vol. 21, No. 4, 2005, pp. 627-635.

Kim, B-D, and **Heister, S. D.**, “Three Dimensional Flow Simulations in Recessed Region of a Coaxial Injector,” *J. Propulsion and Power*, Vol. 21, No. 4, 2005, pp. 728-742.

Conference Proceedings, Presentations, Invited Lectures

Park, H., and **Heister, S. D.**, “A Numerical Analysis for Flow Characteristics in a Swirl Injector,” *ILASS Americas 18th Annual Conference*, 2005

Canino, J., **Heister, S. D.**, Sankaran, V., Zakharov, S., "Unsteady Response of Recessed-Post Coaxial Injectors," 4*1st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*, Tucson, Arizona, July 13-15, 2005.

Austin, B. L., **Heister, S. D.**, **Meyer, S. E.,** and **Anderson, W. A.**, “Torch-ignited Hydrogen Peroxide/Kerosene Thrust Chamber for Liquid Target Booster,” 40th JANNAF Combustion Meeting, Charleston, SC, 2005.

Tsohas, J., and **Heister, S. D.**, “Altitude Compensation using Combustible Nozzle Liners,” *53rd JANNAF Propulsion Meeting*, Monterey, California, 2005.

IVANA HRBUD
2003
Assistant Professor

Degrees

M.S. (Diplom Ingineur), Stuttgart Univ., Germany, Aerospace Engineering, 1993
Ph.D, Auburn University, Aerospace Engineering, 1997

Interests

Electric and Advanced Space Propulsion
Power Systems
Nuclear/Electric Propulsion Spacecraft Concepts

Research Summaries

1. RF Plasma Thruster Experiments – To ease the impact of severe constraints on power, mass, volume and lifetime of small-satellite propulsion system, the RF plasma thruster concept considers capacitive RF discharge between co-axial electrodes. Operating conditions of this concept are dictated by mass flow rate, electrode separation, RF frequency and power input. To investigate this concept's propulsive capability and plasma characteristics, two laboratory-scale test articles have been designed and built. Both devices have been operated with various propellants in DC and RF power modes. A torsional thrust stand was designed, which is currently undergoing calibration and validation.
2. RF Plasma Thruster Modeling – A preliminary effort involved an analytical study incorporating generalized 1-d flow theory and plasma dynamics. The goal of this study is to assess the thruster's propulsive characteristics as a function of mass flow rate, electrode separation, RF frequency and power input.
3. Coil Geometries for Inductively Coupled Plasmas – The main objective of this research is to explore new geometries for a pulsed inductive plasma accelerator by which it can take advantage of innovative powertrain concepts and propellant injection. In general, inductively-coupled thrusters are appealing for high-power electric propulsion applications due to the electrodeless nature of the acceleration process. In addition, this concept operates with a wide variety of propellants, and provides variable specific impulse by varying propellant flow rate into the coupling area. A preliminary study involves Faraday's Law to calculate induced azimuthal electric field for a given geometry and current waveform. Then an RLC circuit analysis is conducted to assess the behavior of the system.

Conference Proceedings, Presentations, Invited Lectures and Reports

Corpening, J.,and **Hrbud, I**., "Preliminary Design and Analysis of the Purdue University Pulsed Inductive Thruster of PuPIT," *42nd AIAA Joint Propulsion Conference*, Sacramento, CA, July 2006.

Corpening, J., and **Hrbud, I**., "Analytical and Experimental Determination of Magnetic Field Strength in Various Current Carrying Coil Geometries," *Space Technology and Applications International Forum (STAIF),* Albuquerque, NM, February 2006.

CHARLES L. MERKLE
2003
Reilly Professor of Engineering

Degrees

B.S., Case Institute of Technology, Engineering Science, 1962
M.S., Rensselaer Polytechnic Institute, Mechanical Engineering, 1966
Ph.D., Princeton University, Aerospace & Mechanical Sciences, 1969

Interests

Computational fluid dynamics and mechanics
Two phase flows
Propulsion components and systems

Publications

Li, D., Keefer, D., Rhodes, R. Kolokolnikov, K., **Merkle, C. L.**, Thibodeaux, R., "Analysis of Magnetohydrodynamic Generator Power Generation," *Journal of Propulsion and Power*, Vol. 21, No. 3, March, 2005, pp. 424-432.

Conference Proceedings, Presentations, Invited Lectures and Reports

Moeller, T., Keefer, D., Rhodes, R., Rooney, D., Li, D., and **Merkle, C. L.**, "Comparison of Experimental and Computational Simulations Results of a Pulsed Plasma Accelerator," IEPC paper 2005-008, *International Electric Propulsion Conference*, Nov. 2005.

Merkle, C. L., "A Gibb's Function Formulation for Computations of General and Multi-Phase Fluids," *Proceedings of Twelfth National Conference on Computational Fluid Dynamics*, Kaohsiung, Taiwan, R.O.C., August 19-21, 2005.

Wennerberg, J., **Anderson, W. E., Heister, S., Meyer, S.,** Jung, H. and **Merkle, C. L.**, "Supercritical Flows in High Aspect Ratio Cooling Channels," AIAA paper 2005-4302, *41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference*, Tucson, AZ, July 10-13, 2005.

Ellis, M., Xia, G., Sankaran, V., **Anderson, W.** and **Merkle, C. L.**, "Acoustic Mode Simulations in Experimental Rocket Combustors," AIAA paper 2005-4300, *41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*, Tucson, AZ, July 10-13, 2005.

Li, D., Xia, G., and **Merkle, C. L.**, "Large-Scale Multidisciplinary Computational Physics Simulations using Parallel Multi-physics Zone Methods," *Proceedings of International Conference on Parallel Computational Fluid Dynamics*, University of Maryland, MD, May 24-27, 2005.

Li, D., Xia, G., and **Merkle, C. L.**, “Parallel Multi-Zone Methods for Large-Scale Multidisciplinary Computational Physics Simulations,” *Proceedings of Linux Clusters: The HPC Revolution 2005 Conference*, Chapel Hill, NC, April 26-28, 2005.

Xia, G., Li, D., and **Merkle, C. L.**, “Modeling of Pulsed Detonation Tubes in Turbine Systems,” AIAA paper 2005-0225, *43rd AIAA Aerospace Sciences Meeting and Exhibit,* Reno, NV, January 10-13, 2005.

Li, D., Sankaran, V. Lindau, J. W., and **Merkle, C. L.**, *‘Computational Formulation for Multi-Phase and Multi-Component Flows,’* AIAA paper 2005-1391, *43rd AIAA Aerospace Sciences Meeting and Exhibit*, Reno, NV, Jan. 10-13, 2005.

SCOTT MEYER
2001
Sr. Engineer

Degrees

B.S.A.A.E., Purdue University, School of Aeronautics & Astronautics, 1990
M.S.A.A.E., Purdue University, School of Aeronautics & Astronautics, 1992

Scott Meyer is a Senior Propulsion Engineer at Purdue University for the Departments of Mechanical Engineering and Aeronautics and Astronautics. He joined the Purdue staff in 2001 to direct propulsion testing operations and to develop the test facilities for the Indiana Propulsion and Power Center of Excellence.

From 1998 to 2001, Mr. Meyer worked at Beal Aerospace in Frisco, Texas as a senior propulsion engineer. In this role, he defined test programs to support the development of the BA2-C launch vehicle stages and rocket engines. He wrote test plans and coordinated test planning with the engine test facilities including mechanical and fluid system interfaces and instrumentation and control requirements. He directed the procurement, manufacture, and assembly activities for the construction of rocket engines and wrote engine assembly and catalyst preparation procedures. He directed testing operations, wrote test procedures, supervised the installation of test hardware, defined requirements for and performed system calibrations, and performed rocket engine tests. Following testing he wrote test and analysis reports and was responsible for the validation and analysis of test data including engine and stage performance and data reduction methodologies.

From 1993 to 1998 Mr. Meyer worked at Arnold Engineering Development Center in Tullahoma, Tennessee as a project engineer in the Propulsion Wind Tunnel Facility. There he directed multi-million dollar propulsion integration wind tunnel tests for contractors on the F-22 and F/A-18 fighter aircraft and the X-33 SSTO launch vehicle. As such his responsibilities included providing instrumentation specifications and hardware design requirements, managing testing operations, and performing project cost estimation and fiscal management.

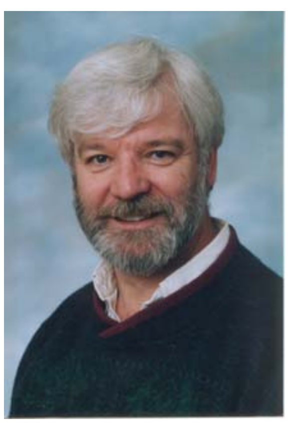
Mr. Meyer is a co-patent holder for a hybrid rocket engine ignition device.

STRUCTURES AND MATERIALS

Faculty Members

W. Chen, joint appointment in MSE, Professor, Ph.D., California Institute of Technology, 1995, experimental solid and structural mechanics

W. A. Crossley, Associate Professor, Ph.D., Arizona State, 1995, optimization, rotorcraft and aircraft design, and structure design



J. F. Doyle, Professor, Ph.D., Illinois, 1977, structural dynamics, experimental mechanics, photomechanics, and wave propagation

T. N. Farris, Professor and Head, Ph.D., Northwestern, 1986, tribology, manufacturing processes, fatigue and fracture

A. F. Grandt, Jr., Professor, Ph.D., Illinois, 1971, damage-tolerant structures and materials, fatigue and fracture, and aging aircraft

P. K. Imbrie, Associate Professor, Engineering, Education, Ph.D., Texas A&M, 2000, educational research, solid mechanics, experimental mechanics, and nonlinear materials characterization

H. Kim, Assistant Professor, Ph.D., University of California-Santa Barbara, 1998, composites, impact, stability, and adhesive joining

R. B. Pipes, joint appointment in Chem. Engrg. and MSE, John L. Bray Distinguished Professor of Engineering; Ph.D., Univ. of Texas, 1972, application of nanotechnology to engineering disciplines including aerospace, composite materials and polymer science and engineering

C. T. Sun, Neil A. Armstrong Distinguished Professor; Ph.D., Northwestern, 1967, composites, fracture and fatigue, and structural dynamics

Terrence A. Weisshaar, Professor, Ph.D., Stanford, 1971, aircraft structural mechanics, aeroelasticity, integrated design

WEINONG WAYNE CHEN
2005
Professor

Degrees

B.S., Beijing University of Aeronautics and Astronautics, Beijing China, Aircraft Structure Design, 1982

M.S., Beijing University of Aeronautics and Astronautics, Aircraft System Engineering, Beijing China, 1985

Ph.D., California Institute of Technology, Aeronautics, minor in Materials Science, 1995

Interests

Experimental Solid and Structural Mechanics
Mechanical Response of Solids at High Strain Rates
Fatigue Behavior of Engineering Materials
Microstructural Effects on Mechanical Behavior
Dynamic Response of Advanced Materials

Awards and Major Appointments

Fellow, American Society of Mechanical Engineers 2005
University Faculty Scholar, Purdue University 2005

Research Areas

Dr. Chen's research activities mainly involve the development of novel dynamic material characterization techniques and the determination of dynamic responses of engineering materials at high loading rates. He built dynamic material characterization laboratories at California Institute of Technology, University of Arizona, and Purdue University. He also assisted the development of such laboratories at Sandia National Laboratories in Albuquerque, NM and Livermore, CA; Army Research Laboratory in Aberdeen Proving Ground, MD; U.S. Army Waterway Experiment Station in Vicksburg, MS; National Institute of Standard and Technology in Gaithersburg MD; and a number of university and industrial laboratories. The techniques he developed are focused on ensuring valid testing conditions during dynamic experiments to obtain accurate material properties at high rates of loading. These techniques, summarized in over 15 journal articles, have been well accepted in the research community. Two of top five, four of top ten "most cited papers of Experimental Mechanics" are from Dr. Chen's group.

Using the novel techniques, Dr. Chen and his students have obtained accurate and reliable material behavior at high rates for soft rubbers, glassy polymers, polymeric foams, gelatins, glass/epoxy composites, soy-bean based clay nanocomposites, biological tissues (muscles, skins, bones), shape memory alloys, high-strength steels, geomaterial, masonry materials, textile materials, and armor ceramics. For each class of the materials under dynamic tension, compression, or multiaxial compression, at various temperatures, his group examined the valid dynamic testing conditions to obtain valid experimental results. Microstructural characterization was carried on some of the materials. Based on the experimental results and microstructural observations, material constitutive models were developed to describe the recorded material behavior. Over forty journal articles have been published based on the results from these research programs.

The research accomplishments demonstrate that Dr. Chen has established himself with unique contributions in the field of experimental solid mechanics. He has developed an independent and well funded research program investigating the dynamic mechanical behavior of materials and the necessary experimental techniques, and has established a national and international reputation in his field.

Publications

Song, B., **Chen, W.**, Yanagita, T., and Frew, D. J., "Temperature Effects on the Dynamic Compressive and Failure Behaviors of An Epoxy Syntactic Foam," *Composite Structures*, Vol. 67, issue 3, 2005, pp. 289-298.

Song, B., **Chen, W.**, Yanagita, T., and Frew, D. J., "Confinement Effects on the Dynamic Compressive and Failure Behaviors of An Epoxy Syntactic Foam," *Composite Structures*, Vol. 67, issue 3, 2005, pp. 279-287.

Song, B., **Chen, W.**, Dou, S., Winfree, N. A., and Kang, J. H., "Strain-rate Effects on Elastic and Early Cell-collapse Responses of a Polystyrene Foam," *International Journal of Impact Engineering*, Vol. 31, No. 5, 2005, pp. 509-521.

Song, B., **Chen, W**., and Jiang, X., "Split Hopkinson Bar Testing of Polymeric Foams," *International Journal of Vehicle Design*, Vol. 37, Nos. 2-3, 2005, pp. 185-198.

Cheng, M., **Chen, W.**, and Weerasooriya, T., "Mechanical Properties of Kevlar® KM2 Single Fiber," *ASME Transactions, Journal of Materials Engineering and Technology*, Vol. 127, No. 2005, pp. 197-203.

Frew, D. J., Forrestal, M. J., and **Chen, W.**, "Pulse Shaping Techniques for Testing High-Strength Steel with a Split Hopkinson Pressure Bar," *Experimental Mechanics*, Vol. 45, No. 2, 2005, pp. 186-195.

Cheng, M. and **Chen, W.**, "Measurement and Determination of Dynamic Biaxial Flexural Strength of Thin Ceramic Substrates under High Stress-rate Loading," *International Journal of Mechanical Sciences*, Vol. 47, No. 8, 2005, pp. 1212-1223.

Cheng, M., **Chen, W**., and Jiang, J. P., "Micro Indentation Fracture Toughness Evaluation with a Novel Microscopy," *Journal of the American Ceramic Society*, Vol. 88 [6], 2005, pp. 1666-1668.

Song, B. and **Chen, W.,** "Split Hopkinson Bar Techniques for Characterizing Soft Materials," *Latin American Journal of Solids and Structures*, Vol. 2, 2005, pp. 113-152.

Pan, Y., **Chen, W.**, and Song, B., "The Upper Limit of Constant Strain Rates in a Split Hopkinson Pressure Bar Experiment with Elastic Specimens," *Experimental Mechanics*, Vol. 45 [5], 2005, pp. 440-446.

Conference Proceedings, Presentations, Invited Lectures

Weerasooriya, T., Moy, P., Casem, D., Cheng, M., and **Chen, W.**, "Determination of Dynamic Fracture Toughness for Brittle Materials with a Modified SHPB," *11th International Conference on Fracture,* Turin, Italy, 20-25 March 2005.

Chen, W. and Song, B., "Dynamic Compression Testing on Polymeric Foams," *SAE 2005 World Congress and Exhibition,* Detroit, Michigan, 11-14 April, 2005.

Moy, P., Weerasooriya, T., and **Chen, W.**, "Deformation and Failure Behavior of a Gelatin Under Different Strain Rates," *Society for Experimental Mechanics 2005 Annual Conference and Expositions on Experimental and Applied Mechanics,* Portland, Oregon, 7-9 June 2005.

Cheng, M. and **Chen, W.**, "Tensile Response of a Soft Tissue at High Loading Rates," *Society for Experimental Mechanics 2005 Annual Conference and Exposition on Experimental and Applied Mechanics,* Portland, Oregon, 7-9 June 2005.

Chen, W., Lu, W.-Y., and Song, B., "Compressive Response of Polymeric Foams at Low, Intermediate, and High Strain Rates," *ASME 2005 International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

Chen, W., and Luo, H., "Fragmentation Effects on the Dynamic Compressive Response of Ceramics," *ASME 2005 International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

Xu, L. R., Wang, P., and **Chen, W.**, "A Biologically Inspired Convex Joint for Dissimilar Materials," *ASME 2005 International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

Chen, W., "Dynamic Behavior of Materials--I," *Society for Experimental Mechanics 2005 Annual Conference and Exposition on Experimental and Applied Mechanics*," 7-9 Portland, Oregon, June 2005.

Chen, W., "Dynamic Behavior of Structures," *Society for Experimental Mechanics 2005 Annual Conference and Exposition on Experimental and Applied Mechanics,* Portland, Oregon, 7-9 June 2005.

Chen, W., "Failure of Multifunctional Materials," Society for Experimental Mechanics *2005 Annual Conference and Exposition on Experimental and Applied Mechanics*, 7-9 Portland, Oregon, June 2005.

Chen, W., "Dynamic Compressive Behaviors of Armor Ceramics Impacted by Consecutive Stress Pulses," *Shock Loading Symposium, Plasticity 2005: The Eleventh International Symposium on Plasticity and Its Current Applications*, Kauai, Hawaii, 3-9 January 2005.

Chen, W., "Modified Split-Hopkinson-Bar Experiments for High-Rate Response of Materials," Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 22, 2005

Chen, W., "Mechanical Behavior of a Zylon Fiber under Axial and Tranverse Loading Conditions," National Institute of Standard and Technology, Gaithersburg, Maryland, March 15, 2005.

Chen, W., "Determination of Mechanical Responses of Soft Biological Tissues at Intermediate Strain Rates with Modified Split Hopkinson Bars," General Motors R&D Center, Warren, Michigan, August 9, 2005.

Chen, W., "Effects of Radial Inertia on the Determination of Dynamic Response of Soft Tissues," U. S. Army Research Laboratory, Aberdeen Proving Ground, Maryland, August 16, 2005.

Chen, W., "Dynamic Composite Testing of Biological Materials," National Center for Agriculture Utilization Research, Peoria, Illinois, November 22, 2005.

WILLIAM A. CROSSLEY
1995
Associate Professor

Degrees

B.S.E. University of Michigan, Aerospace Engineering, 1990
M. S. Arizona State University, Aerospace Engineering, 1992
Ph.D. Arizona State University, Aerospace Engineering, 1995

Interests

Optimization
Rotorcraft and aircraft design
Structure design

Research Areas

Professor Crossley's major research interests are in the area of design methodologies and optimization, with emphasis on techniques like the GA that will allow optimization-like methods to be applied in the conceptual design phase, which traditionally has been dominated by qualitative or subjective decision making. Significant contributions have been made in applications to discrete actuator placement, topology design, and satellite constellation design.

Sponsored Research Summaries

Topology Design of Rotor Blades for Aerodynamic and Structural Concerns. This computational research effort strives to develop a rotor blade design strategy with the potential to improve the aerodynamic, structural, and dynamic performance of advanced rotorcraft. This work investigates the Genetic Algorithm (GA) as a means to combine aerodynamic and structural concerns for topology design of rotor blades. Inverse airfoil design and optimal airfoil design are receiving much attention in both industry and academia; the same holds true for structural optimization. The combination of the two concerns for topology design has not been fully addressed. A multi-disciplinary approach combining structural and aerodynamic concerns for optimal topology design of rotor blades provides potential benefit to the rotorcraft design process. The aerodynamic optimization portion of this research was cited in the technical research highlights of the NASA Ames Research Center, Rotor Aeromechanics Branch for 1999. Contributions in the structural portion of the research have demonstrated capabilities for discrete (on/off) topology; most notably handing connectivity issues and performing design of sections under combinations of bending and torsion that several authors had previously claimed were not possible.

Genetic Algorithm Issues for Optimal Smart Actuator Placement. This research is investigating approaches for smart actuator placement to provide aircraft maneuverability without requiring hinged flaps or other control surfaces. The effort supports many of the goals of the Multidisciplinary Design Optimization focus efforts in NASA's Aircraft

Morphing program. Computational studies are being conducted to allow comparison and selection of appropriate techniques for posing and solving an actuator placement problem. The work began with a geometrically simple wing model, but the approaches identified during this research have been applied to complete aircraft configurations. The problem statement and algorithm application are being used at NASA Langley by researchers working on the Aircraft Morphing Program. Research in this area has been cited twice as technical highlights for the NASA Langley Multidisciplinary Optimization Branch; once in 1998 and again in 1999.

Improved Satellite Constellation Design and Optimization. Improving satellite constellation design is of great interest to any users of satellite communication (e.g. cellular phones, television), location (e.g. global positioning system) and/or observation (e.g. weather). Many of today's satellite constellation designs rely on the "Walker Constellations," a series of designs developed in 1970, which have rarely been improved upon. These constellations make use of symmetric constellations with circular orbits. Using the genetic algorithm to search the constellation design space has begun to yield constellation designs not previously envisioned but with performance equal to or greater than comparable Walker or "streets of coverage" constellations. Research is ongoing for sparse coverage constellations, constellation build-up problems, multiobjective constellation concerns and elliptic orbit constellations. The Aerospace Corporation performs satellite constellation design for its US Air Force customers using the design techniques developed as part of this research. In one of these studies, a multiobjective GA approach was able to generate constellation designs that outperformed constellations that had been under development for several months. The GA was able to do this in a matter of days.

Development of a Genetic Algorithm for Conceptual Design of Aircraft. Air vehicle conceptual design appears to be a promising area for application of the genetic algorithm as an approach to help automate part of the design process. Because the GA-based approach to conceptual design helps to reduce the number of qualitative decisions needed from the design team, this appears to have great potential for application to aircraft design. Work has been extensively conducted for helicopters, some additional work has been conducted for high-speed VTOL rotorcraft (e.g. tilt-rotor and tilt-wing aircraft), and work is currently underway for fixed-wing aircraft. The Systems Analysis Branch at NASA Langley Research Center supports this research.

Methods to Assess Commercial Aircraft Technologies. Increasing competition in the commercial aircraft industry requires that airframe manufacturers be judicious with technology research and development efforts. Currently, technology development strategies for commercial aircraft appear to be lacking; this research presents a methodology to assess new technologies in terms of both cost and performance. This methodology encompasses technologies that can be applied to the aircraft design and technologies that improve the development, manufacturing, and testing of the aircraft. This differs from past studies that focused upon a small number of performance-based technologies. The method is divided into two phases. The first phase evaluates technologies based on cost measures alone. The second phase redesigns an aircraft with new technologies, assesses the relative importance of performance-based technologies, and recognizes technology interactions using Taguchi's Design of Experiments. For a wide-body transport aircraft example, the methodology identifies promising technologies for further study. Recommendations and conclusions about the methodology are made based on the results. This work was done in collaboration with the Configuration Engineering and Analysis group at Boeing Commercial Aircraft.

Response Surface Methods as Approximation Models for Optimization. Approximation techniques, particularly the use of response surfaces (RS), have achieved wide popularity in engineering design optimization, especially for problems with computationally expensive analyses. The chief aims of using RS is to lower the cost of optimization and to smooth out the problem (e.g., for analyses solved iteratively, with a convergence tolerance). In one part of this research effort, an investigation of RS methods to minimize drag of a turbofan nacelle is being pursued in conjunction with engineers at Allison Advanced Development Company. This approach can improve the nacelle design practices at AADC by providing a formalized optimization framework for this CFD-based design exercise. The use of RS raises practical questions about the solution accuracy and computational expense. In particular, building response surfaces may involve a prohibitively large number of high-fidelity function evaluations, depending on problem dimensionality. In another part of this research effort, a computational study to address questions of expense and accuracy was undertaken with researchers in the Multidisciplinary Optimization Branch at NASA Langley Research Center. Important observations about the impact of constructing and using response surfaces for moderately high-dimensional problems were made. NASA researchers are using the RS models constructed during this portion of the research to further investigate techniques to manage approximation models in engineering optimization.

Conference Proceedings, Presentations, Invited Lectures

Frommer, J., and **Crossley, W. A.**, "Enabling Continuous Optimization for Sizing Morphing Aircraft Concepts," AIAA paper 2005-0816, *43rd AIAA Aerospace Sciences Meeting and Exhibit*, Reno, Nevada, January 10-13, 2005.

Skillen, M., and **Crossley, W. A.**, "Developing Response Surface Based Wing Weight Equations for Conceptual Morphing Aircraft Sizing," AIAA paper 2005-1960, *46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and 13th AIAA/ASME/AHS Adaptive Structures Conference*, Austin, Texas, April 18-21, 2005.

Nusawardhana, and **Crossley, W. A.**, "Allocating Variable Resources over a Finite Time Horizon to Combine Aircraft Sizing and Airline Planning," AIAA paper 2005-7415, *AIAA 5th Aviation, Technology, Integration, and Operations Conference (ATIO)*, Crystal City, Virginia, September 26-28, 2005.

Mane, M., and **Crossley, W. A.**, "System of Systems Inspired Aircraft Sizing Applied to Commercial Aircraft/Airline Problems," AIAA paper 2005-7426, *AIAA 5th Aviation, Technology, Integration, and Operations Conference (ATIO)*, Crystal City, VA, September 26-28, 2005.

Habrel, C. and **Crossley, W. A**, "Creating Carpet Plots that Address Uncertainty for Aircraft Sizing," AIAA paper 2005-7427, *AIAA 5th Aviation, Technology, Integration, and Operations Conference (ATIO)*, Crystal City, Virginia, September 26-28, 2005.

Frommer, J. and **Crossley, W. A**, "Evaluating Morphing Aircraft in a Fleet Context Using Reliability and Non-Deterministic Approaches," AIAA paper 2005-7460, *AIAA 5th Aviation, Technology, Integration, and Operations Conference (ATIO)*, Crystal City, Virginia, September 26-28, 2005.

Crossley, W. A., "System of Systems Inspired Aircraft Sizing: some initial investigations," Conceptual Aircraft Design Working Group (CADWG) 21, Reno, NV, January 12, 2005

Crossley W. A., DeLaurentis, D. A., and Peeta, S., "Purdue University Efforts in System of Systems", invited presentation to the U.S. Air Force Scientific Advisory Board quick-look study of Systems of Systems, Arlington, Virginia, May 17, 2005.

Crossley, W. A., "Systems of Systems Inspired Approaches Applied to Combined Airline Allocation and Aircraft Sizing," invited presentation to the Math and Computational Technologies group, Boeing Phantom Works, Bellevue, Washington, July 26, 2005.

JAMES F. DOYLE
1977
Professor

Degrees

Dipl. Eng., Dublin Institute of Technology, Ireland, 1972
M.Sc., University of Saskatchewan, Canada, 1974
Ph.D., University of Illinois, 1977

Interests

Structural dynamics
Experimental Mechanics
Inverse Problems
Wave propagation

Research Areas

Wave Motion in Structures

Because of their size and low stiffness, large space structures are susceptible to wave motions due to transients. New, spectrally formulated, elements are being developed that are suitable for dynamic problems and have the following advantages:

Single elements can extend from joint to joint thus giving a remarkable reduction in the size of the system to be solved (with no loss of resolution).

Inverse problems can be solved conveniently, thus making it useful for experimental systems identification studies.

Experimentally characterized substructures (such as joints) may be easily incorporated in the modeling.

Spectral elements have already been developed for rods, beams and shafts, and their implementation in a general 3-D structural analysis computer program accomplished.

Impact and Damage of Structures

A very important aspect of structural performance is the ability to withstand impact and minimize the amount of damage caused. Impact had two effects on damage: (1) Generation if new damage near the impact site or at a stress concentrator. (2) Increased damage at pre-existing flaws caused by the propagated energy. Current investigations involve wave interactions with delamination flaws. This has direct application to damage in composite materials. Other aspects of the problem include:

FORCE IDENTIFICATION: from measurements made on the structure being able to determine the impact of force history.

REMOTE SENSING: from analysis of the reflected and transmitted waves being able to locate flaws and estimate their size.

LOCAL/GLOBAL ANALYSIS: separate the global structural dynamics from the local behavior near the flaw, thus leading to computational efficiencies. A novel layered spectral element has been developed for use with composite materials.

Whole Field Image Characterization

An alternative to strain gages and accelerometers in dynamic measurements is to use ultra-high speed photography coupled with such methods as photoelasticity; and moiré. The question being investigated is: Under what circumstances is a single (or a limited number) of photographs capable of completely characterizing the wave information? This touches on some fundamental aspects of transform theory coupled with measurement theory. The payoff is that photographs combined with digital imaging techniques offer unique possibilities for recording and post-processing the data. This is essentially an experimental problem because experimental data is always incomplete, so questions of quality of the data, the amount of data, etc. must be confronted, as well as the following aspects: (1) High-Speed photography and photoelasticity (2) Digital imaging techniques (3) 2-D Fast Fourier Transforms.

THOMAS N. FARRIS
1986
Professor and Head

Degrees

B. S., Rice University, Mechanical Engineering, cum laude, 1982
M. S., Northwestern University, Theoretical and Applied Mechanics, 1984
Ph.D., Northwestern University, Theoretical and Applied Mechanics, 1986

Interests

Tribology
Manufacturing processes
Fatigue and fracture

Awards and Major Appointments

General Chair of 42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Seattle WA, April 2001

Research Areas

In tribology, a major research effort is underway in the experimental and analytical characterization of fretting fatigue. The experimental work uses a unique fixture design that allows independent control of the applied clamping and tangential forces. Analytical work combines boundary and finite element analysis of the effect of forces, microslip, and geometry on subsurface stresses. Multiaxial fatigue theories are used to correlate these stresses with experimentally observed crack nucleation and fracture mechanics is used to predict growth of these cracks. The calculations have been used to predict the effect of fretting on multi-site damage nucleation and growth in the aging aircraft problem. The approach is being used to address fretting fatigue in jet engines as part of the Air Force High Cycle Fatigue initiative. Recent effort includes the capability to perform fretting fatigue experiments at high temperatures.

Manufacturing process research includes experimental and analytical work on grinding, turning, and super finishing of hardened steels and ceramics for precision components. The focus is on understanding the mechanics of the material removal process so that the effect of process parameters on component performance can be predicted. To this end, deformation induced during the controlled static and sliding microindentation is being studied. An example of the results of this research is a recently established relationship between grinding temperatures and near surface residual stress and microstructure of the ground component. A model of free abrasive machining that predicts statistical properties of the load/particle relationship has been developed. The model can be used to predict finished surface roughness. A new effort in the area of form generation in centerless grinding is underway. The use of high pressure fracture to produce smooth defect free ceramic surfaces is also being pursued.

Additional work in the area of manufacturing processes is directed at modeling of the heat treatment process. A commercial finite element package has been adapted to predict the microstructure, deformation, and stress induced by quenching and tempering of steel structures. The model includes the effects of latent heat and volumetric strains induced by phase changes. Industrial collaborators are providing requisite material properties as a function of temperature as well as assistance with experimental validation of the modeling.

Publications

Murthy, H., Garcia, D. B., Matlik, J. F. and **Farris, T. N.**, "Fretting Fatigue of Single Crystal/Polycrystalline Nickel Subjected to Blade/Disk Contact Loading," *Acta Astronautica*, **57**(1), pp 1-9 (2005).

Bartha, B. B., Zawadzki, J., Chandrasekar, S., and **Farris, T. N.**, "Wear Performance of Hard Turned AISI 52100 Steel," *Metallurgical and Materials Transactions A-Physical Metallurgy and Materials Science*, **36A**(6), pp 1417-1425 (2005).

Conference Proceedings, Presentations, Invited Lectures and Reports

Gean, M. and **Farris, T. N.**, "Finite Element Analysis of the Mechanics of Blade/Disk Contacts," AIAA 2005-1907 in *Proceedings of 46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*, Austin, TX, April 2005.

Murthy, H. and **Farris, T. N.**, "High Temperature Fretting Fatigue of Single Crystal Nickel," *Proceedings of the 10th National Turbine Engine High Cycle Fatigue (HCF) Conference*, New Orleans, LA, March 2005.

Farris, T. N., "Fretting Fatigue of Aerospace Structures," Northwestern University, January 2005

Farris, T. N., "Fretting Fatigue of Aerospace Structures," University of Illinois, February 2005.

Farris, T. N., "Fretting Fatigue of Aerospace Structures," Korean Advanced Institute of Science and Technology, Seoul, December 2005.

ALTEN F. GRANDT, JR.
1979
Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration

Degrees

B. S., University of Illinois at Urbana-Champaign, General Engineering, 1968

M. S., University of Illinois at Urbana-Champaign, Theoretical and Applied Mechanics, 1969

Ph.D., University of Illinois at Urbana-Champaign, Theoretical and Applied Mechanics, 1971

Interests

Damage-tolerant structures and materials

Fatigue and fracture

Aging aircraft

Nondestructive inspection

Research Areas

General technical interests deal with assuring the safe operation of aerospace and other complex structures through damage tolerance analyses and nondestructive inspection. Particular emphasis is on basic research to predict critical and subcritical crack growth under static and cyclic loads (i.e. fracture and fatigue). The influence of corrosion on structural integrity is also of interest. This research may be characterized by several overlapping categories.

Aging aircraft research is aimed at determining and/or extending the remaining life of structures that have seen extended periods of service, and focuses on determining the effect of multiple site damage on residual strength, and on evaluating the influence of corrosion on fatigue life.

Evaluation of new materials and manufacturing processes includes characterization of new materials in simple coupon or mechanical joint scenarios, analysis of fatigue resistant fastening systems, and evaluation of damage tolerant aspects of unitized construction. Research in this category also includes development of devices to monitor the severity of aircraft loading and has led to one patent.

Crack growth research is directed at predicting crack formation by fretting, corrosion, or cyclic loading, and as well as characterization of fatigue crack growth under complex variable amplitude and/or elevated temperature load histories.

Stress intensity factor analyses are aimed at obtaining solutions to evaluate complex two- and three-dimensional crack configurations common to aerospace structures (e.g. cracked fastener holes, dovetail joints, etc.).

Publications

Garcia, D. B., and **Grandt, Jr., A. F.**, "Fractographic Investigation Of Fretting Fatigue Cracks In Ti-6Al-4V," *Journal of Engineering Failure Analysis*, Vol. 12, No. 4, August 2005, pp. 537-548.

Conference Proceedings, Presentations, Invited Lectures and Reports

Grandt, Jr., A. F., Chiew, L. K., Park, C. Y., and Suh, J., "Experimental Measurements of Stress Intensity Factors for Cracks at Countersunk Holes," *8th Joint NASA/FAA/DoD Conference on Aging Aircraft*, 31 January – 3 February 2005, Palm Springs, CA.

Grandt, Jr., A. F., Rodrian, J. E., and Watkins, W. A., "Design Projects that Emphasize Technical Communication Between Engineering and Technology Students," *American Society for Engineering Education 2005 IL/IN Sectional Conference*, 1-2 April 2005, DeKalb, IL.

Grandt, Jr., A. F., "Fundamentals of Damage Tolerance Analysis and Applications," 30 hours of lecture, Advanced Technology Training, South Melbourne, Australia, 6 – 10 June 2005.

Grandt, Jr., A. F., "Fundamentals of Non-Destructive Evaluation, 18 hours of lecture, Advanced Technology Training, South Melbourne, Australia, 31 May – 2 June 2005.

PETER K. IMBRIE
Engineering Education
Associate Professor

Degrees

B.S.A.E., Texas A&M University, May 1980
M.S.A.E., Texas A&M University, May 1985
Ph.D., Texas A & M University, August 2000

Interests

Solid mechanics
Experimental mechanics
Nonlinear materials characterization
Microstructural evaluation of materials
Mechanics of composites
Engineering materials
Constitutive modeling
Experiment and instrument design
Educational research

Research Areas

Current research interests include, educational research, solid mechanics, experimental mechanics, nonlinear materials characterization, microstructural evaluation of materials, and experiment and instrument design. He has been involved with various research projects sponsored by NSF, NASA, and AFOSR, ranging from education related issues to traditional research topics in the areas of elevated temperature constitutive modeling of monolithic super alloys and environmental effects on titanium based metal matrix composites.

HYONNY KIM
2001
Assistant Professor

Degrees

B. S., University of California, Santa Barbara, Mechanical Engineering, 1993
M. S., Stanford University, Mechanical Engineering, 1994
Ph.D., University of California, Santa Barbara, Mechanical Engineering, 1998

Interests

Composites
Impact
Stability
Adhesive Joining

Research Areas

Adhesive Joining

Current research projects in adhesive joining are focused on (i) buckling stability driven disbonding of bonded composite structures, and (ii) developing nonlinear analysis techniques to predict failure in lap joints.

There exists features in high-performance structures of bonded composite construction that are of minimum gage thickness, or that rely on adhesive bonds to maintain structural stability. When these features develop partial disbonds, they become susceptible to buckling if compressive and/or shear loads are applied. Henceforth they are critical safety concerns, particularly if additional disbonding ensues. Conditions for which buckling initiates, and for which further disbond growth can occur are being investigated. Theoretical models have been developed to predict buckling initiation and the threshold for disbond growth. These models identify which are the critical parameters governing these phenomena. Sub-element level experiments of partially-disbonded splice-jointed sandwich panels are being used to validate the capabilities of these models, and to observe the interplay between buckling and disbond growth. This research addresses important safety issues related to the tolerance of bonded composite airframes to disbonds, particularly if these disbonds are not easily detected by pre-flight ground checks or basic maintenance inspections.

Theoretical models predicting the complex nonlinear behavior, and ultimately failure, of adhesively bonded joints are being developed. In order to predict failure, these models incorporate the highly nonlinear constitutive behavior of adhesives. A current focus is to understand the phenomena of plastic strain localization which develops in a highly concentrated zone at the outer overlap-ends of a bonded joint, near the interface between the adhesive and the adherend. These zones are where fracture initiates, and cracks propagating inwards from these zones ultimately result in failure of the joint.

Impact Simulation

A research project is underway investigating the numerical simulation of high-velocity hailstone impacts on composite structures. Hail ice ingestion in aero-engines is a realistic concern for engines having composite, as well as metallic, fan blades. A key component of this project is the material response of the ice projectile during the impact event: the ice transitions between an elastic-like solid into a fluid-like powder. A material model that accounts for various parameters, principally strain rate and hydrostatic pressure, on the rupture of ice projectiles is being developed based on available experimental data.

Publications

Kim, H., Kayir, T., and Mousseau, S. L, "Mechanisms of Damage Formation in Transversely Impacted Glass/Epoxy Bonded Lap Joints," *Journal of Composite Materials*, Vol. 39, No. 22, 2005, pp. 2039-2052.

Lee, J. and **Kim, H.**, "Analysis of a Single Lap Asymmetric Bonded Joint Under Tension and Eccentricity Moment," *Journal of Adhesion*, Vol. 81, No. 5, 2005, pp. 443-472.

Conference Proceedings, Presentations, Invited Lectures

Lee, J., and **Kim, H.**, "Stress Analysis of Composite Single Lap Joints under Combined Tension and In-Plane Shear Loading," *Proceedings of the Fifth Canadian-International Composites Conference*, August 16-19, 2005, Vancouver, CA.

Kwon, H., and **Kim, H.**, "Buckling and Debond Growth of Partial Debonds in Composite Splice Joints," *Proceedings of the* 20*th Annual ASC Technical Conference on Composite Materials*, September 7-9, 2005, Philadelphia, PA.

R. BYRON PIPES
1972
John L. Bray Distinguished Professor of Engineering

Degrees

B. S., Louisiana Polytechnic Institute, 1964
M. S., Princeton University, 1969
Ph.D., University of Texas at Arlington, 1972

Interests

Application of Nanotechnology to engineering disciplines including:
Aerospace
Composite materials and polymer science
Engineering

Research Areas

Dr. Pipes is a distinguished researcher, currently working on the application of nanotechnology to engineering disciplines including aerospace, composite materials and polymer science and engineering. He has active programs in the study of the advanced manufacturing science for composite materials. He is also engaged in the development of Internet-based collaborative research wherein scientific instruments are shared by research groups located in academic, corporate and government scientific centers worldwide.

Publications

Cano, C. I., Weiser, E. S., Kyu, T., and **Pipes, R. B.**, “Polyimide Foams from Powder: Experimental Analysis of Competitive Diffusion Phenomena”, Polymer, 46(22), (2005), pp. 9296-9303.

Chang, T. E., Jensen, L. R., Kisliuk, A., **Pipes, R. B.**, Pyrz, R., and Sokolov A. P., "Microscopic Mechanism of Reinforcement in Single-Wall Carbon Nanotube / Polypropylene Nanocomposite,", *Polymer*, Vol. 46, (2005), pp 439-444.

C. T. SUN
1968
Neil A. Armstrong Distinguished Professor
of Aeronautical & Astronautical Engineering

Degrees

B. S., National Taiwan University, Taiwan, Civil Engineering, 1962
M. S., Northwestern University, Theoretical & Applied Mechanics, 1965
Ph.D., Northwestern University, 1967

Interests

Composites
Fracture and Fatigue
Structural Dynamics
Smart Materials and Structures
Nano-structured Materials

Research Areas

Current research interests include the following areas:

Composite Materials and Structures – Advanced fiber composites have gained wide applications in aircraft and aerospace structures. Our research programs cover a broad spectrum in mechanics and design of various composite materials and structures. Research topics include developing methods for testing and modeling high strain rate and fracture behavior of polymeric composites, unconventional modeling of heterogeneous solids, exploring the use of nano particles in reinforcing composites, developing self-assembly methods for processing nanocomposites, improving methods for joining composite structures using adhesives, and developing multifunctional composite materials and structures.

Fracture Mechanics – Fracture mechanics is an important tool in analyzing failure in materials and structures. Our current research focuses on fracture of highly ductile metals and cohesive zone fracture modeling. We have successfully demonstrated that the crack tip opening angle (CTOA) as a crack growth criterion is independent of specimen size and can be used for predicting fracture failure in ductile materials. The CTOA approach is being investigated for use in predicting failure in metallic structures with widespread damage. Our effort in the subject of cohesive zone models is centered on the cohesive law: its physical meaning and conditions it must satisfy.

Smart Materials – The use of piezoelectric materials as actuators and sensors in adaptive structures demands these materials to perform under increasingly high electrical and mechanical loads. Durability and reliability of actuators have become important issues. Our current research aims at solving a number of fundamental problems involving cracks in piezoceramics subjected to combined electrical and mechanical loads.

Nanomaterials – Many nanostructured materials possess highly desired physical and mechanical properties and offer tremendous potentials in many applications. Our research is concentrated on developing multiscale modeling techniques for nanomaterials and their composites and on the use of molecular mechanics to study the behavior of nanomaterials including nancomposites.

Publications

Tsai, J. and **Sun, C. T**., "Strain Rate Effect on In-plane Shear Strength of Unidirectional Polymeric Composites," *Composite Science and Technology*, Vol. 65, 2005, pp. 1941–1947.

Kalyanam, S. and **Sun, C. T.**, "Modeling of Electrical Boundary Condition and Domain Switching in Piezoelectric Materials," *Mechanics of Materials*, Vol. 37, 2005, pp. 769–784.

Jin, Z.-H. and **Sun, C. T.**, "Cohesive Zone Modeling of Interface Fracture in Elastic Bi-Materials," *Engineering Fracture Mechanics*, Vol. 72, 2005, pp. 1805–1817.

Bing, Q. and **Sun, C. T.,** "Modeling and Testing Strain Rate Dependent Compressive Strength of Carbon/Epoxy Composite," *Composites Science and Technology*, Vol. 65, 2005, pp. 2481–2491.

Achuthan, A.. and **Sun, C. T.**, "Domain Switching in Ferroelectric Ceramic Materials under Combined Loads," J. Appl. Physics, Vol. 97, 2005, pp. 1114103.

Sun, C. T. and Jin, Z.-H., "Modeling of Composite Fracture Using Cohesive and Bridging Models," *Composites Science and Technology*, in press, 2005.

Huang, G. L. and **Sun, C. T.**, "The Dynamic Behaviour of a Piezoelectric Actuator Bonded to an Anisotropic Elastic Medium," *Int. J. Solids and Structures*, Vol. 43, 2006, pp. 1291–1307.

Jin, Z.-H. and **Sun, C. T.**, "A Comparison of Cohesive Zone Modeling and Classical Fracture Mechanics Based on Near Tip Stress Field," *Int. J. Solids and Structures*, Vol. 43, 2006, pp. 1047–1060.

Jin, Z.-H., and **Sun, C. T.**, "Cohesive Fracture Model Based on Necking," *Int. J. Fracture*, Vol. 134, 2005, pp. 91–108.

Conference Proceedings, Presentations, Invited Lectures

Jin, Z.-H. and **Sun, C. T.**, "Conditions on Cohesive Laws in Cohesive Zone Fracture Models," International Conference on Fracture, March 21-25, 2005, Turin, Italy.

Bing, Q. and **Sun, C. T**., "Determination of Composites Compressive and Shear Strengths Using Off-Axis Specimens," *46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, Austin, Texas, April 18-21, 2005.

Sun, C. T. and Huang, G., "A Method for Modeling Heterogeneous Media with Microstructures of Different Scales," *Computational Methods for Coupled Problems in Science and Engineering*, May 25-27, 2005, Santorini, Greece.

Huang, G. and **Sun, C. T.**, "Continuum Modeling of Heterogeneous Media with Microstructures and Nanostructures," 2005 *Mechanics and Materials Conference*, June 1-3, 2005, Baton Rouge, Louisiana.

Sun, C. T. and Jin, Z.-H., "A Comparison of Cohesive Zone Modeling and Continuum Fracture Mechanics," *2005 Mechanics and Materials Conference,* June 1-3, 2005, Baton Rouge, Louisiana.

Sun, C. T. and Wang, Z., "A Homogeneous Continuum Model with Micro-Inertia for Fiber Composites," *Int. Conference on Structural Stability and Dynamics*, June 20-22, 2005, Orlando, Florida.

Bing, Q. and **Sun, C. T.**, "Determination of Composites Compressive and Shear Strength Using Off-axis Specimens," *SEM Annual Conference and Exposition on Experimental and Applied Mechanics*, June 7-9, 2005, Portland, Oregon.

Sun, C. T. and Jin, Z.-H., "Cohesive Zone and Bridging Zone in Delamination Fracture," 5th Canadian-International Conference on Composite Materials, August 16-19, 2005,Vancouver, Canada.

Subramaniyan, A.K. and **Sun, C. T.**, "Toughening Polymeric Composites Using Nanoclay," 20*th* *Technical Conference, American Society for Composites*, Philadelphia, September 7-9, 2005.

Bing, Q. and **Sun, C. T.**, "Size Effect in Off-axis Compression Test of Fiber Composites," 20*th* *Technical Conference, American Society for Composites*, Philadelphia, September 7-9, 2005.

Merrill, M. and **Sun, C. T.**, "Development of a Self-Assembly Method for Manufacturing Nanocomposites with High Loadings of Nanoparticles," 20*th* *Technical Conference, American Society for Composites*, Philadelphia, September 7-9, 2005.

Park, J. S., **Sun, C.T .**, and Trumble, K. P., "Effect of Contiguity on the Mechanical Behavior of Co-continuous Ceramic Metal Composites," 20*th* *Technical Conference, American Society for Composites*, Philadelphia, September 7-9, 2005.

Adnan, A., **Sun, C. T.**, and Mahfuz, H., "Effect of Particle Size on Mechanical Properties of Polymer Nanocomposites," 20*th* *Technical Conference, American Society for Composites*, Philadelphia, September 7-9, 2005.

Cho, J. and **Sun, C. T.**, "A Molecular Dynamics Simulation Study of Particle Size Effect on Mechanical Properties of Polymeric Nanocomposites**,"** ASME International Mechanical Engineering Congress & Exposition, Orlando, Florida, November 6-11, 2005.

TERRENCE A.WEISSHAAR
1980
Professor

Degrees

B. S., Northwestern University, Mechanical Engineering, (highest distinction), 1965
M. S., Massachusetts Institute of Technology, Aeronautics & Astronautics, 1966
Ph.D., Stanford University, Aeronautics & Astronautics, 1971

Interests

Aircraft structural mechanics
Aeroelasticity
Integrated Design

Research Areas

Primary research areas include optimization of structural concepts for smart aeroelastic structures and efficient multidisciplinary design. Currently, two primary areas are of interest:

- *Aeroelastic tailoring and active flexible wings.* This includes using conventional articulated surfaces such as ailerons and leading edge devices for roll control, as well as using smart materials to change the camber of advanced wing concepts for aircraft control. Objectives also include aeroelastic design for reduced drag and optimization of smart wing flutter suppression systems for micro-air vehicles. We are also developing innovative techniques with advanced composite structure design to find optimal designs and reduce time to develop new concepts.

- *Design methodology – developing new methods and algorithms to improve the ability of a design team to generate innovative, creative concepts for aerospace vehicles.* This includes examining how the external aerodynamic and internal structural topology of lifting surfaces can be addressed simultaneously in the design process. This also includes introducing manufacturing concerns and decisions early in the design process and creating, through the early use of finite element models, more feed-forward/feed-back paths.

  We have been examining how to use new modeling software to generate and present accurate, useful information to designers by displaying load paths and theoretically optimal designs. This leads to an improved conceptual design process for airplane structures that begins with a few participants and quickly proceeds to a high level with diverse technical groups represented. We are involved in the creation of an object-oriented system, using Adaptive Modeling Language (AML), to provide a natural, integrated, virtual environment for modeling, linking and simulating the aircraft design process from its earliest conceptual phase into preliminary design. When completed, this system will allow an integrated product team access to a virtual environment that scientifically simulates the iterative, collaborative process required to design an airplane in a short amount of time.

ADJUNCT FACULTY

D.L. Filmer, Adjunct Professor of Aeronautics & Astronautics,Ph.D., Univ. of Wisconsin, 1961, satellite design, ground station design for acquisition satellite data

J. J. Rusek, Adjunct Assistant Professor, Ph.D., Case Western Reserve, 1983, experimental energy conversion and rocket propulsion

DAVID L. FILMER
2002
Adjunct Professor

Degrees

A.B., Youngstown University (Biology) 1954
M.S., University of Wisconsin (Bacteriology) 1958
Ph.D., University of Wisconsin (Biochemistry, Biophysics) 1961
Postdoctoral Studies, Brookhaven National Lab, 1961-65

Research Areas

- Digital signal processing
- Nonlinear dynamics and chaotic systems
- CubeSat design
- Software design for acquisition of satellite data
- LabView software applications

JOHN J. RUSEK
1998
Adjunct Assistant Professor

Degrees

B. S., Case Western Reserve University, Chemical Engineering, 1976
M. S., Case Western Reserve University, Chemical Engineering, 1981
Ph.D., Case Western Reserve University, Chemical Engineering, 1983

Interests

Energy Conversion
Chemical and Physical Propulsion
Power Generation

Awards and Major Appointments

- Who's Who in the World
- Who's Who in America

Research Areas

Current research is directed towards obtaining a fundamental understanding of hydrogen peroxide decomposition via heterogeneous and homogeneous catalysis for use in rocket propulsion and power generation. Major focus concerns the synthesis, characterization, and testing of these novel catalysts in rocket propulsion, turbine, and fuel cell applications. Areas of interest include the experimental and analytical understanding of catalytic reaction kinetics and thermodynamics.

Another major research direction is the fundamental understanding of aerospace materials, specifically in the safe containment of exotic propellant ingredients. International collaboration with government, academic and industrial research centers is playing an important part in this research.

ACTIVE RESEARCH PROJECTS

July 2005 to June 2006

RESEARCH AND OTHER SCHOLARLY ACTIVITIES

Between July 1, 2005 and June 30, 2006, approximately $6.8 million in external research expenditures were realized in the areas of Aerodynamics, Dynamics and Controls, Propulsion, and Structures and Materials. This represents a growth of more than 30%. Several faculty were recognized for research as is detailed in the "Faculty Highlights" section. The research expenditure for the 2005-2006 year was attributed to the following sources.

SOURCE OF SPONSORED RESEARCH FOR 2005-2006	
Source	**Percentage of Total**
Department of Energy	1.75
Department of Defense	39.62
NASA	24.12
National Science Foundation	8.69
FAA	1.21
Industry	14.66
Indiana 21st Century R & D	5.38
Other	4.57
Total	100.0%

SPONSORED RESEARCH PROJECTS
ACTIVE DURING THE PERIOD JULY 1, 2005 TO JUNE 30, 2006

Sponsor Name	Title	Project Start Date	Project End Date	Staff Award Amt	Staff Role	Staff Name
In Space, Llc	A Generalized Model For Combustion Instability	12/01/05	01/31/06	5691	PI	Anderson
National Aeronautics And Space Admin	Advanced Measurement Techniques For High Pressure Rocket Combustors	08/01/04	07/31/06	48000	PI	Anderson
In Space, Llc	Development Of A Combustion Response Model For Advanced Afterburners, Part Ii	01/01/06	08/31/06	17500	PI	Anderson
In Space, Llc	Innovative Ignition System For Non-Toxic Storable Propellants Phase 2 - Experimental Design	09/28/04	09/27/06	202900	PI	Anderson
Sierra Engineering Inc.	Optical Diagnostic Of Unstable Combustion	03/01/06	12/30/06	45000	PI	Anderson
Sierra Engineering Inc.	Pulsator Devices For Combustion Stability Assessment	10/01/04	12/31/05	80000	PI	Anderson
Sierra Engineering Inc.	Rocket Combustor Heat Transfer Measurements	01/21/05	01/23/06	45000	PI	Anderson
ATK Thiokol, Inc	Single-Phase Nozzle Flow With Contour Step-Down	04/14/05	01/30/06	45589 22794	PI CO-PI	Anderson Meyer
Sierra Engineering Inc.	Transpiration Cooled Chamber Tests	02/01/05	02/28/06	70000	PI	Anderson
Sierra Engineering Inc.	Transpiration Cooled Thrust Chamber Tests	02/28/06	04/24/06	12000	PI	Anderson
Sierra Engineering Inc.	Variable Length Combustion Stability Tests	10/01/04	09/30/06	35000 17500	PI CO-PI	Anderson Meyer
Metron Aviation Inc	Automatic Dependent Surveillance - Broadcast Verification And Validation	01/21/05	07/15/05	20000	PI	Andrisani
United Negro College Fund, Inc.	Gm Sullivan Faculty Fellowship	10/16/02	12/31/75	15000	PI	Andrisani
Rockwell Collins	Portable Data Acquisition And Control System	06/09/00	12/31/75	30000	PI	Andrisani
Rockwell Collins	Remotely Piloted Giant-Scale Aircraft	07/01/03	12/31/75	25000	PI	Andrisani
United Negro College Fund, Inc.	United Negro College Fund, Inc.	07/01/02	12/31/75	5000	PI	Andrisani

Lyndon B. Johnson Space Center	Heat Transfer Computations For Space Shuttle Applications	06/01/06	05/31/09	35767 35766	PI CO-PI	Blaisdell Lyrintzis
National Aeronautics And Space Admin	Turbulence Model Calculations Of Hypersonic Boundary Layer Flows Using The Overflow Code	08/20/04	09/30/06	93972 93970	PI CO-PI	Blaisdell Lyrintzis
Army Research Office	Ceramics Of Vehicle And Transparent Armor Under Compression And Compression Shear	07/01/05	06/30/07	220000	PI	Chen
Sandia National Laboratories	Controlled Shock Testing Of Fuse Components	03/27/06	10/31/06	16750	PI	Chen
General Electric Company	Determination Of Dynamic Delamination Fracture Toughness In Graphite-Epoxy Unidirectional Tape Composites	10/24/05	07/31/06	33500	PI	Chen
Sandia National Laboratories	Dynamic Behavior Of Porous Ceramics	12/01/05	09/30/06	10050	PI	Chen
Sandia National Laboratories	Dynamic Material And Structural Testing	12/17/04	09/30/05	95000	PI	Chen
Sandia National Laboratories	Dynamic Response Of Geo-Materials	12/01/05	09/30/06	33500	PI	Chen
University Of Washington	Dynamic Testing Of Shape-Memory Alloys	05/15/05	03/31/06	10050	PI	Chen
Sandia National Laboratories	High Temperature Metal Testing And High Rate Foam Testing	04/15/06	09/30/06	13400	PI	Chen
Karagozian & Case	Masonry Material Impact Failure	05/15/05	09/30/05	16416	PI	Chen
Army Research Office	Rate-Dependent Deformation And Failure Behavior Of Soft Materials And Biological Tissues	04/30/05	10/30/05	40200	PI	Chen
Semiconductor Research Corporation	Valid Constitutive-And Relevant-Failure Models For Snagcu Solder Alloys	02/01/06	01/31/07	43890	CO-PI	Chen
Rolls-Royce Corporation	Dynamics Of Advanced Engine Oil Sumps And Drains	01/01/06	12/31/06	79887 79887	PI CO-PI	Collicott Heister
Rolls-Royce Corporation	Dynamics Of Engine Oil Sumps And Drains	05/01/02	12/31/05	20000 16000 2000	PI CO-PI CO-PI	Collicott Heister Sankaran
Rolls-Royce North Amer. Tech. Inc	Purdue University Water Spray Development Project	06/15/05	01/31/06	43090	PI	Collicott
National Aeronautics And Space Admin	Three-Dimensional Capillary Interface Topologies And Stability	03/16/05	09/30/07	177523	PI	Collicott
Cessna Aircraft Company	Air Taxi Operations As A System-Of-Systems Problem	01/03/06	08/31/06	48119	PI	Crossley

National Aeronautics And Space Admin	Modeling And Optimization For Morphing Wing Concept Generation	04/11/06	10/31/06	41866	PI	Crossley
Cessna Aircraft Company	System Of Systems Approaches For Corporate And Business Aviation	08/15/05	12/31/05	7500	PI	Crossley
California Space Grant Foundation	Uav Alliance, Research And Curriculum Development Partnership Project	11/21/05	08/31/06	26950	PI	Crossley
National Aeronautics And Space Admin	A Robust, Scalable Transportation System Concept	04/06/05	12/31/06	225000	PI	Delaurentis
United Space Alliance llc	Constellation Concept Of Ground Operations Study	06/30/06	10/05/06	11550	CO-PI	Delaurentis
National Institute Of Aerospace	Methodological Needs For Assessing Future Transportation Architectures	11/15/04	11/30/05	118000	PI	Delaurentis
Pratt & Whitney Group	Analysis Of Fretting Fatigue Of Turbine Materials	10/01/04	12/31/05	50000	PI	Farris
General Electric Aircraft Engines	F110 Experimental Evaluation Of Fretting Fatigue For Turbine Disk - Airfoil Attachments	12/15/04	12/31/05	49657	PI	Farris
General Electric Aircraft Engines	Fretting Fatigue Of Turbine Materials For Propulsion System Prognosis	08/25/04	11/28/05	152200	PI	Farris
General Electric Aircraft Engines	Fretting Fatigue On Rene '95 And Rene'88dt	10/26/05	06/30/06	49998	PI	Farris
LSP Technologies Incorporated	Fretting Fatigue Testing For Lsp Technologies Inc	02/01/06	06/30/06	16000	PI	Farris
Wright-Patterson Air Force Base	Fundamentals Of Fretting Applied To Anisotropic Material	09/06/02	01/05/06	124000 124000	PI CO-PI	Farris Grandt
General Motors Corp	Machining Of Ceramics Project	05/20/98	12/31/75	22500	PI	Farris
Caterpillar Inc.	Materials Processing And Tribology Research Group	06/17/98	12/31/75	15000	PI	Farris
Rolls-Royce Corporation	Materials Processing And Tribology Research Group	12/21/01	12/31/75	70000	PI	Farris
Caterpillar Inc.	Materials Processing Tribology Research	12/17/98	12/31/75	9100	PI	Farris
General Electric Aircraft Engines	Mechanics Of Blade/Disk Contacts	06/18/05	12/31/05	45000	PI	Farris
Pratt & Whitney Group	Multi-Sponsored	10/21/98	12/31/75	2500	PI	Farris
Timken Company	Multi-Sponsored	10/30/98	12/31/75	10000	PI	Farris
General Motors Corp	Multi-Sponsored, Materials Processing Tribology Research	09/01/98	12/31/75	7000	PI	Farris
21st Century Research & Technology Fund	Sustainable Manufacturing Systems For Discrete Products Sector	08/15/03	08/15/05	56538	CO-PI	Farris
General Electric Company	Three-Dimensional Effects In Fretting Fatigue Of Turbine Materials For Propulsion System Prognosis	08/24/04	10/31/05	65000	PI	Farris

National Science Foundation	Analysis And Design Of Multivariable Extremum Seeking Algorithms	09/01/00	08/31/06	229601	PI	Garrison
University Corp For Atmospheric Research	Collaborative Research: Gps Multistatic And Occulation Instrument For Atmospheric, Oceanographic And Land Remoted Sensing From Hiaper	01/01/05	01/01/08	407777	PI	Garrison
National Aeronautics And Space Admin	Investigation Of The Fundamental Properties Of Forward Scattered Gps Signals For Oceanographic Remote Sensing	03/01/02	02/28/06	143636	PI	Garrison
National Aeronautics And Space Admin	Investigation Of Transient Ionospheric Perturbation In The Gps Signal	09/15/04	09/14/07	24000	PI	Garrison
National Aeronautics And Space Admin	Investigation Of Transient Ionospheric Peturbations Observed In The Gps Signal	09/15/04	09/14/07	24000	PI	Garrison
National Aeronautics And Space Admin	Model Function Development For The Retrieval Of Ocean Surface Properties From Scattered Gps Signals	09/15/02	01/14/07	334611	PI	Garrison
National Aeronautics And Space Admin	Nasa Earth System Sciences (Ess) Fellowship	08/01/04	07/31/07	24000	PI	Garrison
Federal Aviation Administration	Analysis Of Fatigue Crack Growth From Countersunk Fastener Holes	07/01/02	09/11/07	69437	PI	Grandt
Alcoa Inc	Fuselage Panel Fatigue Crack Growth And Residual Strength Test Program	09/19/05	12/31/06	96052	PI	Grandt
Boeing Company	Study To Compare Predicted Versus Experimental Crack Shape Changes As Crack Progresses Through Structure	09/01/03	07/31/05	74783	PI	Grandt
National Reconnaissance Office	Altitude Compensation Using Combustible Nozzle Liners	04/01/06	10/31/07	223814 27976	PI CO-PI	Heister Meyer
Aerospace Corporation	Altitude Compensation Using Combustible Nozzle Liners	05/20/05	09/20/05	25000	PI	Heister
University Of Alabama Huntsville	Combustion Instability And Film Cooling Studies For Hydrocarbon Engines	01/31/03	09/20/05	227600 378300 15000 155700	PI CO-PI CO-PI CO-PI	Heister Anderson Farris Merkle
Rolls-Royce North Amer. Technologie, Inc	Expansion Of Propulsion & Power Center Of Excellence With High Mach Turbine-Based Combined Cycle Vehicles And Constant Volume Combustors	08/01/04	12/31/06	97500 97500 48750 243750	PI CO-PI CO-PI CO-PI	Heister Anderson Merkle Meyer

Naval Surface Warfare Ctr Indian Hd Div	Ignition And Combustion Characterization For Advanced Storable Bipropellant Engines	09/21/05	04/20/06	27000 9000 4500	PI CO-PI CO-PI	Heister Anderson Meyer
Air Force Office Of Scientific Research	Modeling Liquid Rocket Engine Atomization And Swirl/Coaxial Injectors	02/01/03	11/30/06	184916	PI	Heister
Spacedev	Nitrous Oxide As A Regenerative Nozzle Coolant	01/01/05	07/31/05	18036	PI	Heister
Sandia National Laboratories	Nonlinear Modeling Of Droplet Splashing	04/25/05	09/15/06	40000	PI	Heister
Allison Advanced Development Company	Rolls-Royce University Technology Center In High Mach Propulsion	01/01/05	12/31/06	144000 60000 19200	PI CO-PI CO-PI	Heister Anderson Meyer
In Space, llc	Torch Ignition Model Development	01/01/06	05/31/06	23048	PI	Heister
Allison Advanced Development Company	University Technology Center In High Mach Propulsion At Purdue University	01/01/03	12/31/06	94000 70500	PI CO-PI	Heister Anderson
University Of Alabama Huntsville	Uttapps	01/31/03	08/09/06	387696 193847	PI CO-PI	Heister Merkle
National Aeronautics And Space Admin	Design And Analysis In Support Of Mission Architectures In Nasa's Vision For Space Exploration	05/24/06	05/23/07	65000	PI	Howell
Jet Propulsion Laboratory	Encore And End-Of-Life Options For The Cassini Spacecraft	04/17/06	02/28/07	54563 54562	PI CO-PI	Howell Longuski
National Aeronautics And Space Admin	Investigation Of The Vertical Orbits For Nasa's Vision For Space Exploration Communications Architecture	07/15/05	08/31/06	30000	PI	Howell
National Aeronautics And Space Admin	Strategies For Trajectory Design And Mission Analysis: Multiple Three-Body And Four-Body Systems Including Sun-Earth-Moon	09/01/04	08/31/07	235000	PI	Howell
Radiance Technologies, Inc	Development Of New Generation Components For Pulsed Plasma Accelerators	03/01/04	12/30/05	30000	PI	Hrbud

Indiana Space Grant Consortium	Purdue Fall Space Day 2005	03/15/05	02/28/06	3000	CO-PI	Hrbud
Indiana Space Grant Consortium	Spring Space Forum	03/15/05	02/28/06	1580	PI	Hrbud
National Aeronautics And Space Admin	Buckling-Driven Disbond Growth In Composite Structures	01/01/04	12/31/05	75000	PI	Kim
Federal Aviation Administration	Damage Tolerance And Durability Of Adhesively Bonded Composite Structure	09/01/04	08/31/06	51340 49830	PI CO-PI	Kim Sun
Randtron Antenna Systems	Failure Threshold Energy Measurement For Hail Ice Impacts Onto Composite Random Materials	10/01/05	03/31/06	31266	PI	Kim
Boeing Company	Hall Ice Impact Investigation	05/01/06	12/31/06	42972	PI	Kim
Odyssian Technology	Multifunctional Composite Structure	02/15/03	02/15/06	76500 74250 74250	PI CO-PI CO-PI	Kim Sun Weisshaar
Jet Propulsion Laboratory	Analysis Of Aerogravity Assist For Interplanetary Missions	05/01/05	03/31/06	45000	PI	Longuski
National Aeronautics And Space Admin	Dual-Use Ballute For Aerocapture And Descent During Planetary Missions	03/01/05	07/31/06	39000	PI	Longuski
National Aeronautics And Space Admin	Low-Thrust Gravity-Assist Trajectory Design And Optimization	01/01/05	11/30/05	90000	PI	Longuski
Ohio Aerospace Institute	An Integrated Cfd Based Methodology For Understanding And Predicting Lobed Mixer Jet Noise	01/01/06	12/31/06	10000 10000	PI CO-PI	Lyrintzis Blaisdell
Education, U.S. Department Of	Interdisciplinary Fellowship Program For Computational Science And Engineering	08/15/02	08/14/06	6559	CO-PI	Lyrintzis
Ohio Aerospace Institute	Understanding Of The Prediction Of Lobed Mixer Noise	05/01/04	12/31/05	10000 10000	PI CO-PI	Lyrintzis Blaisdell
University Of Tennessee Space Institute	Magnito Hydro Dynamics Generator Modeling	08/23/04	12/31/06	125000	PI	Merkle
Boeing Company	Additional Boeing Pulsejet Testing	06/01/06	07/31/06	6463	PI	Meyer

Boeing Company	Boeing Pulsejet Testing: Task 4-Peta Fabrication And Testing	12/16/05	04/10/06	21189	PI	Meyer
Kt Engineering	Kt Engineering Cev Igniter Testing	05/08/06	04/27/07	67118	PI	Meyer
Boeing Company	Pulsejet Hardware For Boeing	03/15/05	05/31/06	29753	PI	Meyer
Boeing Company	Pulsejet Testing For Boeing	03/15/05	12/01/05	20578 41150	PI CO-PI	Meyer Kim
In Univ Purdue Univ At Indianapolis	Purdue University Wave Rotor Combustion Rig Test Facility Design	03/01/06	02/28/07	67500	PI	Meyer
National Science Foundation	Ipa Agreement	01/10/05	01/09/07	350791	PI	Rotea
United Technologies Research Center	Robust Control Analysis And Synthesis	09/01/98	12/31/75	40000	PI	Rotea
Xerox Corp	Xerox Corporation/Rotea	08/07/01	12/31/75	66000	PI	Rotea
P.C. Krause & Assoc. Inc/AFRL	Security of Large Scale Systems/Task 03-07	04/01/05	12/31/31	75,393	PI	Rotea
Sandia National Laboratories	Collaborative Research: Mechanisms Of Hypersonic Boundary-Layer Transition On Reentry Vehicles	08/01/03	09/30/06	120000	PI	Schneider
National Aeronautics And Space Admin	Mechanisms Of Boundary-Layer Transition On Reusable Launch Vehicles:A Proposed Fy04 Supplement For Nasa Grant-1-02047	03/30/04	07/31/05	25000	PI	Schneider
Air Force Office Of Scientific Research	Mechanisms Of Hypersonic Boundary Layer Transition On Two Generic Vehicle Geometries	12/15/02	12/14/05	125000	PI	Schneider
Air Force Office Of Scientific Research	Request For Afosr Fy06 Supplemental Funds To Support A Stability And Transition Analysis For Reentry (Star)	03/01/06	11/30/06	161000	PI	Schneider
Air Force Office Of Scientific Research	Request For Fy05 Supplemental Funds For Afosr Grant F49620-03-1-0030 To Support A Stability And Transition Analysis For Reentry (Star)	12/15/02	12/14/05	160931	PI	Schneider
Air Force Office Of Scientific Research	Towards High-Reynolds-Number Quiet Flow In Hypersonic Wind Tunnels	03/01/06	11/30/06	80000	PI	Schneider
National Aeronautics And Space Admin	Towards Mechanism-Based Models For Laminar-Turbulent Transition On Blunt Reentry Vehicles: Request For Fy06 Supplemental Funds	03/28/06	03/31/08	80000	PI	Schneider

National Aeronautics And Space Admin	Towards Mechanism-Based Models For Laminar- Turbulent Transition On Blunt Reentry Vehicles	03/28/06	03/31/08	135000	PI	Schneider
Tekla Research Inc.	Aim Point Biasing	10/01/04	12/31/05	62653 62652	PI CO-PI	Sullivan Kim
A. T. C. Incorporated	Atc, Inc.	01/01/00	12/31/75	16667	PI	Sullivan
Raisbeck Engineering	Design/Build/Test Laboratory	11/02/99	12/31/75	50000	PI	Sullivan
National Aeronautics And Space Admin	Unsteady Pressure Measurement In Turbomachinery Using Porous Pressure-Sensitive Paint	08/16/04	08/15/05	24000	PI	Sullivan
Office Of Naval Research	Development Of Toughened And Multifunctional Nanocomposites For Ship Structures	04/01/05	03/31/07	110000	PI	Sun
Ball Aerospace & Technologies Corp	High Energy Laser Vulnerability Assessments	10/17/05	06/02/06	57541	PI	Sun
Ball Aerospace & Technologies Corp	High Energy Laser Vulnerability Assessments Modeling Program (Helvamp)	07/11/05	12/31/05	35000	PI	Sun
Tuskegee University	Modeling Of Nanocomposites	09/01/03	08/31/07	120000	PI	Sun
Defense Advanced Res Projects Agency	Ipa Agreement	08/12/04	08/11/06	442225	PI	Weisshaar
Stanford University	Itr: Data Driven Environment For Multiphysics Applications	08/01/04	08/31/06	99304	CO-PI	Weisshaar

GRADUATE THESES

July 2005 to June 2006

MASTER'S THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree Date Granted**
Lamberson, Jr., Steven E. *W. A. Crossley*	"Composite Laminate Optimization Techniques Applied to Load-Bearing Circuit Board Design"	M.S. August 2005
Lee, See-Chen J. L. Garrison	"Investigation of Transient Zonospheric Perturbation Observed in the GPS Signal"	M.S. August 2005
Mane, Muharrem *W. A. Crossley*	"Allocation of Variable Resources and Aircraft Design Using Multidisplinary Optimization for Systems of Systems"	M. S. August 2005
Nankani, Kamlesh *W. A. Crossley*	"Optimization Approaches for Morphine Airfoils Using Drag and Strain Energy as Objectives"	M. S. August 2005
Nehrbass, Jonathan *W. A. Crossley*	"Drag Benefits of Formation Flight and Morphing on Transatlantic Point to Point Commercial Aircraft Service"	M. S. August 2005
Rausch, Raoul *K. C. Howell*	"Earth to Halo Orbit Transfer Trajectories"	M. S. August 2005
Robarge, Tyler W. *S. P. Schneider*	"Laminar Boundary-Layer Instabilities on Hypersonic Cones: Computations for Benchmark Experiments"	M. S. August 2005
Tanner, Travis N. *C. T. Sun*	"Applications of Crack Tip Opening Angle for Ductile Fracture Analysis"	M. S. August 2005
Yu, Yen Ching *W. E. Anderson*	"Swirl Liquid Film Cooling of a Modeled Combustor"	M. S. August 2005
Bies, Christopher *S. D. Heister*	"Analysis of an Advanced Aero-Engine Bearing Chamber"	M. S. December 2005
Briggs, Eric *W. E. Anderson*	"Comparative Study of Pyrolytic Coking of JP-8 and JP-10 on Inconel and Stainless Steel Surfaces"	M. S. December 2005
Butt, Adam *I. Hrbud*	"Acoustic Inertial Confinement Fusion: Potential Applications to Space Power and Propulsion"	M. S. December 2005
Djibo, Louise-Olivia K.	"Natural Conformations: A Study of the Shape of Structures in Equilibrium"	M. S. December 2005

Eichel, Brenda *J. L Garrison*	"Model-Based Compression of GPS Ephemeris"	M. S. December 2005
Ge, Yun *W. Chen*	"Radial Inertia Effects on Dynamic Behavior of Extra-Soft Materials in Split Hopkinson Bar Experiments"	M. S. December 2005
Habrel, Christopher *W. A. Crossley*	"Addressing Uncertainty in Aircraft Sizing During Conceptual Design"	M. S. December 2005
Jos, Cyril *W. E. Anderson*	"Direct-Connect Testing of a Rocket-Based Combined Cycle Engine"	M. S. December 2005
Kakoi, Masaki *K. C. Howell*	"Transfers Between the Earth-Moon and Sun-Earth Systems Using Manifolds and Transit Orbits"	M. S. December 2005
Lovera-Yepes, Javier A. *M. A. Rotea*	"Pilot's Intent Inference and Aircraft Trajectory Prediction with Applications to Air Traffic Control"	M. S. December 2005
Merrill, Marriner H. *C. T. Sun*	"Development of a Simple and Inexpensive Method for Manufacturing High Quality Nanoparticle/Polymer Nanocomposites"	M. S. December 2005
Smajlovic, Dino *J. L. Garrison*	"Obtaining Ocean Roughness Statistics from Reflected GPS Signals"	M. S. December 2005
Spohn, Jason *H. Kim*	"The Design, Build, and Testing of an Infrared Aim Point Biasing Structure"	M. S. December 2005
Chen, Jit-Tat *D. Andrisani*	"Use of a PID Control Structure to Design an Autopilot for an Autonomous Aircraft"	M.S. May 2006
Churchfield, Matthew *G. A. Blaisdell*	"Numerical Computations of a Wingtip Vortex in the Near Field"	M.S. May 2006
Deitemeyer, Adam *C. T. Sun*	"Three-Dimensional Characteristics of the Plastic Zone and Necking in the Crack Tip Region"	M.S. May 2006
Grebow, Daniel *K. C. Howell*	"Generating Orbits in the Circle Restricted Three-Body Problem with Application to Lunar South Pole Coverage"	M.S. May 2006

Grupido, Christopher *W. Chen*	"Development of a Split Hopkinson Pressure Bar Method for Intermediate Strain Rate Experimental Testing"	M. S. May 2006
Hsieh, Kelli *H. Kim*	"Study of Fatigue Behavior of Embedded Copper in Multi-functional Composite Material"	M. S. May 2006
McDonald, Seth *H. Kim*	"Design Methodology for Airships of Non-Axisymmetric Cross-Section Geometry"	M. S. May 2006
Miller, Christopher *J. P. Sullivan*	"High Altitude Airship Simulation and Control"	M. S. May 2006
Moyle, Nicholas *A. F. Grandt, Jr.*	"Experimental Determination of the Model I Stress Intensity Factor for a Corner Cracked Lug using a Marker Banding Technique"	M. S. May 2006
Mseis, George *T. N. Farris*	"Mechanical Characterization of an Electrodeposited Nanocrystalline Copper"	M. S. May 2006
Pan, Yi *W. Chen*	"The Upper Limit of Constant Strain Rate in a SHPB Experiment for a Linearly Elastic Material"	M. S. May 2006
Park, Hwun *H. Kim*	"Resistance of Adhesively Bonded Composite Lap Joints to Damage by Transverse Ice Impact"	M. S. May 2006
Sardeshmukh, Swanand *C. L. Merkle*	"Performance Analysis of Coupled and Segregated CFD Methods"	M. S. May 2006
Ventre, Brian *J. L. Garrison*	"Open-Loop Tracking of an Occulting GNSS Signal"	M. S. May 2006

DOCTORAL THESES

Student/ *Major Professor*	**Thesis Title**	**Degree Date Granted**
Bartha, Bence *T. N. Farris*	"Modeling of Geometry Effects in Fretting Fatigue"	Ph.D. May 2005
Garcia, Daniel *A. F. Grandt, Jr.*	"Crack Propagation Analysis of Surface Enhanced Titanium Alloys with Fretting Induced Damage"	Ph.D. May 2005
You, Huai-Tzu *J. L. Garrison*	"Stochastic Model for Ocean Surface Reflected GPS Signal and Satellite Remote Sensing Applications"	Ph.D. May 2005
Cho, Jeong-Min *C. T. Sun*	"Effect of Inclusion Size on Failure Mechanism and Mechanical Properties of Polymeric Composites Containing Micro and Nano Particles"	Ph.D. August 2005
Gao, Guofeng *T. N. Farris*	"Fretting Induced Plasticity in Blade/Disk Contacts"	Ph.D. August 2005
Gregory, James W. *J. P. Sullivan*	"Development of Fluidic Oscillators as Flow Control Actuators"	Ph.D. August 2005
Mamun, Md-Wahid Al *P. K. Imbrie*	"Investigation of the Photo Stimulated Luminescence Spectroscopy Technique for Measuring 3-D Stresses"	Ph.D. August 2005
Park, Hongbok *S. D. Heister*	"Flow Characteristics of Viscous High-Speed Jets in Axial/Swirl Injectors"	Ph.D. August 2005
Suh, Jungjun *A. F. Grandt, Jr.*	"Analysis of Fatigue Crack Growth from Countersunk Fastener Hole"	Ph.D. August 2005
Namgoong, Howoong *W. A. Crossley*	"Airfoil Optimization for Morphing Aircraft"	Ph.D. December 2005
Pourpoint, Timothee *W. E. Anderson*	"Hypergolic Ignition of a Catalytically Promoted Fuel with Rocket Grade Hydrogen Peroxide"	Ph.D. December 2005
Rufer, Shann *S. P. Schneider*	"Hot-wire Measurements of Instability Waves on Sharp and Blunt Cones at Mach-6"	Ph.D. December 2005

Skoch, Craig *S. P. Schneider*	"Disturbances from Shock/Boundary Layer Interactions Affecting Upstream Hypersonic Flow"	Ph.D. December 2005
Garrison, Loren *A. Lyrintzis*	"Computational Fluid Dynamics Analysis and Noise Modeling of Jets with Internal Forced Mixers"	Ph.D. May 2006
Hanna, Ihab M. *T. N. Farris*	"Thermal Modeling of Grinding for Process Optimization and Durability Improvements"	Ph.D. May 2006
Huang, Chihyung *J. P. Sullivan*	"Molecular Sensors for MEMS"	Ph.D. May 2006
Kwon, Hyukbong *H. Kim*	"Buckling and Debond Growth of Partial Debonds in Adhesively Bonded Composite Flanges"	Ph.D. May 2006
Tseng, Kuotung *S. H. Collicott*	"Fluidic Spray Control"	Ph.D. May 2006

COLLOQUIUM SERIES

July 2005 to June 2006

Colloquium Series – Fall 2005

DATE/TIME	TOPIC	SPEAKER
September 8, 2005 3:00 p.m. GRIS 180	“NASA Kepler Project”	**Dr. Janice Voss** NASA Astronaut Kepler Science Director NASA Ames Res. Center Moffett Field, CA
September 15, 2005 3:00 p.m. GRIS 180	“ARO/ARL Research Opportunities in Applied Mechanics”	**Dr. A. M. Rajendran** Senior Scientist Engineering Directorate Army Research Office RTP, NC
September 30, 2005* 4:00 p.m. GRIS 274	“Turbulent Pipe Flow and Why Moody Was Wrong”	**Prof. Alexander J. Smits** Dept. of Mechanical and Aerospace Engrg. Princeton University Princeton, NJ
October 6, 2005 3:00 p.m. GRIS 180	“Robust Stability Analysis of Uncertain Dynamic Systems with Applications”	**Dr. Rama K. Yedavalli** Dept. of Aerospace Engrg. Ohio State University Columbus, OH
October 13, 2005 3:00 p.m. GRIS 180	“NASA’s In-Space Propulsion Program”	**John Dankanich** Gray Research Inc. NASA/Inspace Propulsion Program
October 21, 2005 4:00 p.m. BROWN 1154	“Results of NASA’s Exploration Systems Architecture Study”	**Robert Sackheim** Chief Engr. Space Propulsion NASA Marshall Space Flight Center
October 27, 2005 3:00 p.m. GRIS 180	“Detonation Structure”	**Prof. Joanna M. Austin** Dept. of Aerospace Engrg. Univ. of Illinois @ Champaign Urbana

November 3, 2005 3:00 p.m. GRIS 180	"The Columbia Accident Investigation"	**R.S. Piascik** NASA Engineering & Safety Center NASA Langley Research Center Hampton, VA
November 10, 2005 3:00 p.m. GRIS 180	"Challenges that Continuum Theory Faces in the Age of Nanotechnology"	**C. T. Sun** Neil A. Armstrong Distinguished Professor School of Aeronautics & Astronautics Purdue University
November 17, 2005 3:00 pm. GRIS 180	"Coverage Control for Mobile Sensing Networks"	**Dr. Islam I. Hussein** Coordinated Systems Lab Univ. of Illinois @ Urbana-Champaign
December 8, 2005 3:00 p.m. GRIS 180	"Hydrodynamic Models of Projectile Penetration into Elastic-plastic Targets Including a Description of Fragmentation and Vulnerability"	**Dr. Ilia Roisman** Chair of Fluid Mech. & Aerodyn. Darmstadt Univ. of Tech**.**

*Jointly sponsored by the School of Aeronautics & Astronautics and the Student American Institute of Aeronautics and Astronautics Chapter

**Jointly sponsored by the School of Aeronautics & Astronautics and the Mechanical Engineering Dept.; Midwest Mechanics Seminar

***William E. Boeing Distinguished Lecture sponsored by the School of Aeronautics and Astronautics Department

****Jointly sponsored by the School of Aeronautics & Astronautics and Sigma Xi

Colloquium Series – Spring 2006

DATE/TIME	TOPIC	SPEAKER
February 16, 2006 3:00 p.m. GRIS 180	"Changing the Shape of Aircraft-New Frontiers in Aerospace Design"	**Dr. Terry Weisshaar** DARPA Morphing Prog.Mgr. & Purdue Professor, School of Aero. & Astro.
February 23, 2006 3:00 p.m. GRIS 180	"Paths to Transition and their Implications for Transition Prediction and Control"	**Dr. Eli Reshotko** Kent H. Smith Professor Emeritus of Engineering Dept.of Mech.& Aerosp. Engr. Case Western Reserve Univ.
March 9, 2006 3:00 p.m. GRIS 180	"High Cycle Fatigue of Metals"	**Dr. Ted Nicholas** Air Force Institute of Tech.
April 6, 2006 3:00 p.m. GRIS 180	"Control and Optimization of Multi-Agent Systems"	**Dr. Dusan Stipanovic** Univ. of Illinois @ Urbana Champaign
April 13, 2006 3:00 p.m. GRIS 180	"The Intriguing Structure of a Sunspot"	**Professor John H. Thomas** Dept. of Mech. Engrg. Univ. of Rochester
April 20, 2006 3:00 p.m. GRIS 180	"Turbulent Hypersonic Flows: Physics and Simulation"	**Dr. Pino Martin** Princeton University Princeton, NJ
April 26, 2006** 3:30 p.m. GRIS 274	"A Quiet Free Shear Flow"	**Dr. Jon Freund** Univ. of Illinois @ Urbana/Champaign
April 27, 2006 3:00 p.m. GRIS 180	"The Cassini/Huygens Project"	**Mr. Robert T. Mitchell** Cassini Project Manager Jet Propulsion Lab California Inst. Tech.

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**Jointly sponsored by the School of Aeronautics & Astronautics and the Mechanical Engineering Dept.; Midwest Mechanics Seminar

***William E. Boeing Distinguished Lecture sponsored by the School of Aeronautics and Astronautics Department

****Jointly sponsored by the School of Aeronautics & Astronautics and Sigma Xi

Highlights & Awards

July 2005 to June 2006

FACULTY HIGHLIGHTS

Several faculty continue their visible service as editors and on various visiting committees.

Other highlights include:

- Professors William Anderson and Stephen Heister were recipients of the C. T. Sun School of Aeronautics and Astronautics Research Award.
- Professor William Anderson again received the AIAA Liquid Propulsion Committee Best Paper Award
- Professor Weinong Wayne Chen has been named College of Engineering University Faculty Scholar.
- Professor William Crossley received the School's Gustafson Outstanding Teacher Award.
- Professor James Longuski received the School's Elmer F. Bruhn Excellence in Teaching Award and had his book published "The Seven Secrets on how to Think like a Rocket Scientist."
- Professor C. T. Sun was the recipient of the Sigma Xi Faculty Award and had the 2nd edition of his book "Mechanics of Aircraft Structures" published.
- Professor Marc Williams received the College of Engineering Outstanding Advisor Award.

STUDENT HIGHLIGHTS

There are several student organizations with a relationship with the School. They are the Aeronautics and Astronautics Engineering Student Advisory Council (AAESAC); American Institute of Aeronautics and Astronautics (AIAA); Students for the Exploration and Development of Space (SEDS); and Sigma Gamma Tau (SGT). SEDS coordinated the annual Spring Space Forum, and is parent organization for the 10th annual Fall Space Day. AAESAC hosted "Professor Pizzas," an opportunity for students to interact one-on-one with AAE professors and visiting dignitaries; and. "Aero Social Night" a program aimed to provide a social event for professors, students and staff to interact on an informal level. Several student groups continue to perform well in national design competitions.

The SEDS Spring Space Forum was held on April 20, 2006 which was organized by SEDS and sponsored by the Indiana Space Grant Consortium. This is an educational community-driven event geared toward generating interest in both students and the public on issues concerning space exploration. Four VIP's took part in the forum and talked about the possibility of returning to the Moon and the potential research that can be done there.

Student Awards

Congratulations to the following students who have earned top honors during the 2005-06 academic year.

Purdue Engineering Foundation Outstanding Senior Student Award –
May 2006 – Gregory Wilson

Purdue Engineering Foundation Outstanding Graduate Student Award
May 2006 – James Canino

Outstanding Senior Award – Phillip Boettcher

Magoon Graduate Teaching Award –Mohammad Ayoubi; Erik Dambach; Jit-Tat Chen; Geraldine Fritsch; Daniel Grebow; Masaki Kakoi

Outstanding Graduate Teaching Assistant – Mohammad Ayoubi

Astronaut Scholar (Hall of Fame Induction)– Jayleen Guttromson

Elmer F. Bruhn Undergraduate Research Assistantship – Joshua Dais, Fabien Klussendorf, Ross Spoonire

Russell O. Cedars Scholarship – Pritesh Mody

Amelia Earhart Scholarship – Laura Brower

David L. Filmer Scholarship – Laura Brower

Koerner Scholarships – Sophomore: Pritesh Mody and Courtney Rogge; Junior: Andrew Mundell and Breanne Wooten; Senior: Phillip Boettcher and Ariane Chepko

Gary and Sue Payton Scholarship – Poorvi Kalaria

Purdue Forever Fellowship – James Canino, Jeremy Corpening, Loren Garrison, Raymond Joshua, James Sisco

John and Patricia Rich Scholarship – Jayleen Guttromson

Herbert F. Rogers Scholarship – Nick Chachor

David and Linda Schimmel Swain Scholarship – Freshman: George Samuel; Sophomore: Daniel Kipfer; Junior: Timothy Rebold

Marc Weaver Memorial Scholarship – Alan Schwing

Society of Women Engineers Awards – Jasmine Cashbaugh, Ball Aerospace & Technologies Corp.; Dawn Gordon, Outstanding Sr., Corning, Inc.; Kathryn Mitchell, Shirley McCarty Award; Courtney Rogge, Lockheed Martin; Christine Troy, Women in Engineering Award; Elisabeth Wahl, Rockwell Collins; Elizabeth Wolfe, Vought Aircraft; Danielle Yaple, The Boeing Company.

Winners of the AAE 251 ATK Thiokol Propulsion S.P.A.C.E. Awards

Fall 2005 First Place Team: Levi Brown, Nicole Bryan, Albert Chaney, Kyle Donahue, Andrew Mundell

Spring 2006 First Place Team: Molly Kane, Pritesh Moody, Stephanie Morris, Kyle Noth, Jessica Schoenbauer, Jeff Stuart

OUTREACH HIGHLIGHTS

The School's 10th annual Fall Space Day held on October 22, 2005, with C**olonel Mark N. Brown** as guest VIP Astronaut, was shared with over 380 third through eighth graders from 91 schools in three states, Illinois, Indiana, and Ohio to Purdue, with a strong volunteer crew of over 150 Purdue students from 22 majors. Additionally, the children participated in many interactive lessons that reinforced basic science and math principles. Purdue Fall Space Day was hosted by Students for the Exploration and Development of Space (SEDS) and sponsored by: the Indiana Space Grant Consortium; School of Aeronautics and Astronautics; Purdue Engineering Student Council (PESC); Daimler Chrysler, Eli Lilly & Co., and Office Max.

Several faculty gave presentations to local schools. Many students of the School take time to interact with students in K-12 and share their excitement of space exploration. The inherent excitement of aerospace leads to these invitations and generates great responses from the students.

Curriculum &
Course Offerings

July 2005 to June 2006

CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

Course Enrollments
School of Aeronautics and Astronautics
2005-2006 Academic Year

A&AE Course	Most Recent Title	Cr.	Fall 2005		Spring 2006	
			Enroll-ment	Instructor	Enroll-ment	Instructor
203	Aeromechanics I	3	114	Garrison	61	Corless
204	Aeromechanics II	3	36	Farris	87	Chen
204L	Aeromechanics II Lab.	1	38	Doyle	89	Doyle
241	Industrial Practice I	0	10	Williams	2	Williams
242	Industrial Practice II	0	3	Williams		
251	Intro. Aerosp. Design	3	57	DeLaurentis	95	DeLaurentis
301	Engrg. Systems Anal.	3	79	Frazho	47	Garrison
333	Fluid Mechanics	3	91	Lyrintzis	32	Lyrintzis
333L	Fluid Mechanics Lab.	1	90	Collicott	34	Collicott
334	Aerodynamics	3	41	Sankaran	83	Li
334L	Aerodynamics Lab.	1	15	Collicott	50	Rufer
340	Dynamics & Vibration	3	78	Longuski	69	Howell
341	Industrial Practice III	0	4	Williams	8	Williams
342	Industrial Practice IV	0	2	Williams	3	Williams
352	Structural Anal. I	3	78	Sun	40	Kim
352L	Struct. Anal. I Lab.	1	30	Doyle	36	Doyle
364	Control System Analy.	3	57	Hwang	71	Hwang
364L	Control Systems Lab.	1	74	Frazho	64	Frazho
372	Jet Propl. Power Plt.	3			108	Sankaran
412	Intro. Comp. Fluid Dyn.	3	48	Blaisdell		
415	Aerodynamic Design	3	27	Sullivan		
421	Flt. Dyn. Control	3	60	Corless	37	Corless
439	Rocket Propulsion	3	83	Hrbud		
440	Spacecr. Attitude Dyn.	3			54	Howell
442	Industrial Practice V	0				
450	Spacecraft Design	3	20	Schneider	43	Longuski
451	Aircraft Design	3	26	Andrisani	43	Crossley

A&AE Course	Most Recent Title	Cr.	Fall 2005 Enroll-ment	Fall 2005 Instructor	Spring 2006 Enroll-ment	Spring 2006 Instructor
453	Matr. Meth. Aerosp. Struc.	3			28	Doyle
454	Design Aerosp. Struct.	3	47	Grandt		
490A	Flight Testing				19	Andrisani
490G	Technical Comm.	3			8	Grandt
507	Principles of Dynam.	3	48	Longuski		
508	Optimiz. Aerosp. Engr	3			49	Longuski
511	Intro. Fluid Mech.	3	33	Blaisdell		
512	Comput. Aerodyn.	3			25	Merkle
512Q	Comput. Aerodyn.	3			59	Merkle
514	Intermediate Aerodyn.	3			59	Lyrintzis
514Q	Intermediate Aerodyn.				10	Lyrintzis
515	Rotorcraft Aerodyn.	3	22	Lyrintzis		
518	Low-Grav. Fluid Dyn.	3	17	Collicott		
519	Hyper. Aerothermo.	3	20	Schneider		
520	Experimental Aerody.	3			24	Schneider
532	Orbit Mechanics	3	39	Howell		
535	Prop; Des. Build, Test	3			15	Anderson
538	Air Breath. Propul.	3	39	Merkle		
539	Adv. Rocket Prop.	3			37	Heister
546	Aero Struct Dyn Stab.	3	17	Doyle		
550	Multidisciplinary Des. Opt.	3	57	Crossley		
550Q	Multidisciplinary Des. Opt.	3	53	Crossley		
552	Nondes. Eval. Struct. Matrls.	3			37	Grandt
552Q	Nondes. Eval. Struct.	3			15	Grandt
553	Elasticity Aerosp. I	3	18	Sun		
554	Fatigue Struct. & Matrl.	3	37	Grandt		
554Q	Fatigue Struct. & Matrl.	3	76	Grandt		
555	Mechanics Comp. Matl.	3			29	Sun
558	Finite Elem Meth. in Aerospace Structures	3	31	Kim		
558Q	Finite Elem. Meth. in Aerospace Struct.	3	9	Kim		

A&AE Course	Most Recent Title	Cr.	Fall 2005		Spring 2006	
			Enroll-ment	Instructor	Enroll-ment	Instructor
564	System Anal. & Synth.	3	31	Corless		
565	Guidance Aerospace Veh.	3			19	Andrisani
567	Intro. Appl. Stoch. Proc.	3			23	Frazho
590C	Propul. Sys. Design	3	20	Heister		
590D	Intro. To Labview	3	6	Filmer	6	Filmer
590E	Intro. Electric Propul.	3			21	Hrbud
590F	Dyn. Behav. Matrls.	3	6	Chen		
590G	Intro. Sate. Nav.&Pos.	3	10	Garrison		
590K	Sys. of Sys. Model. & Analysis	3			27	DeLaurentis
590M	Manuf. of Adv. Comp.	3			3	Pipes
590R	Exp. Char. Of Adv. Composite Matrls.	3	12	Pipes		
646	Elastic Wave Propag.	3			5	Doyle
690A	Combust. Stability	3	16	Anderson		
690B	Hybrid Sys. Theory & Applications	3			10	Hwang
690D	Sel. Topics Nonlinear Mech.				11	Doyle
690G	Astro. Nav. & Guidance	3	7	Howell		
690S	Adv. Satellite Nav.	3			2	Garrison
698	M.S. Thesis Research	--				
699	Ph.D. Thesis Research	--				

Aerospace Engineering Requires a Multidisciplinary Curriculum

Required Introductory 251-Introduction to Aerospace Design; 203 Aeromechanics I (statics/dynamics)

Aerodynamics	*Dynamics and Control*	*Propulsion*	*Structures and Materials*
Required Undergraduate			
333-Fluid Mechanics & Lab.	340-Dynamics and Vibrations	372-Jet Propulsion or	204-Aeromech. II (Str of Mat.) and lab
334-Aerodynamics and Lab	364-Controls and Lab	439-Rocket Propulsion	352-Structural Analysis & Lab
	421-Flight Dynamics or		
	440-Spacecraft Att. Dynamics		
Undergraduate Electives			
412-Intro to CFD	421-Flight Dynamics or	372-Jet Propulsion or	453-Matrix Methods in Struct.
414-Compressible Aero	440-Spacecraft Att. Dynamics	439-Rocket Propulsion	
416-Viscous Flows	490A Flight Testing		
415-Aerodynamic Design	490R-Control Systems Design	590C Propulsion Design	454-Structural Design
Multidiscipl. Required 301 Signals for Aero. Systems; **Required Capstone Design** 450 Spacecraft Design or 451 Aircraft Design			
Multidisciplinary Electives 490E-Introduction to Satellite Systems; 490B Aerospace Systems Design; 490S-Satellite Design			
Undergraduate/ Graduate Electives			
511-Intro. to Fluid Mech.	564-Systems Anal. and Control	537-Hypersonic Propulsion	546-Struct. Dyn and Stability
512-Computational Aero	565-Guidance and Control	538-Air Breathing Propulsion	547-Experimental Stress Anal.
514-Intermediate Aero	567-Intro to Stochastic Proc.	539-Adv. Rocket Propulsion	552-NDE of Struct and Mat.
515-Rotorcraft Aerodynamics	590W-Estimation Theory	590E-Electrical Propulsion	553-Elasticity in Aero. Eng
518-Low Gravity Fluid Mech.	660-Operator Methods	590R-Aerospace Propulsion	554-Fatigue in Struct. and Mat.
519-Hypersonic Aero.	666-Nonlinear Dynamics	630-Stability of Free Surfaces	555-Mech. of Composite Mat.
520-Experimental Aero.	696-Multivariable Control	637-Future Prop Concepts	556-Aeroelasticity
590D-Molecular Gas Dynam	**Astrodynamics**	690C-Combustion Stability	558-Finite Element Methods
613-Viscous Flow Theory	507-Basic Mechanics		559-Mech. of Friction & Wear
615-Aerocoustics	508-Optimization in Aero. Eng.	**Aerospace Systems**	590F-Dynamic Behav of Mater
624-Lam-Tur Transition	532-Orbital Mechanics	550-MDO	590M-Manufac. Of Adv Compos
626-Turbulence	575-Satellite Nav and Pos	551-Design Th and Methods	646 Elastic Wave Propaga
	607-Var Prin of Mechanics	590K Systems of Systems	654-Fracture Mechanics
	632-Adv Orbital Dynamics	690B Hybrid Systems	655-Adv Topics in Composites
	690G-Astro Navig. & Guidance		

Summarized Class Enrollment Statistics
for the 2005-2006 Academic Year

Semester	Statistic	Three-Credit Courses				One-Credit Laboratory Courses
		100, 200, 300, 400, Levels	500 Levels	600 Level	All Levels	
Fall of 2005	No. of classes offered	20	21	2	43	5
	Total Enrollment	961	597	23	1581	247
	Average number of students per class	48	28	12	37	49
Spring of 2006	No. of classes offered	20	17	4	41	5
	Total enrollment	938	456	19	1413	273
	Average number of students per class	47	27	5	34	55

(does not include AAE 490, 590, 698 and 699)

STAFF FOR THE 2005-2006 ACADEMIC YEAR

Administrative Assistants
Linda Flack, Terri Moore

Business Office
Joan Jackson, Michelle Kidd, Sherry Wagner, Tonya Yoder

Clerical
Karen Johnson, Paula Kerkhove

Director of Communications and Development
Eric Gentry

Communications Administrator
Ann Broughton

Professional/Technical
Madeline Chadwell, Lisa Crain, Gerald Hahn, Joe Kline, Scott Meyer, John Phillips, David Reagan, Robin Snodgrass, Jim Younts