PURDUE
UNIVERSITY

School of Aeronautics & Astronautics

2004-2005

Research Report

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OUR MISSION

Established as an independent school on July 1, 1945, the School of Aeronautics and Astronautics celebrates 60 years of existence and 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 465 for the Fall of 2004 Graduate enrollment of 206 was the largest graduate enrollment in the School's history. During academic year 2004-05, 142 students earned their Bachelor of Science degree, 42 earned their Master of Science degree, and 12 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	**99-00**	**00-01**	**01-02**	**02-03**	**03-04**	**04-05**
B.S.	43	60	65	90	116	142
M.S.	35	23	34	24	47	42
Ph.D.	9	17	14	10	11	12

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 student exchange agreements with: 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 an EPE M.S. in Aeronautics and Astronautics.

DEVELOPMENT HIGHLIGHTS

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 November 2004 and April 2005. IAC members are: Dr. William Ailor III, The Aerospace Corporation; Mr. Frank Bauer, NASA Goddard Space Flight Center; Mr. Bradley Belcher, Rolls Royce; Dr. Paul Bevilaqua, Lockheed Corporation; Ms. Nancy Carpenter, ATK Thiokol Propulsion; Ms. Andrea Chavez, Ball Aerospace; Mr. Daniel Devitt, Vought Aircraft Industries, Inc; Mr. Joseph Gernand, Boeing; Dr. William C. Kessler, Lockheed Martin Aeronautics, Dr. Andrew King, Boeing; Mrs. Mary Kriebel, Northrop Grumman; Dr. William Kessler, Lockheed Martin Aeronautics; Dr. Donald Lamberson, Major General, USAF (ret.); Mr. David McGrath, ATK Tactical Systems; Mr. G. Thomas McKane, A.M. Castle & Co.; Mr. Hank Queen, Boeing, Mr. Charles Saff, Boeing; Mr. Randal Secor, Northrop Grumman Corp.; and Dr. Robert Strickler, Sangamon LLC. In Spring 2005 Mr. Hank Queen stepped down from his position with the IAC, and the School welcomed Mr. Craig A. Saddler, Boeing to the IAC.

As of June 30, 2005, The Campaign for Purdue has resulted in $14 million in gifts to AAE. Construction of Neil Armstrong Hall of Engineering is on track for the School to move during the Summer of 2007.

Purdue and Rolls-Royce signed an agreement on April 7, 2005 to cooperate with state businesses in developing basic and applied manufacturing processes and technologies. The Indiana Advanced Aerospace Manufacturing Alliance Voluntary Collaboration agreement between Rolls-Royce and Purdue's Center for Advanced Manufacturing, under the direction of Purdue's Aeronautics and Astronautics Professor John Sullivan, establishes an initiative to work with existing and "aerospace-capable" Indiana manufacturing and repair companies.

ALUMNI HIGHLIGHTS

The School named the following six new Outstanding Aerospace Engineers (OAEs) to be honored on October 6, 2005: Ms. Andrea M. Chavez (B.S.A.A.E. 1988); Dr. Thomas S. Gates (B.S.A.A.E. 1981, M.S.A.A.E. 1983, Ph.D. 1989); Ms. Debra L. Haley (B.S.A.A.E. 1978); Dr. Stephen A. Rizzi (M.S.A.A.E. 1985, Ph.D. 1989); Dr. William E. Schmitendorf (B.S.A.E. 1963, M.S.A.E. 1965, Ph.D. 1968) and Dr. Richard E. VanAllen (B.S.A.A.E. 1968, M.S.A.A.E. 1969, Ph.D. 1977).

Dr. Paul M. Bevilaqua (M.S.A.A.E. 1968, Ph.D. 1973) was awarded the College of Engineering 2005 Distinguished Engineering Alumnus (DEA) Award. Dr. Bevilaqua is currently Chief Engineer, Advanced Development Projects Lockheed Martin Skunk Works.

Mr. James D. Raisbeck (B.S.A.E. 1961) was awarded the honorary doctorate degree during the May 2005 graduation ceremonies. Mr. Raisbeck is founder and CEO of Raisbeck Engineering, Inc. and Raisbeck Commercial Air Group, Inc.

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2004 are given in the "Faculty Summary" section of this report. Only documents that actually appeared in print during 2004 are listed. Note that 4 books, 58 journal articles or book chapters, and 114 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 2004-05 academic year, 59 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 16 of 36 new applicants in Spring 2005 received appointments this year. Eight unsuccessful and three successful candidates later transferred out of AAE to other Schools. 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, 2004-June 30, 2005

Company	Location	Number of A&AE Co-op Students
Aerospace Corporation	Los Angeles, CA	1
American Trans Air	Indianapolis, IN	0
ATA Engineering Inc.	San Diego, CA	9
Atlantic Research Automotive Group	Knoxville, TN	0
BAE Systems Control	Ft. Wayne, IN	0
Ball Aerospace & Tech. Corp.	Boulder, CO	9
Boeing Satellite Systems	Long Beach, CA	1
Delta Air Lines	Atlanta, GA	0
General Electric GE Transportation/Aircraft Engines	Cincinnati, OH	9
General Electric Transportation*	Madisonville, KY	0
International Truck and Engine Corp.*	Fort Wayne, IN	0
Rockwell Collins	Cedar Rapids, IA	2
Rolls-Royce	Indianapolis, IN	1
Structural Analysis Engineering Corp.	Cincinnati, OH	3
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	1
U. S. Gov. NASA-Goddard Space Center	Greenbelt, MD	1
U.S. Gov. NASA-Johnson Space Center	Houston, TX	8
U.S. Gov. NASA-Kennedy Space Center	Kennedy Space Ctr., FL	2
U.S. NASA-Langley Research Center	Hampton, VA	1
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	4
United Parcel Service (Air Group)	Louisville, KY	0
United Technologies Pratt & Whitney	W. Palm Beach, FL	0
United Technologies Pratt & Whitney	East Hartford, CT	1

*indicates new co-op company

OVERVIEW OF RESEARCH AREAS AND FACILITIES

With the support of the Boeing Company and the Intel Corporation, the School was able to enhance the Design/Build/Test Laboratory. This laboratory prepares students for integrated product teams in industry. The DBT Laboratory facilitates the reduction of the build time to give students a complete design and manufacturing experience. The lab is also currently being enhanced with state-of-the-art multimedia equipment.

Many personal computers are located throughout the School. High performance computing is available using many Solaris service and Linux servers using Xeon and Opteron processors. The **High Performance Computing Cluster for Aerospace Applications** consists of a 104-CPU Linux cluster using 1.2 GHz AMD Athlon processors allowing distributed and parallel processing.

AERODYNAMICS

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

Experimental facilities include four 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. Instrumentation includes a two-component laser Doppler velocimeter system and a computer data acquisition 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.

Three small high-speed facilities are located in the **Boeing Compressible-Flow Laboratory**. The first is a 2-inch Mach-2.5 blowdown tunnel, and the second is a one-inch supersonic jet apparatus designed for nozzle-flow studies. Both can be operated in pressure-vacuum mode 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.

Lastly, the Boeing Compressible-Flow Laboratory also includes two large Ludwieg tubes. The first has a 4-inch Mach-4 test section and remains quiet to a length Reynolds number of about 400,000. A 4-inch transonic test section, completed in 2004, can also be installed. The Boeing/AFOSR Mach-6 Quiet Tunnel has a 9.5-inch Mach-6 test section, and is presently quiet to a unit Reynolds number of 2 million per foot, with further improvements expected. 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.

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 5000 lbf and pressures up to 5000 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.

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**, resides 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. Nondestructive inspection equipment includes an x-ray machine and an ultrasonic C-scan system. Additional facilities for preparing laminated composites, impact testing, and creep testing are 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.

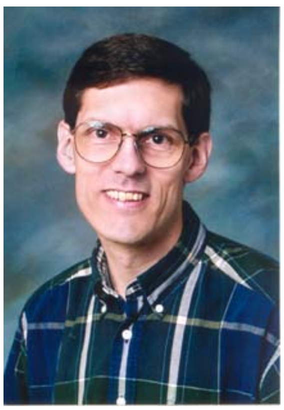
The **Tribology and Materials Processing Laboratory,** maintained jointly with the **Center for Materials Processing and Tribology** contains tribological instrumentation as well as up-to-date machines for manufacturing processes. Equipment includes a 22 kip computer-controlled electro-hydraulic test 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

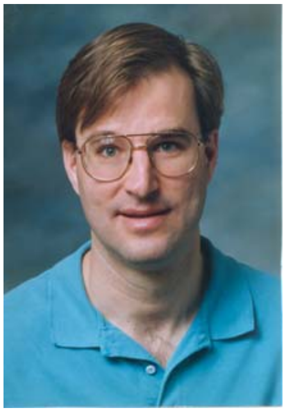


G. A. Blaisdell, Associate Professor, Ph.D. Stanford, 1991, computational fluid mechanics, transition, and turbulence

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

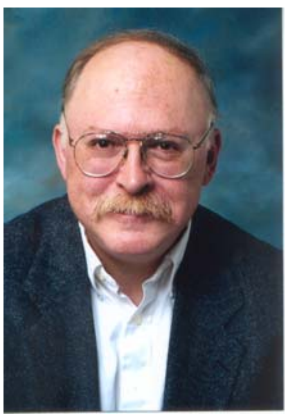
M. C. Jischke, University President, Ph.D., Massachusetts Institute of Technology, 1968

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.

Publications

Xu, C., **Heister, S. D.,** and **Blaisdell, G. A.,** "Simulation of Cavitated Flow in Orifices Fed by a Manifold," *Atomization and Sprays*, Vol. 14, January-February 2004, pp. 37-52.

Uzun, A., **Blaisdell, G. A.**, and **Lyrintzis, A. S**., "Coupling of Integral Acoustics Methods with LES for Jet Noise Prediction," *International Journal of Aeroacoustics*, October 2004, Vol. 3, No. 4, pp. 297-346(50).

Uzun, A., **Blaisdell, G. A.,** and **Lyrintzis, A. S.,** "Application of Compact Schemes to Large Eddy Simulation of Turbulent Jets," *Journal of Scientific Computing*, Vol. 21, No. 3, December 2004, pp. 283-319.

Zhang, X., **Blaisdell, G. A.,** and **Lyrintzis, A. S.,** "High-Order Schemes with Filters on Multi-Block Domains," *Journal of Scientific Computing*, Vol. 21, No. 3, December 2004, pp. 321-339.

Conference Proceedings, Presentations, Invited Lectures and Reports

Lew, P., Uzun, A., **Blaisdell, G. A**., and **Lyrintzis, A. S.**, "Effects of Inflow Forcing on Jet Noise Using Large Eddy Simulation," AIAA Paper 2004-0516, presented by P. Lew at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (9 pages).

Uzun, A., **Lyrintzis, A. S.**, and **Blaisdell, G. A.**, "Coupling of Integral Acoustics Methods with LES for Jet Noise Prediction," AIAA Paper 2004-0517, presented by A. S. Lyrintzis at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (20 pages).

Wright, C., **Blaisdell, G. A.**, and **Lyrintzis, A. S.**, "Using RANS to Predict Performance of Mixers in Reducing Jet Noise," AIAA Paper 2004-1274, presented by C. Wright at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (14 pages).

Garrison, L. A., Dalton, W. N., **Lyrintzis, A. S., Blaisdell, G. A.,** "On the Development of Semi-Empirical Noise Models for the Prediction of the Noise from Jets with Forced Mixers," AIAA Paper 2004-2898, presented by L. A. Garrison at the *10th AIAA/CEAS Aeroacoustics Conference,* Manchester, United Kingdom, May 2004.

Blaisdell, G. A., and Eshpuniyani, B., "A DNS Study of Strained Turbulent Axial Vortices," Bulletin of the American Physical Society, Vol. 49, No. 9, p. 88. Presented at the *57th Annual Meeting of the Division of Dynamics of the American Physical Society,* Seattle, Washington, November 21-23, 2004.

STEVEN C. COLLICOTT
1991
Associate 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

Weislogel, M. M., and **Collicott, S. H.,** "Computing Existence and Stability of Capillary Surfaces using Surface Evolver," *AIAA Journal*, Vol. 42, February 2004, pp. 289-295.

Chen, Y., and **Collicott, S. H.,** "Investigation of the Symmetric Wetting of a Vane-Wall Gap in Propellant Tanks," *AIAA Journal*, Vol. 42, February 2004, pp. 305-314.

Weislogel, M. M., and **Collicott, S. H.,** "Capillary Re-Wetting of Vaned Containers: Application to Spacecraft Tank Rewetting Following Thrust Resettling," *AIAA Journal,* Vol. 42**,** June 2004**,** pp. 2551-2561.

Conference Proceedings, Presentations, Invited Lectures and Reports

Chen, Y., and **Collicott, S. H.,** "Experimental study on the Capillary Flow in the Vane-Wall Gap Geometry," *42nd AIAA Aerospace Sciences Meeting,* Reno, Nevada, January 2004.

Weislogel, M. M., **Collicott, S. H.,** Gotti, D., Bunnel, C., Kurta, C., and Golliher, E., "The Capillary Flow Experiment: Handheld Fluids Experiments for the International Space Station," AIAA paper 2004-1148, *42nd AIAA Aerospace Sciences Meeting,* Reno, Nevada, January 2004.

Yip, A., Yendler, B., Martin, T. A., and **Collicott, S. H.,** "Anik-E Spacecraft Life Extension," *Eighth International Conference on Space Operations*, Montreal, Quebec, Canada. May 17-21, 2004.

Collicott, S. H., Chen, Y., and Karnes, R., "Fluids Research in the Purdue University Drop Tower," *7th Drop Tower Days*, University of Bremen, Bremen, Germany. September 12-15, 2004.

Lindsley, W., **Collicott, S. H.,** and Frazer, D. G., "Asymmetric Droplets vs. Axisymmetric Toroids: Liquid-Gas Interfaces in Small Pulmonary Airways," *Biomedical Engineering Society 2004 Annual Fall Meeting*, Philadelphia, Pennsylvania, October 13-16, 2004. (Poster)

Collicott, S. H., and Manning, R. E., "Critical Bond Numbers for Bubbles in Pores of Packed Spheres," *American Physical Society Division of Fluid Dynamics Meeting,* Seattle, Washington. November 21-23, 2004.

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

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 source 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.

Rotorcraft Impulsive Noise: In recent years the increasing use of helicopters and the projected use of tiltrotor aircraft have drawn attention to the noise that they generate. Among the several types of helicopter and tilt rotor noise, that due to helicopter impulsive noise is the most important. Dr. Lyrintzis has introduced the application of Kirchhoff's methodology for rotorcraft impulsive noise prediction. The details of the noise mechanisms are studied extensively and analogies to other unsteady motions are drawn. Both full potential as well as Euler/Navier Stokes codes are employed for the aerodynamic near-field prediction. Dr. Lyrintzis also investigates ideas for noise reduction (e.g. blade tip shape).

Jet Noise: Jet noise prediction is a very important part of aircraft noise. Dr. Lyrintzis has employed Kirchhoff's method in jet noise prediction as well. He introduced an important extension to the method in order to include non-linear flow regions that exist downstream of the computational Computational Fluid Dynamics (CFD) domain. Dr. Lyrintzis proved the equivalence of Acoustic Analogy methods (based on the Ffowcs Williams Hawkings [FWH] equation) and Kirchhoff's methods, as part of the extensions of the Kirchhoff method. He also added mean flow refraction corrections (downstream of the control surface) in the methodology. Currently, a new high-order accurate three-dimensional Large Eddy Simulation (LES) CFD code is being developed (with Professor Blaisdell) to provide accurate input data for the Kirchhoff and FWH equation methods. This is part of a large-scale effort in jet noise reduction in collaboration with Rolls-Royce, Indianapolis.

Dr. Lyrintzis' research demonstrates 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.

b. Efficient Parallel Methods for Transonic Flow Calculations.

Dr. Lyrintzis is also investigating the development of efficient computational techniques for the calculation of unsteady transonic flow on parallel machines. The goal is to improve efficiency and parallelization of legacy CFD codes. Dr. Lyrintzis studies unsteady three-dimensional problems in rotorcraft aerodynamics to enhance the computational efficiency of impulsive rotorcraft noise calculations. The algorithm methodologies developed are general and can be readily applied to several existing CFD codes. This work has been funded by NASA Ames Research Center.

Sponsored Research Summaries

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.

Aerodynamic and Aeroacoustic Optimization of Airfoils via a Parallel Genetic Algorithm (Principle Investigator: H. Namgoong; Co-Principal Investigator: W. A. Crossley; Sponsored by Purdue Research Foundation)

A parallel genetic algorithm (GA) was used to generate, in a single run, a family of aerodynamically efficient, low-noise rotor blade designs representing the Pareto optimal set. The n-branch tournament, uniform crossover, genetic algorithm operates on twenty design variables which constitute the control points for a spline representing the airfoil surface. The GA takes advantage of available computer resources by operating in either serial mode or manager/worker parallel mode. The multiple objectives of this work were to maximize lift-to-drag of a rotor airfoil shape and to minimize an overall noise measure including effects of loading and thickness noise of the airfoil. Constraints are placed on minimum lift coefficient, pitching moment and boundary layer convergence. The program XFOIL provides aerodynamic analysis, and the code WOPWOP provides aeroacoustic analysis. The Pareto-optimal airfoil set has been generated and is compared to the performance of a typical rotorcraft airfoil under identical flight conditions.

Conference Proceedings, Presentations, Invited Lectures and Reports

Pan F., Uzun, A., and **Lyrintzis, A. S.**, “Refraction Corrections for Surface Integral Methods in Jet Aeroacoustics,” AIAA paper 2004-2873, presented at the *10th AIAA/CEAS Aeroacoustics Conference,* Manchester, United Kingdom, May 2004.

Lew, P., Uzun, A., **Blaisdell, G. A**., and **Lyrintzis, A. S.**, “Effects of Inflow Forcing on Jet Noise Using Large Eddy Simulation,” AIAA paper 2004-0516, presented by P. Lew at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (9 pages).

Uzun, A., **Lyrintzis, A. S.**, and **Blaisdell, G. A.**, “Coupling of Integral Acoustics Methods with LES for Jet Noise Prediction,” AIAA paper 2004-0517, presented by A. S. Lyrintzis at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (20 pages).

Wright, C., **Blaisdell, G. A.**, and **Lyrintzis, A. S.**, “Using RANS to Predict Performance of Mixers in Reducing Jet Noise,” AIAA paper 2004-1274, presented by C. Wright at the *42nd Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 5-8, 2004 (14 pages).

Garrison, L. A., Dalton, W. N., **Lyrintzis, A. S.,** and **Blaisdell, G. A.,** “On the Development of Semi-Empirical Noise Models for the Prediction of the Noise from Jets with Forced Mixers,” AIAA paper 2004-2898, presented by L. A. Garrison at the *10th AIAA/CEAS Aeroacoustics Conference,* Manchester, United Kingdom, May 2004.

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

Hypersonic and supersonic laminar-turbulent transition
Experimental fluid mechanics

Research Areas

High-speed laminar-turbulent transition increases heating and skin friction by a factor of 2-8, making it critical for applications including air-breathing hypersonic cruise vehicles, re-entry vehicles, supersonic transports, and 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 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

NASA Langley developed quiet supersonic tunnels during the 70's, 80's, and 90'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 complement the expensive quiet-flow facilities developed at NASA Langley, an 18-inch stainless-steel Ludwieg tube with a 9.5-inch quiet-flow Mach-6 test section has been developed. Quiet-flow operation was recently achieved to a unit Reynolds number of 2 million per foot, 2/3 of the design value, with further improvements expected. This Boeing/AFOSR Mach-6 Quiet Tunnel is presently the only hypersonic quiet tunnel in the world. Modern digital and optical instrumentation enable efficient use of the 6 to 10 second run-time, and the short duration keeps operating costs low. The larger test section enables testing with larger models and thicker boundary layers. Instrumentation includes a laser perturber to generate repeatable wave packets in the flow and a glow-discharge apparatus for generating repeatable surface perturbations. Instabilities are measured using hot wires, high-sensitivity laser differential interferometry, arrays of surface hot films, fast pressure transducers, and temperature-sensitive paints.

Publications

Schneider, S. P., "Hypersonic Laminar-Turbulent Transition on Circular Cones and Scramjet Forebodies," *Progress in Aerospace Sciences*, Vol. 40, No. 1-2, January-February 2004, pp. 1-50.

Conference Proceedings, Presentations and Invited Lectures

Schneider, S. P., Rufer, S., Skoch, C., Swanson, E., and Borg, M., "Instability and Transition in the Mach-6 Quiet Tunnel," AIAA paper 2004-2247, presented at the *AIAA Fluid Dynamics Meeting,* Portland, Oregon, January 2004.

Schneider, S. P., Skoch, C., Rufer, S., and Swanson, E., "Bypass Transition on the Nozzle Wall of the Boeing/AFOSR Mach-6 Quiet Tunnel," AIAA paper 2004-0250, presented at the *AIAA Aerospace Sciences Meeting,* Reno, Nevada, January 2004.

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 paper 2004-0097, presented at the *AIAA Aerospace Sciences Meeting,* Reno, Nevada, January 2004, 15 pages including 15 figures.

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

Book

Liu, T. and **Sullivan, J. P.**, <u>Pressure and Temperature Sensitive Paint</u>, Springer-Verlag, 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Gregory, J. W., and. **Sullivan J. P.,** "Effect of Quenching Kinetics on the Unsteady Response of Pressure-Sensitive Paint," AIAA paper 2004-879, *42nd AIAA Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January. 5-8, 2004

Gregory, J. W., **Sullivan, J. P.**, Raman, G, and Raghu, S., "Characterization of a Micro Fluidic Oscillator for Flow Control," AIAA paper 2044-2692, *2nd AIAA Flow Control Conference,* Portland, Oregon, 2004.

Gregory, J. W., and **Sullivan, J. P.**, and Raghu, S.,"Visualization of Internal Jet Mixing in a Fluidic Oscillator," *11th International Symposium on Flow Visualization,* University of Notre Dame, 2004.

Smith, J. A., and **Sullivan J. P.**, "A CCD System for Capturing Wave Profiles in Deicer/Anti-icer Fluids" *11th International Symposium on Flow Visualization,* University of Notre Dame, 2004.

Gnanamanickam, E. P., **Sullivan, J. P**., and Shelley II, W. F. "Material Properties of Piezoeceramics at Elevated Temperatures," *Proceedings of SPIE – The International Society for Optical Engineering,* Vol. 5387, *Smart Structures and Materials 2004 – Active Materials: Behaviour and Mechanics, 2004,* pp. 421-431

Gnanamanickam, E. P., **Sullivan J. P**., and Brosch J., "Temperature Dependence of a Piezoelectric Sensor," *Proceedings of IEEE - UFFC 50th Annual Joint Conference,* Montreal, Canada, August 23-27, 2004.

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

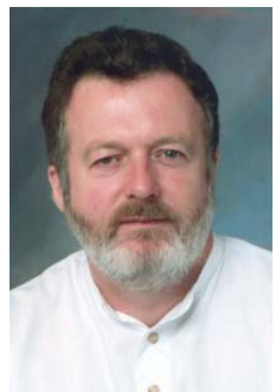
The determination of aeroelastic stability and forced response characteristics of flight vehicles requires methods for predicting the unsteady aerodynamic loads that are induced by structural deformation and/or free stream disturbances. Current research is directed at developing such methods for transonic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

Publications

Hoshizaki, T., **Andrisani, II, D.,** Braun, A. Mulyana, A., and Bethel, J.,"Performance of Integrated Electro-Optical Navigation Systems," *NAVIGATION: Journal of the Institute of Navigation*, Vol. 51, No. 2, 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Krozel, J., and **Andrisani II, D.,** Ayoubi, M., and Hoshizaki, T., "ADS-B Data Integrity Check," AIAA paper 2004-6263, *AIAA Fourth Aviation Technology Integration and Operations (ATIO) Forum*, Chicago, Illinois, September, 20–22, 2004.

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

Tu, J. F., **Corless, M.**, and Jeppson, J., "Robust Control of High Speed End Milling with Unknown Process Parameter and CNC Delay," *Journal of Aerospace Engineering*, Vol. 17, No. 1, 2004.

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

Publications

DeLaurentis, D. A., and Callaway, R. K., "A System-of-Systems Perspective for Future Public Policy," *Review of Policy Research*, Vol. 21, Issue 6, November 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Lim, C., **DeLaurentis, D. A.**, and Mavris, D., "A Methodology for Assessing Business Models of Future Air Transportation in the Atlanta Regional Transportation System," AIAA paper 2004-634, *Proceedings of AIAA 4th Aviation Technology, Integration and Operations (ATIO) Forum,* Chicago, Illinois, September 20-22, 2004.

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

Frazho, A.E. and Kaaeshoek, M.A., "A Naimark Dilation Perspective on Nevanlinna-Pick Interpolation," *Integral Equations and Operator Theory*, Vol. 49, (2004), pp. 323–378.

Frazho, A.E., Yagci, B., and Sumali, H., "On Sinusoid Estimation in Nonstationary Noise," *Institute of Electrical and Electronics Engineers (IEEE) Transactions on Automatic Control*, Vol. 49, No. 5, (2004), pp. 777–781.

JAMES L. GARRISON
Assistant 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

You, H., **Garrison, J. L**., Heckler, G. W., and Zavorotny, V. U., "Stochastic Voltage Model and Experimental Measurement of Ocean Scattered GPS Signals," *IEEE Transactions on Geoscience and Remote Sensing,* Vol. 42, No. 10, October 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Ziedan, N., and **Garrison, J. L**., "Unaided Acquisition of Weak GPS Signals Using Circular Correlation and Double-Block Zero Padding," *IEEE Position, Location and Navigation Symposium (PLANS*), Monterey, California, April 26-29, 2004.

Heckler, G .W., and **Garrison, J. L**., "Architecture of a Reconfigurable Software Receiver," *ION GNSS 2004*, Long Beach, California, September 21-24, 2004

Ziedan, N., and **Garrison, J. L.**, "Extended Kalman Filter-Based Tracking of Weak GPS Signals Under High Dynamic Conditions," *ION GNSS 2004*, Long Beach, California, September 21-24, 2004.

You, Huaizu, **Garrison, J. L**., Heckler, Greg W., and Smajlovic, Dino, "Correlation Time Analysis of Delay-Doppler Waveforms Generated from Ocean-Scattered GPS Signals," *International Geosciences and Remote Sensing Symposium*, Anchorage, Alaska, September 20-24, 2004.

Garrison, J. L., "Computationally Efficient Inversion of Scattered GPS Signals for the Retrieval of Surface Winds or Roughness from and Airborne Receiver," *American Geophysical Union Fall Meeting,* San Francisco, California, December 13-17, 2004.

Lee, See-Chen, **Garrison, J. L**., Calais, E., and Haase, J., "Detection and Investigation of Ionospheric Disturbances using the SCIGN Network," *American Geophysical Union Fall Meeting,* San Francisco, California, December 13-17, 2004.

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 Formations and Control Strategies for Non-Natural Formation near the Libration Points," *Dynamical Systems: an International Journal, Special Issue*: "Dynamical Systems in Dynamical Astronomy and Space Mission Design," 2004 (invited).

Conference Proceedings, Presentations, Invited Lectures and Reports

Marchand, B. G., and **Howell, K. C.**, "Aspherical Formations Near the Libration Points in the Sun-Earth/Moon Ephemeris System," AAS paper 04-157, *2004 AAS/AIAA Space Flight Mechanics Conference,* Maui, Hawaii, February 8-11, 2004.

Howell, K., Beckman, M., Patterson, C., and Folta, D., "Representations of Invariant Manifolds for Applications in Three-Body Systems," AAS paper 04-287, *2004 AAS/AIAA Space Flight Mechanics Conference,* Maui, Hawaii, February 8-11, 2004.

Folta, D., Hartman, K., **Howell, K**., and Marchand, B., "Formation Control of the MAXIM L_2 Libration Point Mission," AIAA paper 2004-5211, *AIAA/AAS Astrodynamics Conference,* Providence, Rhode Island, August 2004.

Howell, K. C., and Marchand, B. G., "Formations Near the Libration Points: Design Strategies Using Natural and Non-Natural Arcs," *2nd International Symposium on Formation Flying Missions & Technologies,* Washington, DC, September 2004.

Howell, K. C., "Spacecraft Mission Design in Multi-Body Regimes and the Application of Dynamical Systems," Department of Mathematics, NSF IGERT Program: Dynamics of Complex Systems in Science and Engineering, Northwestern University, October 29, 2004.

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

Publications

Balakrishnan, H., **Hwang, I.,** Jang, J., and Tomlin, C., "Inference Methods for Autonomous Stochastic Linear Hybrid Systems," In *Hybrid Systems: Computation and Control, Lecture Notes in Computer Science*, Springer Verlag, March 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Hwang, I., Roy, K., Balakrishnan, H., and Tomlin, C., "A Distributed Multiple-Target Identity Management Algorithm in Sensor Networks," *Proceedings of the 43rd IEEE Conference on Decision and Control,* Atlantis, Paradise Island, Bahamas, December 2004.

Balakrishnan, H., **Hwang, I.,** and Tomlin, C., "Polynomial Approximation Algorithm for Belief Matrix Maintenance in Identity Management," *Proceedings of the 43rd IEEE Conference on Decision and Control,* Atlantis, Paradise Island, Bahamas, December 2004.

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.

Book

Longuski, J. M., Advice to Rocket Scientists, American Institute of Aeronautics and Astronautics, Inc., Restin, Virginia, January 2004, 86 pages.

Publications

McConaghy, T. T., **Longuski, J. M**., and Byrnes, D. V., "Analysis of a Class of Earth-Mars Cycler Trajectories," *Journal of Spacecraft and Rockets*, Vol. 41, No. 4, July–August 2004, pp. 622–628.

Petropoulos, A. E. and **Longuski, J. M**., "Shape-Based Algorithm for Automated Design of Low-Thrust, Gravity-Assist Trajectories," *Journal of Spacecraft and Rockets*, Vol. 41, No. 5, September–October 2004, pp. 787–796.

Johnson, W. R., **Longuski, J. M.**, and Lyons, D. T., "Six-Degree-of-Freedom Modeling of Semi-Autonomous Attitude Control During Aerobraking," *Journal of Spacecraft and Rockets*, Vol. 41, No. 5, September–October 2004, pp. 797–804.

Jokic, M. D. and **Longuski, J. M**., "Design of Tether Sling for Human Transportation Systems Between Earth and Mars," *Journal of Spacecraft and Rockets*, Vol. 41, No. 6, November–December 2004, pp. 1010–1015.

Conference Proceedings, Presentations, Invited Lectures and Reports

Landau, D. F. and **Longuski, J. M**., "A Reassessment of Trajectory Options for Human Missions to Mars," AIAA paper 2004-5095, *AAS/AIAA Astrodynamics Specialist Conference,* Providence, Rhode Island, August 16-19, 2004.

McConaghy, T. T. and **Longuski, J. M**., "Parameterization Effects on Convergence When Optimizing a Low-Thrust-Trajectory with Gravity Assists," AIAA paper 2004-5403, *AAS/AIAA Astrodynamics Specialist Conference,* Providence, Rhode Island, August 16-19, 2004.

Park, R. S., Scheeres, D. J., Giampieri, G., **Longuski, J. M**., and Fischbach, E., "Orbit Design for General Relativity Experiments: Heliocentric and Mercury-centric Cases," AIAA paper 2004-5394, *AAS/AIAA Astrodynamics Specialist Conference,* Providence, Rhode Island, August 16-19, 2004.

Yam, C. H., McConaghy, T. T., Chen, K. J., and **Longuski, J. M.**, "Preliminary Design of Nuclear Electric Propulsion Missions to the Outer Planets," *AAS/AIAA Astrodynamics Specialist Conference,* Providence, RI, August 16-19, 2004.

Yam, C. H., McConaghy, T. T., Chen, K. J., and **Longuski, J. M**., "Design of Low-Thrust Gravity-Assist Trajectories to the Outer Planets," paper IAC-04-A.6.02, *55th International Astronautical Congress,* Vancouver, Canada, October 4–8, 2004.

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

Research Areas

Active Projects

Analysis and Design of Multivariable Extremum Seeking Algorithms, NSF, September 2000—August 2004

Parameter Estimation for Airdrop System, Fleet and Industrial Supply Center, July 2000—September 2003

Colorimetric Modeling using Robust Parameter Estimation, Xerox, August 2001—July 2004

Mission Design and Analysis Involving Formation Flying Near Libration Point Orbits, NASA (PI: K. Howell), July 2003—June 2006

Air Traffic Management for the 21st Century and Beyond, e-Enterprise Center & VP for Research (with D. Andrisani, A. Chaturvedi, T. Carney, M. Nolan), July 2003—June 2004

Purdue Center for Security of Large Scale Systems, Task on Real-Time Thermal Monitoring of Electric Machines, March 2004 – February 2005

Conference Proceedings, Presentations, Invited Lectures and Reports

Li, Y., **Rotea, M.,** Chiu, G., Mongeau, L., and Paek, I., "Extremum Seeking Control of Tunable Thermoacoustic Cooler," *2004 American Control Conference,* Boston, Massachusetts, June 2004, pp. 2033-2038.

Rotea, M., and Lana, C., "A Robust Estimation Algorithm for Printer Modeling," Tutorial Session on: Sensing, Modeling and Control of Xerography, *2004 American Control Conference,* Boston, Massachusetts, June 2004, pp. 2636-2641, (invited paper).

Adams; D.E., Smith; M. J., Chaturvedi; A., **Rotea, M.,** Hoffmann; C., and Craig, B., **"**Integrated Prognostic System of Systems Health Management," *Proceedings of the Materials Science and Technology Conference,* New Orleans, Louisiana, September 26-29, 2004, (invited paper).

Adams, D. E., Smith, M. J., Chaturvedi, A., **Rotea, M.**, Hoffmann, C., and Craig, B., **"**Integrated Prognostic System of Systems Health Management," Workshop on Integrated Systems Health Monitoring, Air Force Research Laboratory, Dayton, Ohio, 2004.

Rotea, M., "Optimization and Control of Civil and Mechanical Systems," Civil and Mechanical Systems Division, NSF, Arlington, VA, 2004.

PROPULSION

Faculty & Staff Member

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

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

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

C. L. Merkle, 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

Anderson, W. E., "Rocket Engines," *Encyclopedia of Energy*, Elsevier Press, 2004, pp. 483-491.

Anderson, W. E., Long, M. R., and **Heister, S. D.**, "Liquid Bipropellant Injectors," *Liquid Rocket Thrust Chambers: Aspects of Modeling, Analysis, and Design*, Chapter 4, AIAA Progress in Astronautics and Aeronautics, Volume 200, 2004.

Conference Proceedings, Presentations, Invited Lectures and Reports

Anderson, W. E., Long, M. R., **Heister, S. D.,** and Canino, J. V., "Main Chamber Injector Studies for Advanced Hydrocarbon Booster Engines," *52nd JANNAF/1st Liquid Propulsion Subcommittee Meeting,* Las Vegas, Nevada, May 12-15, 2004.

Miller, K. J., **Anderson, W. E**., and **Heister, S. D.,** "Investigation of Liquid Rocket Injector Element Stability Margins," *52nd JANNAF/1st Liquid Propulsion Subcommittee Meeting,* Las Vegas, Nevada, May 12-15, 2004.

Yu, Y.-C., Schuff, R. W., and **Anderson, W. E.**, "Liquid Film Cooling Using Swirl in Rocket Combustors," AIAA paper 2004-3360, *40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Fort Lauderdale, Florida, July 12-14, 2004.

Jos, C. C., Miller, K. J., and **Anderson, W. E.**, "Ducted Rocket with Simultaneous Mixing and Combustion Direct-Connect Testing," AIAA paper 2004-3650, *40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Fort Lauderdale, Florida, July 12-14, 2004.

Long, M. R., and **Anderson, W. E.**, "Oxidizer-Rich Staged Combustion Preburner and Main Chamber Injector Testing at Purdue University," AIAA paper 2004-3524, *40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Fort Lauderdale, Florida, July 12-14, 2004.

Pourpoint, T. L., and **Anderson, W. E.**, "Physical and Chemical Processes Controlling Fuel Droplet Ignition," AIAA paper 2004-4009, *40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Fort Lauderdale, Florida, July 12-14, 2004.

Anderson, W.E., "Combustion at Purdue," General Electric Combustion Symposium, October 2004.

Anderson, W.E., "Propulsion at Purdue," 2004 FAA Launch Forecast, Washington, DC, February 20, 2004.

Heister, S. D., Anderson, W. E., Merkle, C. L., and **Hrbud, I.**, "Propulsion Educational Programs and Facilities at Purdue University," AIAA paper 2004-3324, *40th AIAA Joint Propulsion Conference,* 2004.

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.

Book Chapter

Heister, S. D., Rockets, *World Book Encyclopedia*, pp 185-204, World Book Publishing, 2004

Publications

Yoon, S. S., and **Heister, S. D.**, "A Nonlinear Atomization Model Based on a Boundary Layer Instability Mechanism," *Physics of Fluids*, Vol. 16, No.1, 2004, pp. 47-61.

Yoon, S. S., and **Heister, S. D**., "A Fully Nonlinear Model for Atomization of High-Speed Jets," *Engineering Analysis with Boundary Elements*, Vol. 28, 2004, pp 345-357.

Chao,C.-C., and **Heister, S. D**., "Contributions of Atomization to F-1 Engine Combustion Instabilities," *Engineering Analysis with Boundary Elements*, Vol. 28, 2004, pp. 1045–1053.

Kim, B-D, and **Heister, S. D.**, "Two-Phase Modeling of Hydrodynamic Instabilities in Coaxial Injectors," *J. Propulsion and Power*, Vol. 20, 2004, pp. 468-479.

Yoon, S. S., and **Heister, S. D.**, "Analytical Formulas for the velocity field induced by an infinitely thin Vortex Ring," *International J. for Numerical Methods in Fluids*, Vol. 44, 2004, pp. 665-672.

Xu, C., **Heister, S.D.,** and **Blaisdell, G.A.,** "Simulation of Cavitated Flow in Orifices Fed by a Manifold," Atomization and Sprays, Vol. 14, 2004, pp. 37-52.

Conference Proceedings, Presentations, Invited Lectures and Reports

Kim, B. D., and **Heister, S. D**., "Effect of Chamber Pressure Variation on High-Frequency Hydrodynamic Instability of Shear Coaxial Injector," AIAA paper 2004-3522, *40th AIAA Joint Propulsion Conference,* 2004.

Corpening, J., **Heister, S. D., Anderson, W. E**, and Austin, B., "A Model for Thermal Decomposition of Hydrogen Peroxide," AIAA paper 2004-3373, *40th AIAA Joint Propulsion Conference,* 2004.

Hawkins, T. W., Brand, A. J., Drake, G. W., Austin, B. J., and **Heister, S. D**., "Development of Bipropellants Based on Ionic Liquid Fuel," *JANNAF Combustion Meeting,* 2004.

Park, H., and **Heister, S. D.**, "A Numerical Study of Primary Instability of Viscous High-Speed Jets," *ILASS Americas 17th Annual Conference,* 2004.

Canino, J. V., **Heister, S. D.**, and Garrison, L. A., "Hydrodynamic Modeling of Oxidizer-Rich Staged Combustion Injector Flow," *52nd JANNAF Propulsion Meeting,* 2004.

Hawk, C., Santoro, R., **Heister, S. D.,** and **Merkle, C.,** "The Rocket Engine Advancement Program (REAP2)," *52nd JANNAF Propulsion Meeting,* 2004.

IVANA HRBUD
2003
Assistant Professor

Degrees

Diplom-Ingenieur (Master's Degree) Stuttgart University, Germany, Aerospace Engineering 1993
Ph.D., Auburn University, Aerospace Engineering, 1997

Interests

Electric Propulsion
Space Power
Advanced In-Space Propulsion

Publications

Hrbud, I., "Electron Density and Two-Channel Neutron Emission Measurements in Steady-State Spherical Inertial Electrostatically Confined Plasmas, with Review of the One-dimensional Kinetic Model," *Journal of Applied Physics*, Vol. 96, No. 1, July 2004, pp. 94-108.

Conference Proceedings, Presentations, Invited Lectures and Reports

Heister, S. D., Anderson, W. E., Merkle, C. L., and **Hrbud, I.**, "Propulsion Educational Programs and Facilities at Purdue University," AIAA paper 2004-3324, *40th AIAA Joint Propulsion Conference,* 2004.

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

Sankaran, V., **Merkle, C**., Zeng, X., and Li, D., "Influence of Large-Scale Pressure Changes on Preconditioned Solutions at Low Speeds," *AIAA Journal,* Vol. 42, No. 12, December 2004, pp. 2490–2498.

Conference Proceedings, Presentations, Invited Lectures and Reports

Hawk, R.. Santoro, **Heister, S. D.,** and **Merkle, C.,** "The Rocket Engine Advancement Program (REAP2)," *52nd JANNAF Propulsion Meeting,* 2004.

Heister, S. D., Anderson, W. E., Merkle, C. L., and **Hrbud, I.**, "Propulsion Educational Programs and Facilities at Purdue University," AIAA paper 2004-3324, *40th AIAA Joint Propulsion Conference,* 2004.

Merkle, C., Li, D., and Sankaran, V., "Analysis of Regen Cooling in Rocket Combustors," *JANNAF Propulsion Conference,* Las Vegas, Nevada, May 10–13, 2004.

Merkle, C., Sankaran, V., and Ellis, M., "Computational Simulation of Acoustic Modes in Rocket Combustors," *ANNAF Propulsion Conference,* Las Vegas, Nevada, May 10–13, 2004.

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.

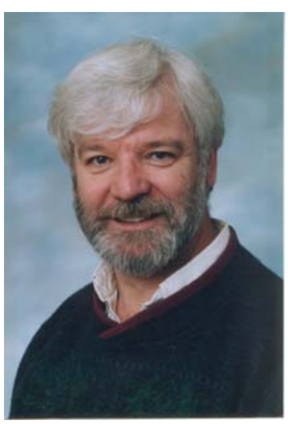
Mr. Meyer is a co-patent holder for a hybrid rocket engine ignition device.

STRUCTURES AND MATERIALS

Faculty Members

W. Chen, Associate 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, Assistant Professor, Freshman Engineering, 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, 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
Associate 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

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.,** and Chen, M., "A Novel Model for Uniaxial Strain-Rate-Dependent Stress-Strain Behavior of EPDM Rubber in Compression or Tension," *Journal of Applied Polymer Science*, Vol. 92, 2004, pp. 1553-1558.

Song, B. and **Chen, W.,** "Dynamic Compressive Behavior of EPDM Rubber under Nearly Uniaxial Strain Condition," *Transaction of the ASME, Journal of Engineering Materials and Technology*, Vol. 126, No. 2, 2004, pp. 213-217.

Chen, W. and Luo, H., "Dynamic Compressive Responses of Intact and Damaged Ceramics from a Single Split Hopkinson Pressure Bar Experiment," *Experimental Mechanics*, Vol. 44, No. 3, 2004, pp. 295-299.

Song, B. and **Chen, W.,** "Dynamic Stress Equilibrating Process in a Rubber Specimen during a Split Hopkinson Pressure Bar Experiment," *Experimental Mechanics*, Vol. 44, no. 3, 2004, pp. 300-312.

Song, B., **Chen, W.,** and Frew, D. J., "Quasi-Static and Dynamic Compressive and Failure Behaviors of An Epoxy Syntactic Foam," *Journal of Composite Materials*, Vol. 38, no. 1, 2004, pp. 915-936.

Luo, H. and **Chen, W.,** "Dynamic Compressive Responses of Intact and Damaged AD995 Alumina," *International Journal of Applied Ceramic Technology*, Vol. 1, issue 3, 2004, pp. 254-260.

Cheng, M. **Chen, W.,** and Song, B., "Phenomenological Modeling of the Stress-Strain Behavior of EPDM Rubber with Loading-Rate and Damage Effects," *International Journal of Damage Mechanics*, Vol. 13, no. 4, 2004, pp. 371-381.

Cheng, M., **Chen, W.,** and Weerasooriya, T., "Experimental Investigation of the Transverse Mechanical Properties of a Single Kevlar KM2 Fiber," *International Journal of Solids and Structures*, Vol. 41, issues 22-23, 2004, pp. 6215-6232.

Song, B. and **Chen, W.,** "Loading and Unloading SHPB Pulse Shaping Techniques for Dynamic Hysteretic Loops," *Experimental Mechanics*, Vol. 44, issue 6, 2004, pp. 622-627.

Conference Proceedings, Presentations, Invited Lectures and Reports

Cheng, M. and **Chen, W.,** "Compressive stress-strain behavior of a porcine skin perpendicular to the body axis at various loading rates," *Proceedings of the Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,* Costa Mesa, CA, June 7-10, 2004.

Song, B. and **Chen, W.,** "Loading and Unloading SHPB Pulse Shaping Techniques for Dynamic Hysteretic Loops," *Proceedings of the Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,* Costa Mesa, CA, June 7-10, 2004.

Luo, H. and **Chen, W.,** "Dilatation of AD995 Alumina Impacted by Two Consecutive Stress Pulses during a SHPB Experiment," *Proceedings of the 2004 International Conference on Computational & Experimental Engineering & Sciences,* pp. 69-74, July 26-29, 2004.

Chen, W., "Dynamic Behavior of Biological Tissues," US Army Research Laboratory, Aberdeen Proving Ground, MD, July 1, 2004.

Chen, W., "Challenges Compressive Response and Failure Behavior of Intact and Damaged Ceramics with a SHPB Experiment," Sandia National Laboratories, Albuquerque, NM, November 11, 2004.

Weerasooriya, T., Moy, P., Hsieh, A., and **Chen, W.,** "Effect of the Weight Percent of Nano-Silicate Filler on the Deformation of a Polycarbonate Nano-Composite under Different Strain Rates," *Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,* Costa Mesa, CA, June 7-10, 2004.

Forrestal, M. J., Wright, T. W., and **Chen, W.,** "The Effect of Radial Inertia on Brittle Samples During the Split Hopkinson Pressure Bar Test," *Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,* Costa Mesa, CA, June 7-10, 2004.

Frew, D. J., Forrestal, M. J., and **Chen, W.,** "Pulse Shaping Techniques to Obtain Elastic-Plastic Material Properties with a Split Hopkinson Pressure Bar," *Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,*Costa Mesa, CA, June 7-10, 2004.

Pilcher, A., Wang, X., Niebur, G., Mason, J., Song, B., Cheng, M., and **Chen, W.,** "High Strain Rate Behavior of Cancellous Bone," *Society for Experimental Mechanics 2004 Annual Meeting on Experimental and Applied Mechanics,* Costa Mesa, CA, June 7-10, 2004.

Cheng, M., **Chen, W.,** and Weerasooriya, T., "Mechanics Properties of Kevlar KM2 Single Fiber," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Chen, W. and Song, B., "Quasi-static to Dynamic Compressive Response of a Low-Density Rigid Polyurethane Foam," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Song, B., Forrestal, M. J., and **Chen, W.**, "Quasi-static Propagation of Compaction Waves in a Low Density Epoxy Foam," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Song, B., Forrestal, M. J., and **Chen, W.**, "Dynamic Propagation of Compaction Waves in a Low Density Epoxy Foam," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Frew, D. J., Forrestal, M. J., and **Chen, W.,** "Pulse Shaping Techniques to Obtain Elastic-Plastic Material Properties with a Split Hopkinson Pressure Bar," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Cheng, M., **Chen, W.,** and Weerasooriya, T., "Experimental Analysis of Damage in a Single Kevlar KM2 Fiber Caused by Transverse Compression," *ASME 2004 International Mechanical Engineering Congress and Exposition,* Anaheim, CA, November 13-19, 2004.

Chen, W., "Dilatation of AD995 Alumina Impacted by Two Consecutive Stress Pulses during a SHPB Experiment," Symposium on Advanced Computational Algorithms for Shock, Impact and Penetration Problems," *ICCES'04 International Conference on Computational & Experimental Engineering & Sciences,* Madeira, Portugal, 26-29 July 2004.

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.

Publications

Martin, E. T., Hassan, R. A., and **Crossley, W. A.,** "Comparing the N-Branch Genetic Algorithm and the Multi-Objective Genetic Algorithm," *AIAA Journal,* Vol.42, No.7, July 2004, pp. 1495-1500.

Conference Proceedings, Presentations, Invited Lectures and Reports

Hassan, R. A., and **Crossley W. A**., "Variable Population-Based Sampling for Probabilistic Design Optimization with a Genetic Algorithm," AIAA paper 2004-0452, *42nd AIAA Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 2004.

Nankani, K., **Crossley W. A.** and Raymer, D. P., "Comparison of Bit-String Affinity and Consecutive Generation Stopping Criteria for Genetic Algorithms," AIAA paper 2004-0449, *42nd AIAA Aerospace Sciences Meeting and Exhibit,* Reno, Nevada, January 2004.

Crossley, W. A., "System of Systems: An Introduction of Purdue University Schools of Engineering's Signature Area," *Engineering Systems Symposium,* MIT Engineering Systems Division, Cambridge, Massachusetts, March 2004.

Tidwell, Z., Joshi, S., **Crossley, W. A**., and Ramakrishnan, S., "Comparison of Morphing Wing Strategies Based upon Aircraft Performance Impacts," AIAA paper 2004-1722, *45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Palm Springs, California, April 2004.

Hassan, R., and **Crossley, W. A.**, “Discrete Design Optimization under Uncertainty: A Generalized Population-based Sampling Genetic Algorithm,” AIAA paper 2004-1586, *45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Palm Springs, California, April 2004.

Lamberson, S., and **Crossley, W. A.**, “Initial Optimization Studies of Multifunctional Structures With Electronic Components,” AIAA paper 2004-4555, *10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Symposium,* Albany, New York, August 2004.

Crossley, W., Mane, M., and Nusawardhana, A., “Variable Resource Allocation Using Multidisciplinary Optimization: Initial Investigations for System of Systems,” AIAA-paper 2004-4605, *10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Symposium,* Albany, New York, August 2004.

Nehrbass, J., Frommer, J., Loffing, D., Garrison, L., and **Crossley, W. A.**, “Point to Point Commercial Aircraft Service Design Study Including Formation Flight and Morphing,” AIAA paper 2004-6404 , *4th AIAA ATIO Forum,* Chicago, Illinois, September 2004.

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.

Book

Doyle, J. F., Modern Experimental Stress Analysis: Completing the Solution of Partially Specified Problems, Wiley & Sons, UK, 2004.

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 42^{nd} 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., Harish, G. and **Farris, T. N.**, "Efficient Modeling of Fretting of Blade/Disk Contacts Including Load History Effects," *ASME Journal of Tribology,* **126**, 2004, pp 56-64.

Rajeev, P. T., Murthy, H. and **Farris, T. N.**, "Load History Effects on Fretting Contacts of Isotropic Materials," *ASME Journal of Engineering for Gas Turbines and Power,* **126**, 2004, pp 385-390.

Shankar, M. Ravi, Chandrasekar, S. and **Farris, T. N.**, "Interaction Between Dislocations in a Couple Stress Medium," *ASME Journal of Applied Mechanics*, **71**, 2004, pp 546-550.

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Widdle, Jr., R. D., **Farris, T. N**., Bajaj, A. K., and Davies, P., "Modeling the contact stiffness between a 2D Voronoi Honeycomb and a Flat Rigid Surface," in *Mechanical Properties of Nanostructured Materials and Nanocomposites*, I. Ovid'ko, C.S. Pande, R. Krishnamoorti, E. Lavernia, G. Skandan, eds., Materials Research Society Symposium Proceedings, V. 791, 2004.

Matlik, J. F. and **Farris, T. N**., "Fretting of Single Crystal/Polycrystalline Nickel Contacts at Elevated Temperature and Frequency," AIAA paper 2004-1551 in *Proceedings of 45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*, Palm Springs, California, April 2004.

Farris, T. N., Murthy, H. and Gao, G., "High-Temperature Fretting Fatigue," *Proc of the 9th National Turbine Engine High Cycle Fatigue (HCF) Conference*, Pinehurst, North Carolina, April 2004.

Farris, T. N., "Fretting Fatigue," GE GRC Advanced Mechanical Technologies Seminar Series, Albany, NY, June 2004.

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.).

Book

Grandt, Jr., A. F., Fundamentals of Structural Integrity: Damage Tolerant Design and Nondestructive Evaluation, John Wiley and Sons Inc., 2004, ISBN 0-471-21459-0, 538 pages.

Publications

Grandt, Jr., A. F., and W. A. Gustafson, W. A., "History of Aerospace Education and Research at Purdue University: 1910-2002," *Aerospace Engineering Education During the First Century of Flight,* eds. B. McCormick, C. Newberry, E. Jumper, American Institute of Aeronautics and Astronautics, 2004, Chapter 30, pp. 379-398.

Golden P. J., Bartha, B. B., and **Grandt, Jr., A. F.,** T. Nicholas, "Measurement of the Fatigue Crack Propagation Threshold of Fretting Cracks in Ti-6Al-4V," *International Journal of Fatigue* Vol. 26, No. 3, 2004, pp. 281-288.

P. J. Golden, P. J., and **Grandt, Jr., A. F.,** "Fracture Mechanics Based Fretting Fatigue Life Predictions in Ti-6Al-4V," *Engineering Fracture Mechanics*, Vol. 71, Issue 15, October 2004, pp. 2229-2243.

Conference Proceedings, Presentations, Invited Lectures and Reports

Grandt, Jr., A. F., "Fundamentals of Damage Tolerance Analysis and Applications," 30 hours of lecture, AeroStructures Training, South Melbourne, Australia, 15-19 March 2004

Grandt, Jr., A. F., "Advanced Damage Tolerance Analysis," 6 hours of lecture, Rolls-Royce Royce Corporation, Indianapolis, Indiana, 14 July 2004.

Grandt, Jr., A. F., "Fundamentals of Structural Integrity," 12 hours of lecture, Naval Air Systems Command, 21-22 June 2004.

Grandt, Jr., A. F., "Fundamentals of Damage Tolerance Analysis and Applications," 30 hours of lecture, AeroStructures Training, South Melbourne, Australia, 2-6 August 2004.

Grandt, Jr., A. F., "Fundamentals of Damage Tolerance Analysis and Applications," 30 hours of lecture, Woodbourne Royal New Zealand Air Force Base, Blenheim, New Zealand, 9-13 August 2004.

Grandt, Jr., A. F., "Fundamentals of Structural Integrity," 30 hours of lecture, FAA Technical Center, Atlantic City, New Jersey, 4-8 October 2004.

PETER K. IMBRIE
Engineering Education
Assistant 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. and Kwon, H., "Buckling of Composite Flanges in Partially Disbonded Adhesive Joints," *Journal of Composite Materials*, Vol. 38, No. 24, 2004, pp. 2213-2230.

Conference Proceedings, Presentations, Invited Lectures and Reports

Kim, H., Kayir, T., and Steber, S. L., "Characterization of Transverse Impact Damage on Adhesively Bonded Glass/Epoxy Composite Joints," *Proceedings of the 45th AIAA / ASME / ASCE / AHS / ASC Structures, Structural Dynamics, and Materials (SDM) Conference*, Palm Springs, California, April 19-22, 2004.

Park, M., Hsieh, K., and **Kim, H.**, "Failure Mechanisms of Cu Embedded Multifunctional Composite Structures," *Proceedings of the 19th Annual ASC Technical Conference on Composite Materials*, Atlanta, Georgia, October 17-20, 2004.

Kim, H., "Damage Tolerance Assessment of Adhesive Joints Using VCCT," *ASTM Workshop on Computational Fracture Mechanics*, Salt Lake City, Utah, March 22-23, 2004.

Kim, H., "Embedded Electrical Interconnects in Multifunctional Composite Structures," *2004 US-Korea Conference*, Durham, North Carolina, August 12-14, 2004.

Park, M., Hsieh, K., and **Kim, H.**, "Fatigue Fracture of Cu-Embedded Multifunctional Composite Structures," *11th US-Japan Conference on Composite Materials*, Yamagata University, Yonezawa, Japan, September 9-11, 2004.

Kim, H., "Fracture-Based Disbond Growth Prediction of Postbuckled Composite Adhesive Joints," *2004 ASME International Mechanical Engineering Congress and RD&D Exposition*, Anaheim, California, November 13-19, 2004.

Kim, H. and Lee, J., "Adhesive Nonlinearity and the Prediction of Failure in Bonded Composite Lap Joints," *Joining and Repair of Composite Structures, ASTM Special Technical Publication STP1455*, ASTM International, West Conshohocken, Pennsylvania, pp. 22-41, 2004.

Tomblin, J., Seneviratne, W., **Kim. H**., and Lee, J., "Box Beam Lap Shear Torsion Testing for Evaluating Structural Performance of Adhesive Bonded Joints," *Joining and Repair of Composite Structures, ASTM Special Technical Publication STP1455*, ASTM

Kedward, K.T. and **Kim, H.,** *Joining and Repair of Composite Structures*, ASTM Special Technical Publication 1455, West Conshohocken, Pennsylvania, 2004.

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

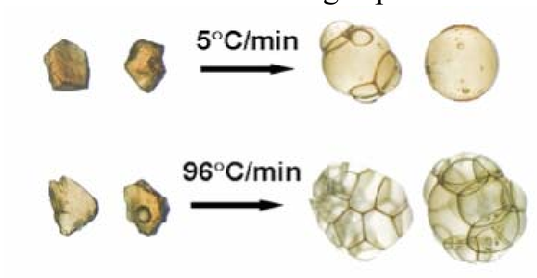
Professional Activities

US Chair, US/Japan Conference on Composite Materials, 2008 (in Japan)
Editorial Board, Composites Science and Technology

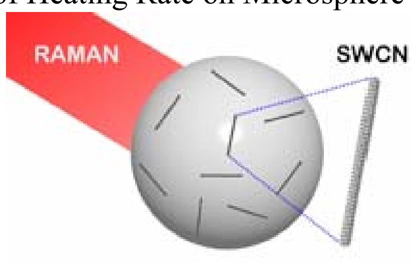
Research Areas

Functionally Gradient Polyimide Foams with insitu Carbon Nanotube Sensors

The integration of carbon nanotechnology and solid state forming of high temperature polymeric cellular materials has the potential to yield functionally gradient cellular materials with insitu sensing to meet a number of important aerospace applications. Cellular microstructures of high temperature polymers can provide both high specific strength and stiffness in thermal, acoustic and structural applications. In the former case these material systems offer excellent thermal insulation as neat polymers or conduction properties by the incorporation of a carbon nanotube second phase. Through their Raman spectra, the carbon nanotube second phase can also serve as an insitu sensor for the determination of local phenomena such as strain, pressure and temperature in the cellular structure. Functionally gradient cellular structures can be produced through the solid state synthesis of polyimide polymer foams. By controlling the particle size distribution, the powder precursor form of the polyamic acid can be deposited and foamed in place to achieve the layered microstructure and designed gradients in properties of the cellular material. First, a thorough development of the processing-structure-property relationships for these innovative material forms must be undertaken. The proposed work follows earlier work by the author in the solid state synthesis of polyimide foams wherein the kinetics and kinematics of foam formation were studied. The new efforts will focus on development of layered structures in cellular materials wherein the cell size or polymer composition is varied in a prescribed manner. In the next phase, the incorporation of single-walled carbon nanotubes (SWCN) within the cell walls of the cellular structure will be examined by adding and dispersing SWCN in the polyamic acid precursor prior to the imidization step. The production of single polyimide microspheres will provide a platform for development of the sensor technology. Polarized micro-Raman spectroscopy will be utilized to examine spherical deformations due to external loading environments by observing the Raman spectrum. Both laser scanning of cellular structure surface and subsurface sensing via fiber optic connections to microsphere sensors will be examined. These concepts will be integrated in the final step in order to demonstrate the concept of functionally gradient materials with insitu sensing capabilities.



Influence of Heating Rate on Microsphere Morphology.



Polyimide Microsphere with SWCN as Raman-Active Embedded Sensor.

Ultra Lightweight Skin Material Systems for High Altitude Vehicles

The performance of high altitude vehicles is enhanced as vehicle weight is reduced and since the largest fraction of vehicle structure is likely the skin, the benefit in development of ultra-light materials systems is clear. Nature often responds to similar requirements in physiological systems through cellular material structures. The present approach to development of ultra-light materials is to produce cellular polymer structures that can be combined with ultra-thin, high performance fiber composites to produce hybrid materials systems with extraordinary specific strength (strength-to-weight ratio). In a second step will be to explore the concept of encapsulation of helium within the closed cells of the cellular material with the goal of developing material systems that approach "lighter than air materials." In order to achieve a significant performance increase, a goal of 200 grams/square meter has been established for the skin material. The development of barrier film technology to be combined with the polymer composite for retention of the small molecule of helium within the skin will also be pursued.

The ultra-light materials will be developed from a high temperature polymer with acceptable performance properties above 300 degrees Centigrade. Functionally gradient cellular structures will allow for tailoring the cellular structure to allow for optimum compatibility with the ultra-thin polymer composite, as well as, providing for enhance helium encapsulation.

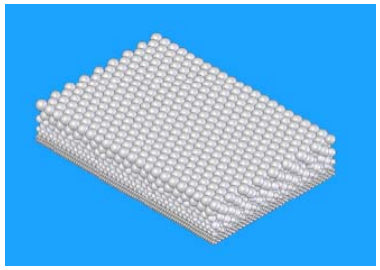


Figure 1. Functionally gradient cellular polymer structures.

Recently, polyimide foams made from solid-state solutions of poly(amic acid) have been obtained with the blowing agent used as a solvent such as THF, Glyme or Dioxane, (that complex by hydrogen bonding to the diacid-diester and later to the poly(amic acid) structure [1] while serving as the solvent for the poly(amic acid) formation. The presence of the complexing solvent allows for a more controlled reaction until optimum foaming conditions are developed.

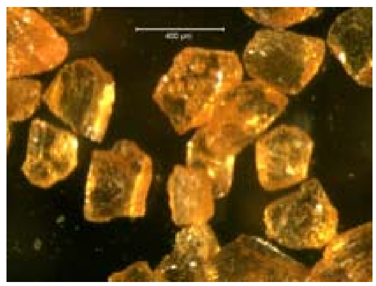


Figure 2. Poly(amic acid) particles.

This method has also been used to produce hollow polymeric microspheres of diameters from 100 to 1500 μm. Another of the advantages of the solid phase process over the earlier approaches is the potential to foam in place where a prior foam exists so in-situ repair of existing foams is possible, while another advantage is the production of hollow microspheres. A more recent modification to this process [2] consists of the partial inflation of the powder into friable balloons by a short heating cycle, avoiding imidization and blowing agent depletion. These friable balloons with remaining blowing agent and low molecular weight serve as the starting component to make foams. Foams made from friable balloons have reached high closed cell content (i.e. approximately 80% in foams of 0.048 g/cm^3).

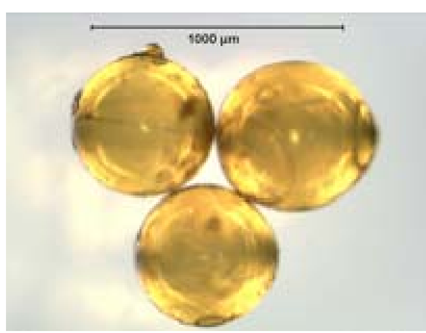
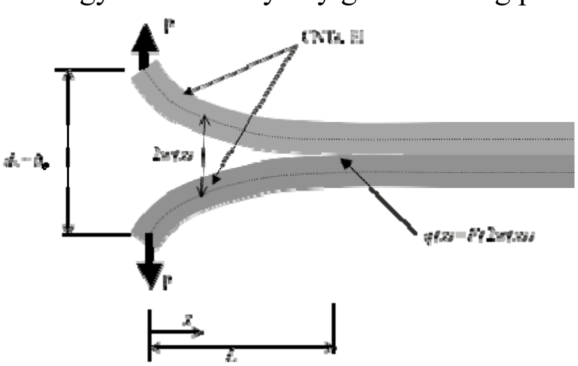


Figure 3. Hollow Microspheres of Polyimide.

Carbon Nanotube–Fluid Interactions in Mixing and Comminution

The potential of Raman spectroscopy as a tool to determine the state of deformation and orientation of a carbon nanotube has been proved theoretically and experimentally for solids[1,2] but literature is not abundant on fluids[3]. We have been able to obtain reproducible spectra from dispersions of CNTs in quiescent organic solvents typically used in mixing. Some issues like the minimum detectable concentration and optimum laser frequency are being investigated experimentally with promising results. Ultimately that will open a way to compare and contrast different mixing protocols and methods. On the other hand, ultrasonication is being used extensively by the research community working with carbon nanotubes as a mixing tool[4]. However there is a lack of fundamental understanding of its effects on dispersion and our main goal is to build a consistent physical picture that explains how the cavitation events that occur in the solvent lead to breakup of the aggregates (so called bundles) or even to rupture of the nanotubes themselves. That leads us to study bubble nucleation and dynamics[9] and ultimately the interaction of solid inclusions in a fluid. Both problems are nearly a century old and not completely solved even for simple fluids and laminar regimes. We have carried out a through literature review on the last subject focusing on the classic papers in the field[5,6,7] in order to understand the motion of the particles as a function of the flow conditions and the interactions among them. Most recent publications in the field treat the problem numerically requiring large computational capabilities due to the interaction of particles with the fluid and also among themselves. It is interesting to note that the stresses inside the solid inclusions have been ignored in most of the analyses, and this is precisely where we want to focus. Additionally, calculations of the strength of interaction between carbon nanotubes in a bundle can be done in several ways ranging from stress analysis of nanoflexural tests to integrations of the cohesive energy density or electrostatic potential of a perfect bundle. Results from these approaches will be compared and matched to the energy delivered by any given mixing process.



Energy of Separation and Dispersion of Carbon Nanotubes

The energy density and forces required to separate nanoropes into individual nanotubes was examined by studying both the dilatation separation of arrays and the peeling of a pair of single wall carbon nanotubes. The cohesive energy per unit length was determined from the universal graphitic potential. The magnitude of the peeling force for a pair of tubes configured in a double cantilever beam was calculated over a range of peeling lengths using a cohesive zone model, and compared to predictions from linear elastic fracture mechanics. The results of the analysis reveal that a linear elastic fracture model that incorporates an inherent initial crack length yields a reasonable estimation of the peeling force-deformation response. The energy of separation for the dilatation mechanism was shown to be a strong function of the array size with twice the energy density necessary to separate an array of three CNT as compared to separation of a large array. Estimates of the energy of peeling separation of 0.30 nJ/m is in good agreement with previous work.

Publications

Odegard, G. M., **Pipes, R. B.,** and Hubert, P., "Comparison of Two Models of SWCN Polymer Composites," *Composites Science and Technology*, Vol. 64, 2004, pp. 1011-1020.

Cano, C. I., Weiser, E. S., and **Pipes, R. B**., "Solid State Polyimide Foaming from Powder Precursors: Effect of Morphology and Process Parameters in the Diffusive Phenomena," *Cellular Polymers,* Vol. 23, No. 5, 2004, pp. 299-309.

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

Zeng, Q., and **Sun, C. T.,** "Fatigue Performance of a Bonded Wavy Composite Lap Joint," *Fatigue and Fracture of Engineering Materials and Structures,* Vol. 27, 2004, pp. 413-422.

Sun, C. T., and Achuthan, A., "Domain Switching Criteria for Ferroelectric Materials Subjected to Electrical and Mechanical loads," *J American Ceramic Society,* Vol. 83, No. 3, 2004, pp. 395-400.

Tsai, J., and **Sun, C. T.,** "Effect of Platelet Dispersion on the Load Transfer Efficiency in Nanoclay Composites," *J Composite Materials,* Vol. 38, No 7, 2004, pp. 567-579.

Tsai, J., and **Sun, C. T.,** "Dynamic Compressive Strength of Polymeric Composites," *Int J Structures and Solids,* Vol. 41, 2004, pp.3211-3224.

Sun, C. T., and Han, C., "A Method for Testing Interlaminar Dynamic Fracture Toughness of Polymeric Composites," *Composites Part B,* Vol. 35, Issues 6-8, September-December 2004, pp. 647-655.

Jin, Z.-H., and **C.T. Sun**, C. T., "On J-Integral and Potential Energy Variation," *International J. Fracture*. Vol. 126, 2004, pp. L19-L24.

Agrawal, P., and **Sun, C. T.,** "Fracture in Metal-Ceramic Composites," *Composites Science and Technology,* Vol. 64, No. 9, 2004, pp.1167-1178.

Qian, H., and **Sun, C. T.,** "Performance of a Composite Double Strap Joint with Attachments," *Joining and Repair of Composite Structures*, *ASTM STP 1455,* American Society of Testing and Materials, Eds: K. T. Kedward & H. Kim, ASTM International, West Conshohocken, PA, 2004, pp. 55-66.

Sun, C. T., "Unconventional Testing and Modeling Methods for Composite Materials and Laminates," (Invited paper), Transactions of the Aeronautical and Astronautical Society of the Republic of China, Vol. 36, No. 1, 2004, pp.001-006.

Zhang, H., and **Sun, C. T.,** "Nanoplate Model for Plate-like Nanomaterials," *AIAA J.*, Vol. 42, No. 10, 2004, pp. 2002-2009.

Fang, D. N., Liu, B., and **Sun, C. T.,** "Fatigue Crack Growth in Ferroelectric Ceramics Driven by Alternating Electric Fields," *J. American Ceramic Society*, Vol. 87, No. 5, 2004, pp. 840-846.

Conference Proceedings, Presentations, Invited Lectures and Reports

Achuthan, A., and **Sun, C. T.,** "Effect of Residual stresses on Domain switching in Ferroelectric Ceramic Materials," *SPIE 11th Annual International Symposium on Smart Structures and Materials,* Vol. 5387, San Diego, California, March 14-18, 2004.

Sun, C. T., Deo, A., and Qian, H., "Effects of Shape and Surface Area of Fiber in Short Fiber Composites," *45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Palm Spring, California, April 19-22, 2004.

Bing, Q., and **Sun, C. T.,** "A Technique for High Strain Rate SHPB Testing of Off-Axis Carbon Fiber Composites," the *11th European Conference on Composite Materials,* Rhodes, Greece, May 31-June 3, 2004.

Subramaniyan, A. K., and **Sun, C. T.,** "The Use of Nanoclay Platelets to Enhance Compressive Strength of Fiber Composites," *14th US-Japan Conference on Composite Materials,* Yonezawa, Japan, September 9 – 11, 2004.

Jin, Z.-H., and **Sun, C. T.,** "A Cohesive Zone Model Based on Crack Front Necking," Mahfuz, H, Hosur, M. V. editors. Developments in Theoretical and Applied Mechanics, Vol. 22, Tuskegee University, Tuskegee, Alabama; pp. 579-586, 2004.

Sun, C. T., "Homogenization of Heterogeneous Solids Under Dynamic Loads," (plenary lecture) the *22nd Southeastern Conference on Theoretical and Applied Mechanics,* Tuskegee University, Tuskegee, Alabama, August 17-18, 2004.

Jin, Z.-H., and **Sun, C. T.,** "A Cohesive Zone Model Based on Crack Front Necking," the *22nd Southeastern Conference on Theoretical and Applied Mechanics,* Tuskegee University, Tuskegee, Alabama, August 17-18, 2004.

Wang, C. Y., and **Sun, C. T.,** "Energy Variation During Crack Growth in Cohesive Fracture Model." *Proceedings of the 4th European Congress on Computational Methods in Applied Sciences and Engineering* (ECCOMAS 2004), Jyvaskyla, Finland, July 24-28, 2004.

Sun, C. T., "Novel Methods for Testing and Modelling Composite Materials and Laminates," (plenary lecture) *2nd International Conference on Composites Testing and Model Identification,* Bristol, United Kingdom, September 21-23, 2004.

Sun, C. T., "Issues of Size in Composite Materials," (ASTM Committee D-30 Wayne W. Stinchcomb Memorial Lecture). *19th Technical Conference, American Society for Composites*, Atlanta, Georgia, October 17-19, 2004.

Deo, A., and **Sun, C. T.,** "Effect of Thickness of Platelet on Load Transfer Efficiency in Platelet-Reinforced Composites," *19th Technical Conference, American Society for Composites*, Atlanta, Georgia, October 17-19, 2004.

Cho, J., and **Sun, C. T.,** "Failure Mechanisms in Polymer Composites Containing Micro and Nano Particles," *19th Technical Conference, American Society for Composites*, Atlanta, Georgia, October 17-19, 2004.

Sun, C.T., "Design of Efficient Bonded Joints for Thin-Walled Composite Structures," *19th Technical Conference, American Society for Composites*, Atlanta, Georgia, October 17-19, 2004.

Merrill, M., and **Sun, C. T.,** "Processing Nanocomposites of High Volume Nanoclay Contents," presented at *ASME International Mechanical Engineering Congress & Exposition,* Anaheim, California, November 14-19, 2004.

Sun, C. T., and Bing, Q., "Modeling Compressive Strength of Fiber Composites as Fiber Microbuckling," presented at *ASME International Mechanical Engineering Congress & Exposition,* Anaheim, California, November 14-19, 2004.

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 Associate Professor of Biology,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 Associate Professor of Biology

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, 1961-62

Research Areas

- Measurement and recording of fast enzymatic reactions. Computer methods for the extraction of rate constants.
- Three dimensional reconstruction of biological structures obtained from serial electron microscope sections.
- Computer applications to research and teaching of Microbiology.
- Digital Signal Processing.
- Nonlinear dynamics and chaotic system analysis as applied to biological diversity.
- Satellite Design
- Ground station design for acquisition satellite data.

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 2004 to June 2005

RESEARCH AND OTHER SCHOLARLY ACTIVITIES

Between July 1, 2004 and June 30, 2005, approximately $5.2 million in research expenditures were realized in the areas of Aerodynamics, Dynamics and Controls, Propulsion, and Structures and Materials. Several faculty were recognized for research as is detailed in the "Faculty Highlights" section. The research expenditure for the 2004-2005 year was attributed to the following sources.

SOURCE OF SPONSORED RESEARCH FOR 2004-2005	
Source	**Percentage of Total**
Department of Defense	36.69%
NASA	27.94%
National Science Foundation	5.20%
FAA	3.79%
Industry	5.44%
Indiana 21st Century R & D	12.94%
Other	8.00%
Total	100.0%

SPONSORED RESEARCH PROJECTS
ACTIVE DURING THE PERIOD JULY 1, 2004 TO JUNE 30, 2005

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	PI/I	P.I.
NATIONAL AERONAUTICS AND SPACE ADMIN	ADVANCED MEASUREMENT TECHNIQUES FOR HIGH PRESSURE ROCKET COMBUSTORS	08/01/04 - 07/31/05	$24,000	PI	ANDERSON
IN SPACE, LLC	INNOVATIVE IGNITION SYSTEM FOR NON-TOXIC STORABLE PROPELLANTS PHASE 1-EXPERIMENTAL DEISGN	03/01/04 - 11/30/04	$22,500	PI CO-PI CO-PI	ANDERSON HEISTER MEYER
IN SPACE, LLC	INNOVATIVE IGNITION SYSTEM FOR NON-TOXIC STORABLE PROPELLANTS PHASE 2 - EXPERIEMENTAL DESIGN	09/28/04 - 09/27/06	$157,900	PI	ANDERSON
SIERRA ENGINEERING INC.	PULSATOR DEVICES FOR COMBUSTION STABILITY ASSESSMENT	10/01/04 - 12/31/05	$80,000	PI	ANDERSON
NATIONAL AERONAUTICS AND SPACE ADMIN	RISK REDUCTION FOR THE ORSC MAIN CHAMBER INJECTORS AND COOLING	01/08/03 - 07/31/04	$30,030	PI CO-PI	ANDERSON HEISTER
SIERRA ENGINEERING INC.	ROCKET COMBUSTOR HEAT TRANSFER MEASUREMENTS	01/21/05 - 01/23/06	$45,000	PI	ANDERSON
ATK THIOKOL, INC	SINGLE-PHASE NOZZLE FLOW WITH CONTOUR STEP-DOWN	04/14/05 - 01/30/06	$68,383	PI CO-PI	ANDERSON MEYER
IN SPACE, LLC	SWIRL INJECTOR TESTS	07/01/04 - 11/12/04	$22,223	PI	ANDERSON
SIERRA ENGINEERING INC.	TRANSPIRATION COOLED CHAMBER TESTS	02/01/05 - 12/31/05	$70,000	PI	ANDERSON
SIERRA ENGINEERING INC.	VARIABLE LENGTH COMBUSTION STABILITY TESTS	10/01/04 - 12/31/05	$52,500	PI CO-PI	ANDERSON MEYER
METRON AVIATION INC	AUTOMATIC DEPENDENT SURVEILLANCE - BROADCAST VERIFICATION AND VALIDATION	01/21/05 - 07/15/05	$20,000	PI	ANDRISANI
UNITED NEGRO COLLEGE FUND, INC.	GM SULLIVAN FACULTY FELLOWSHIP	10/16/02 - 12/31/75	$15,000	PI	ANDRISANI
METRON, INC.	INTENT INFERENCE ALGORITHM	09/17/02 - 09/17/04	$203,355	PI	ANDRISANI
ROCKWELL COLLINS	PORTABLE DATA ACQUISITION AND CONTROL SYSTEM	06/09/00 - 12/31/75	$30,000	PI	ANDRISANI
ROCKWELL COLLINS	REMOTELY PILOTED GIANT-SCALE AIRCRAFT	07/01/03 - 12/31/75	$25,000	PI	ANDRISANI
UNITED NEGRO COLLEGE FUND, INC.	UNITED NEGRO COLLEGE FUND, INC.	07/01/02 - 12/31/75	$5,000	PI	ANDRISANI
NATIONAL AERONAUTICS AND SPACE ADMIN	TURBULENCE MODEL CALCULATIONS OF HYPERSONIC BOUNDARY LAYER FLOWS USING THE OVERFLOW CODE	08/20/04 - 07/31/06	$158,227	PI CO-PI	BLAISDELL LYRINTZIS
SANDIA NATIONAL LABORATORIES	DYNAMIC MATERIAL AND STRUCTURAL TESTING	12/17/04 - 09/30/05	$95,000	PI	CHEN
KARAGOZIAN & CASE	MASONRY MATERIAL IMPACT FAILURE	05/15/05 - 09/30/05	$16,416	PI	CHEN
ARMY RESEARCH OFFICE	RATE-DEPENDENT DEFORMATION AND FAILURE BEHAVIOR OF SOFT MATERIALS AND BIOLOGICAL TISSUES	04/30/05 - 10/30/05	$40,200	PI	CHEN
ROLLS-ROYCE CORPORATION	DYNAMICS OF ENGINE OIL SUMPS & DRAINS	06/01/03 - 05/31/05	$136,946	PI CO-PI	COLLICOTT HEISTER
ROLLS-ROYCE CORPORATION	DYNAMICS OF ENGINE OIL SUMPS AND DRAINS	05/01/02 - 12/31/05	$38,000	PI CO-PI CO-PI	COLLICOTT HEISTER SANKARAN
CUMMINS ENGINE COMPANY INC.	NSF MATCHING FOR INDUSTRIALS	04/20/99 - 12/31/75	$20,000	PI	COLLICOTT
ROLLS-ROYCE NORTH AMER. TECHNOLOGIE, INC	PURDUE UNIVERSITY WATER SPRAY DEVELOPMENT PROJECT	06/15/05 - 01/31/06	$43,090	PI	COLLICOTT
NATIONAL AERONAUTICS AND SPACE ADMIN	THREE-DIMENSIONAL CAPILLARY INTERFACE TOPOLOGIES AND STABILITY	03/16/05 - 12/31/08	$92,062	PI	COLLICOTT
UNITED TECHNOLOGIES	UNITED TECHNOLOGIES/PRATT & WHITNEY	04/01/96 - 12/31/75	$18,000	PI	COLLICOTT
STAR ENTERPRISES, INC.	ZERO-GRAVITY WICKING OF BIOFLUIDS	06/07/04 - 12/31/04	$25,060	PI	COLLICOTT
NATIONAL AERONAUTICS AND SPACE ADMIN	DESIGN METHODS AND OPTIMIZATION FOR MORPHING AIRCRAFT	08/15/01 - 02/14/05	$227,010	PI CO-PI	CROSSLEY WEISSHAAR
NEXTGEN AERONAUTICS, INC	GENETIC ALGORITHM APPROACHES FOR SIZING,SHAPE AND TOPOLOGY OPTIMIZATION	02/01/04 - 07/31/04	$14,990	PI	CROSSLEY
MIDE TECHNOLOGY CORPORATION	SELF CONSUMING SPACECRAFT	12/01/99 - 12/31/75	$2,000	PI	CROSSLEY
FLORIDA SPACE RESEARCH INSTITUTE	2004-05 LUNAR IN-SITU RESOURCE UTILIZATION UNIVERSITY DESIGN COMPETITION	01/01/05 - 06/30/05	$12,000	PI	DELAURENTIS
NATIONAL AERONAUTICS AND SPACE ADMIN	A ROBUST, SCALABLE TRANSPORTATION SYSTEM CONCEPT	04/06/05 - 04/05/06	$225,000	PI	DELAURENTIS
NATIONAL INSTITUTE OF AEROSPACE	METHODOLOGICAL NEEDS FOR ASSESSING FUTURE TRANSPORTATION ARCHITECTURES	11/15/04 - 11/30/05	$118,000	PI	DELAURENTIS

PRATT & WHITNEY GROUP	ANALYSIS OF FRETTING FATIGUE OF TURBINE MATERIALS	10/01/04 -	12/31/05	$50,000	PI	FARRIS
GENERAL ELECTRIC AIRCRAFT ENGINES	F110 EXPERIMENTAL EVALUATION OF FRETTING FATIGUE FOR TURBINE DISK - AIRFOIL ATTACHMENTS	12/15/04 -	12/31/05	$49,657	PI	FARRIS
GENERAL ELECTRIC AIRCRAFT ENGINES	FRETTING FATIGUE OF TURBINE MATERIALS FOR PROPULSION SYSTEM PROGNOSIS	08/25/04 -	11/28/05	$152,200	PI	FARRIS
ANALYTICAL PROCESSES/ENGINEERED SOL INC	FRETTING FATIGUE TESTING OF ALUMINUM	06/01/03 -	04/30/05	$100,000	PI	FARRIS
WRIGHT-PATTERSON AIR FORCE BASE	FUNDAMENTALS OF FRETTING APPLIED TO ANISOTROPHIC MATERIAL	09/06/02 -	01/05/06	$263,000	PI CO-PI	FARRIS GRANDT
HERTZ FOUNDATION FELLOWSHIP	HERTZ FOUNDATION FELLOWSHIP FOR TYLER ROBARGE	08/01/03 -	07/31/05	$18,645	PI	FARRIS
GENERAL ELECTRIC COMPANY	HIGH-TEMPERATURE FRETTING FATIGUE FEATURE TESTING	01/01/03 -	12/31/04	$125,294	PI	FARRIS
GENERAL MOTORS CORP	MACHINING OF CERAMICS PROJECT	05/20/98 -	12/31/75	$22,500	PI	FARRIS
CATERPILLAR INC.	MATERIALS PROCESSING AND TRIBOLOGY RESEARCH GROUP	06/17/98 -	12/31/75	$15,000	PI	FARRIS
ROLLS-ROYCE CORPORATION	MATERIALS PROCESSING AND TRIBOLOGY RESEARCH GROUP	12/21/01 -	12/31/75	$70,000	PI	FARRIS
CATERPILLAR INC.	MATERIALS PROCESSING TRIBOLOGY RESEARCH	12/17/98 -	12/31/75	$9,100	PI	FARRIS
GENERAL ELECTRIC AIRCRAFT ENGINES	MECHANICS OF BLADE/DISK CONTACTS	05/21/04 -	12/31/05	$90,000	PI	FARRIS
NATIONAL SCIENCE FOUNDATION	MICRO-SCALE CHARACTERIZATION OF MACHINING INTERFACES	08/15/01 -	07/31/04	$9,900	CO-PI	FARRIS
PRATT & WHITNEY GROUP	MULTI-SPONSORED	10/21/98 -	12/31/75	$2,500	PI	FARRIS
TIMKEN COMPANY	MULTI-SPONSORED	10/30/98 -	12/31/75	$10,000	PI	FARRIS
GENERAL MOTORS CORP	MULTI-SPONSORED, MATERIALS PROCESSING TRIBOLOGY RESEARCH	09/01/98 -	12/31/75	$7,000	PI	FARRIS
AMERICAN SOCIETY FOR ENGINEERING EDUC	NDSEG FELLOWSHIP	08/01/03 -	07/31/04	$20,695	PI	FARRIS
PRATT & WHITNEY GROUP	SSME SINGLE CRYSTAL CRACKING CONTACT FATIGUE TEST	06/18/02 -	02/28/05	$170,000	PI	FARRIS
21ST CENTURY RESEARCH & TECHNOLOGY FUND	SUSTAINABLE MANUFACTURING SYSTEMS FOR DISCRETE PRODUCTS SECTOR	08/15/03 -	08/15/05	$56,538	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	$65,000	PI	FARRIS
GILLETTE TECHNOLOGY CENTER	HIGH SPEED GRINDING OF STAINLESS STEEL	11/15/04 -	05/31/05	$11,958	CO-PI	FARRIS
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	$407,777	PI	GARRISON
NATIONAL SCIENCE FOUNDATION	ANALYSIS AND DESIGN OF MULTIVARIABLE EXTREMUM SEEKING ALGORITHMS	09/01/00 -	08/31/06	$196,008	PI	GARRISON
NATIONAL AERONAUTICS AND SPACE ADMIN	AUTONOMOUS NAVIGATION FOR ALTERNATE ACCESS TO THE INTERNATIONAL SPACE STATION	05/18/01 -	12/31/04	$49,283	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	$412,805	PI	GARRISON
NATIONAL AERONAUTICS AND SPACE ADMIN	INVESTIGATION OF TRANSIENT IONOSPHERIC PERTURBATION IN THE GPS SIGNAL	09/15/04 -	09/14/07	$24,000	PI	GARRISON
NATIONAL AERONAUTICS AND SPACE ADMIN	MODEL FUNCTION DEVELOPMENT FOR THE RETRIEVAL OF OCEAN SURFACE PROPERTIES FROM SCATTERED GPS SIGNALS	09/15/02 -	09/14/06	$334,611	PI	GARRISON
FEDERAL AVIATION ADMINISTRATION	ANALYSIS OF FATIGUE CRACK GROWTH FROM COUNTERSUNK FASTENER HOLES	07/01/02 -	09/11/07	$69,437	PI	GRANDT
ALCOA INC	ALCOA TECHNICAL CENTER	09/27/01 -	12/31/75	$25,000	PI	GRANDT
BOEING COMPANY, THE	STUDY TO COMPARE PREDICTED VERSUS EXPERIMENTAL CRACK SHAPE CHANGES AS CRACK PROGRESSES THROUGH STRUCTURE	09/01/03 -	07/31/05	$74,783	PI	GRANDT
NATIONAL RECONNAISSANCE OFFICE	ALTITUDE COMPENSATION USING COMBUSTIBLE NOZZLE LINERS	11/24/03 -	02/28/05	$192,000	PI CO-PI	HEISTER MEYER
AEROSPACE CORPORATION	ALTITUDE COMPENSATION USING COMBUSTILE NOZZEL LINERS	05/20/05 -	09/20/05	$25,000	PI	HEISTER
UNIVERSITY OF ALABAMA HUNTSVILLE	COMBUSTION INSTABILITY AND FILM COOLING STUDIES FOR HYDROCARBON ENGINES	01/13/03 - -	08/09/05	$50,000	PI CO-PI CO-PI	HEISTER ANDERSON FARRIS

ALLISON ADVANCED DEVELOPMENT COMPANY	CYCLIC PDE COMBUSTION RESEARCH	03/09/01 - -	07/30/04	$20,000	PI CO-PI	HEISTER MEYER
ALLISON ADVANCED DEVELOPMENT COMPANY	EXPANSION OF PROPULSION & POWER CENTER OF EXCELLENCE WITH HIGH MACH TURBINE-BASED COMBINED CYCLE VEHICLES AND CONSTANT VOLUME COMBUSTORS	08/01/04 -	03/31/06	$487,500	PI CO-PI CO-PI CO-PI	HEISTER ANDERSON MERKLE MEYER
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH	MODELING LIQUID ROCKET ENGINE ATOMIZATION AND SWIRL/COAXIAL INJECTORS	02/01/03 -	12/31/05	$171,342	PI	HEISTER
SPACEDEV	NITROUS OXIDE AS A REGENERATIVE NOZZLE COOLANT	01/01/05 -	07/31/05	$18,036	PI	HEISTER
EDWARDS AIR FORCE BASE	NON-CATALYTIC IGNITION OF ADVANCED MONOPROPELLANTS -COMPRESSIBLE IGNITION	10/12/04 -	04/21/05	$25,000	PI CO-PI	HEISTER ANDERSON
SANDIA NATIONAL LABORATORIES	NONLINEAR MODELING OF DROPLET SPLASHING	04/25/05 -	09/15/06	$40,000	PI	HEISTER
DAVIDSON INST FOR TALENT DEVELOPMENT	ONLINE COLLOQUIUM ON THE TOPIC OF "ROCKET PROPULSION TESTING" FOR THE DAVIDSON INSTITUTE FOR TALENT DEVELOPMENT	03/28/05 -	04/01/05	$1,000	PI	HEISTER
ALLISON ADVANCED DEVELOPMENT COMPANY	ROLLS-ROYCE UNIVERSITY TECHNOLOGY CENTER IN HIGH MACH PROPULSION	01/01/05 -	12/31/05	$163,200	PI CO-PI CO-PI	HEISTER ANDERSON MEYER
ALLIED-SIGNAL FOUNDATION	SPECIAL PROGRAMS	05/01/98 -	12/31/75	$4,800	PI PI	HEISTER COLLICOTT
ALLIED-SIGNAL AEROSPACE CO	STUDY OF THE RAMJET INLET	09/09/97 -	12/31/75	$20,000	PI	HEISTER
ALLISON ADVANCED DEVELOPMENT COMPANY	UNIVERSITY TECHNOLOGY CENTER IN HIGH MACH PROPULSION	01/01/03 -	02/15/05	$210,000	PI CO-PI	HEISTER ANDERSON
UNIVERSITY OF ALABAMA HUNTSVILLE	UTTAPPS	01/31/03 - -	08/09/05	$532,043	PI CO-PI	HEISTER MERKLE
NATIONAL AERONAUTICS AND SPACE ADMIN	APPLICATIONS OF DYNAMICAL SYSTEMS THEORY, CONTROL METHODS AND OPTIMIZATION STRATEGIES TO TRAJECTORY DESIGN AND MISSION ANALYSIS INVOLVING FORMATION FLYING AT LIBRATION POINTS FOR GSFC MISSIONS	04/15/02 -	09/30/04	$106,000	PI	HOWELL
NATIONAL AERONAUTICS AND SPACE ADMIN	MISSION DESIGN AND ANALYSIS INVOLVING FORMATION FLYING NEAR LIBRATION POINT ORBITS	07/01/03 - -	06/30/05	$40,033	PI CO-PI	HOWELL ROTEA
NATNL CONSORT GRAD MINORITIES ENGR & SCI	NAT CONSORTIUM FELLOWSHIP	09/01/83 -	12/31/75	$3,250	PI	HOWELL
NORTHEASTERN IN FLOWER GROWERS ASSOC	NATIONAL CONSORTIUM FELLOWSHIP	09/01/83 -	12/31/75	$3,250	PI	HOWELL
JET PROPULSION LABORATORY	STATIONKEEPING ANALYSIS IN SUPPORT OF THE TERRESTRIAL PLANET FINDER (TPF) MISSION	04/09/04 -	09/26/04	$10,000	PO	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	$130,000	PI	HOWELL
NATIONAL AERONAUTICS AND SPACE ADMIN	STRATEGIES FOR TRAJECTORY DESIGN AND MISSION ANALYSIS: MULTIPLE THREE-BODY AND FOUR-DOBY SYSTEMS INCLUDING SUN-EARTH MOON	09/01/04 -	08/31/07	$50,000	PI	HOWELL
RADIANCE TECHNOLOGIES, INC	DEVELOPMENT OF NEW GENERATION COMPONENTS FOR PULSED PLASMA ACCELERATORS	03/01/04 -	12/30/05	$30,000	PI	HRBUD
CALIFORNIA SPACE GRANT FOUNDATION	FEASIBILITY OF ENDO-ATMOSPHERIC ELECTRIC PROPULSION	06/01/04 -	05/31/05	$18,000	PI	HRBUD
INDIANA SPACE GRANT CONSORTIUM	PURDUE FALL SPACE DAY 2005	03/15/05 -	02/28/06	$3,000	CO-PI	HRBUD
INDIANA SPACE GRANT CONSORTIUM	SPRING SPACE FORUM	03/15/05 -	02/28/06	$1,580	PI	HRBUD
NATIONAL AERONAUTICS AND SPACE ADMIN	BUCKLING-DRIVEN DISBOND GROWTH IN COMPOSIT STRUCTURES	01/01/04 -	12/31/05	$75,000	PI	KIM
BOEING COMPANY, THE	HAIL ICE IMPACT DAMAGE ON STIFFENED COMPOSITE PANELS	05/01/04 -	05/01/05	$20,000	PI	KIM
UNITED TECHNOLOGIES PRATT & WHITNEY	MODELING HAIL ICE IMPACTS ON AERO-ENGINE STRUCTURES	08/27/02 -	12/31/04	$33,789	PI	KIM
ODYSSIAN TECHNOLOGY	MULTIFUNCTIONAL COMPOSITE STRUCTURE	02/15/03 - -	02/15/06	$225,000	PI CO-PI CO-PI	KIM SUN WEISSHAAR
NATIONAL AERONAUTICS AND SPACE ADMIN	DUAL-USE BALLUTE FOR AEROCAPTURE AND DESCENT DURING PLANETARY MISSIONS	03/01/05 -	10/31/05	$15,000	PI	LONGUSKI
JET PROPULSION LABORATORY	INTERPLANETARY MISSION DESIGN	05/14/03 -	11/30/04	$91,510	PI	LONGUSKI
NATIONAL AERONAUTICS AND SPACE ADMIN	LOW-THRUST GRAVITY-ASSIST TRAJECTORY DESIGN AND OPTIMIZATION	01/01/05 -	11/30/05	$90,000	PI	LONGUSKI

EDUCATION, U.S. DEPARTMENT OF	INTERDISCIPLINARY FELLOWSHIP PROGRAM FOR COMPUTATIONAL SCIENCE AND ENGINEERING	08/15/02	-	08/14/06	$6,559	CO-PI	LYRINTZIS
OHIO AEROSPACE INSTITUTE	UNDERSTANDING OF THE PREDICTION OF LOBED MIXER NOISE	05/01/04	-	12/31/05	$20,000	PI	LYRINTZIS
			-			CO-PI	BLAISDELL
FEDERAL AVIATION ADMINISTRATION	DAMAGE TOLERANCE AND DURABILITY OF ADHESIVELY BONDED COMPOSITE STRUCTURE	09/01/04	-	08/31/05	$50,585	PI	KIM
						CO-PI	SUN
UNIVERSITY OF	MAGNITO HYDRO DYNAMICS GENERATOR MODELING	08/23/04	-	12/31/05	$75,000	PI	MERKLE
BABCOCK AND WILCOX COMPANY	AIR TESTING	05/14/04	-	12/31/04	$26,821	PI	MEYER
						CO-PI	MERKLE
NORTHROP GRUMMAN SPACE TECHNOLOGY	5K THRUST CHAMBER ASSEMBLY TESTING	04/15/03	-	11/30/04	$12,470	PI	MEYER
GENERAL KINETICS, LLC	GK 90% 02 150 LB. THRUST MONOPROP WEAR-IN AND HOT FIRE TESTING	09/17/03	-	12/31/04	$2,738	PI	MEYER
GENERAL KINETICS, LLC	GK CAVITATING VENTURI CALIBRATION TESTING	09/17/03	-	12/31/04	$1,460	PI	MEYER
BOEING COMPANY, THE	PULSEJET HARDWARE FOR BOEING	03/15/05	-	10/15/05	$25,248	PI	MEYER
BOEING COMPANY, THE	PULSEJET TESTING FOR BOEING	03/15/05	-	12/01/05	$61,728	PI	MEYER
						CO-PI	KIM
N.S. GOWADIA, INC.	STATIC AND FREE JET INLET TESTING	11/15/02	-	12/31/04	$35,972	PI	MEYER
SCIENCE APPLICATIONS INTERNATIONAL CORP	SYSTEMS SUPPORT TESTING OF SAIC'S INTELLIGENT MUNITIONS SYSTEMS PROGRAM	01/10/05	-	06/24/05	$10,528	PI	MEYER
COMPOSITEX INC	VACUUM COMP-L TESTING FOR COMPOSITES, INC	08/23/04	-	05/31/05	$4,975	PI	MEYER
NATIONAL SCIENCE	IPA AGREEMENT	01/10/05	-	01/09/06	$171,008	PI	ROTEA
UNITED TECHNOLOGIES RESEARCH CENTER	ROBUST CONTROL ANALYSIS AND SYNTHESIS	09/01/98	-	12/31/75	$40,000	PI	ROTEA
UNITED TECHNOLOGIES RESEARCH CENTER	UTRC INDUSTRIAL MATCH	11/01/96	-	12/31/75	$20,000	PI	ROTEA
XEROX CORP	XEROX CORPORATIN/ROTEA	08/07/01	-	12/31/75	$66,000	PI	ROTEA
P. C. KRAUSE AND ASSOCIATES, INC.	CENTER FOR SECURITY OF LARGE SCALE SYSTEMS	03/25/04	-	08/31/07	$133,637	CO-PI	ROTEA
						CO-PI	SULLIVAN
PRATT & WHITNEY GROUP	HYDROGEN PEROXIDE DECOMPOSITION STUDY	05/01/99	-	12/31/75	$62,000	PI	RUSEK
SANDIA NATIONAL LABORATORIES	COLLABORATIVE RESEARCH: MECHANISMS OF HYPERSONIC BOUNDARY-LAYER TRANSITION ON REENTRY VEHICLES	08/01/03	-	09/30/06	$120,000	PI	SCHNEIDER
NATIONAL AERONAUTICS	MECHANISMS OF BOUNDARY-LAYER TRANSITION ON	04/10/03	-	01/31/05	$40,000	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	$25,000	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	$250,000	PI	SCHNEIDER
NATIONAL AERONAUTICS AND SPACE ADMIN	MECHANISMS OF BOUNDARY-LAYER TRANSITION ON REUSABLE LAUNCH VEHICLES	02/01/02	-	01/31/05	$60,000	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	$160,931	PI	SCHNEIDER
AIR FORCE OFFICE OF	REQUEST FOR SUPPLEMENTAL FUNDS FOR AFOSR	07/01/04	-	12/14/04	$95,000	PI	SCHNEIDER
TEKLA RESEARCH INC.	AIM POINT BIASING	10/01/04	-	12/31/05	$125,305	PI	SULLIVAN
						CO-PI	KIM
A. T. C. INCORPORATED	ATC, INC.	01/01/00	-	12/31/75	$16,667	PI	SULLIVAN
RAISBECK ENGINEERING	DESIGN/BUILD/TEST LABORATORY	11/02/99	-	12/31/75	$50,000	PI	SULLIVAN
COOPERATIVE STATE RESEARCH SERVICE	TECHNOLOGY DEVELOPMENT, TRANSFER, AND MARKETING OF INDUSTRIAL PRODUCTS FOR RURAL COMMUNITIES	09/15/01	-	09/30/04	$240,000	CO-PI	SULLIVAN
NATIONAL AERONAUTICS AND SPACE ADMIN	UNSTEADY PRESSURE MEASUREMENT IN TURBOMACHINERY USING POROUS PRESSURE-SENSITIVE PAINT	08/01/03	-	08/15/05	$48,000	PI	SULLIVAN
IBM	MULTISPONSORED	05/13/04	-	12/31/75	$50,000	PI	SULLIVAN
ROLLS-ROYCE CORPORATION	PURDUE STUDENT PARTICIPATION IN THE RRC PLM INITIATIVE	06/20/05	-	01/13/06	$45,000	PI	SULLIVAN
OFFICE OF NAVAL RESEARCH	APPLICATIONS OF NANOMATERIALS IN POLYMERIC COMPOSITES FOR MARINE STRUCTURES	12/01/02	-	02/28/05	$220,000	PI	SUN

PHYSICAL ACOUSTICS CORPORATION	COMPOSITE ARMOR MAGERIAL CHARACTERIZATION	07/01/99 -	12/31/75	$46,500	PI	SUN
AKRON RUBBER DEVELOPMENT LAB INC.	COMPOSITE ARMOR MATERIAL CHARACTERIZATION	01/04/01 -	12/31/75	$9,000	PI	SUN
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH	DEVELOPMENT OF COMPOSITES REINFORCED WITH SHORT WAVY FIBERS	12/01/01 -	05/31/05	$100,000	PI	SUN
OFFICE OF NAVAL RESEARCH	DEVELOPMENT OF TOUGHENED AND MULTIFUNCTIONAL NANOCOMPOSITES FOR SHIP STRUCTURES	04/01/05 -	03/31/07	$110,000	Pi	SUN
BALL AEROSPACE & TECHNOLOGIES CORP	EFFECTS RESEARCH MODELING AND ASSESSMENTS	06/01/04 -	06/25/05	$145,000	PI	SUN
NAVAL RESEARCH & DEVELOPMENT	DYNAMIC CONSTITUTIVE AND FAILURE MODELING OF MATERIALS AND STRUCTURES	10/01/99 -	02/28/05	$20,000	PI	SUN
NATIONAL AERONAUTICS AND SPACE ADMIN	MODELING OF NANO MATERIALS	01/01/01 -	08/31/04	$85,000	PI	SUN
TUSKEGEE UNIVERSITY	MODELING OF NANOCOMPOSITES	09/01/03 -	08/31/06	$120,000	PI	SUN
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH	PREDICTION OF DUCTILE FRACTURE OF THIN-WALLED CYLINDERS SUBJECTED TO LOCALIZED INTENSE HEAT	06/01/03 -	09/30/04	$199,999	PI	SUN
TUSKEGEE UNIVERSITY	DEVELOPMENT OF FLEXIBLE EXTREMITIES PROTECTION UTILIZING SHEAR THICKENING FLUID/FABRIC COMPOSITES	11/18/04 -	11/17/05	$70,000	PI	SUN
DEFENSE ADVANCED RES PROJECTS AGENCY	IPA AGREEMENT	08/12/02 -	08/11/06	$859,087	PI	WEISSHAAR
STANFORD UNIVERSITY	ITR: DATA DRIVEN ENVIRONMENT FOR MULTIPHYSICS APPLICATIONS	08/01/04 -	08/31/06	$99,304	CO-PI	WEISSHAAR
UNIVERSITY OF COLORADO	ITR; A DATA DRIVEN ENVIRONMENT FOR MULTIPHYSICS APPLICATIONS	10/01/02 -	09/30/04	$51,467	CO-PI	WEISSHAAR
NORTON COMPANY	GENERAL ELECTRIC SUPERABRASIVES	08/28/97 -	12/31/75	$3,700	PI	CHANDRASEKAR
EXXON RESEARCH & ENGINEERING CO	WIND COEFFICIENTS FOR MEDIUM SIZE TANKERS AND GAS SHIPS	07/01/79 -	12/31/75	$1,450	PI	PALMER

GRADUATE THESES

July 2004 to June 2005

MASTER'S THESES

Student/ *Major Professor*	**Thesis Title**	**Degree Date Granted**
Lee, Chiew *A. F. Grandt, Jr.*	"Stress-Intensity Factors Solutions for Countersunk Holes Under Pin-Loading"	M.S. August 2004
D'Alto, Luis *M. Corless*	"Incremental Quadratic Stability"	M.S. August 2004
Kumari, Shyama *T. N. Farris*	"A Statistical Account of the Effect of Arbitrary Profile Variation on Fretting Fatigue Behavior of the Contact Surface of a Dovetail Joint"	M.S. August 2004
Martin, III Thomas N. *W. E. Anderson*	"Infrared Spectroscopy for the Measurement of In-Situ Deposition of Thermally Stressed Hydrocarbon Fuels"	M.S. August 2004
Nugent, Nicholas J. *W. Anderson*	"Control and Data Acquisition System for Rocket Combustor Experimentation"	M.S. August 2004
Pearson, Nicholas S. *W. Anderson*	"Vaporization and Decomposition of Hydrogen Peroxide Droplets"	M.S. August 2004
Qian, Haiyang *C. T. Sun*	"Improved Double-Strap Joint Design"	M.S. August 2004
Subramaniyan, Arunkarthi *C. T. Sun*	"Study on Effect of Nanoclay on Compressive Behavior of Polymeric Composites"	M.S. August 2004
Hrach, Michael A. *S. D. Heister*	"Investigation of Oil Drainage from the Bearing Chamber of a Gas Turbine Engine"	M.S. December 2004
Kibbey, Timothy Paul *S. D. Heister*	"Impinging Jets for Application in High-Mach Aircraft Thermal Management"	M.S. December 2004
Liang, Liang *J. L. Garrison*	"Numerical Simulation of GPS Code Tracking Loop"	M.S. December 2004
Pan, Fongloon *A. S. Lyrintzis*	"The Use of Surface Integral Methods in Computational Jet Aeroacoustics"	M.S. December 2004
Quintana, Juan Antonio *J. F. Doyle*	"Structural Parameter Monitoring"	M.S. December 2004

Rubel, Ken *S. D. Heister*	"Thermal Decomposition of Advanced Monopropellant"	M.S. December 2004
Smith, Justin A. *J. P. Sullivan*	"A Qualification Testing and Fluorescent Imaging of Biobased Aviation Deicer Fluids"	M.S. December 2004
Walters, Leon T. *J. P. Sullivan*	"Experimental Study of Diffusing S-Ducts"	M.S. December 2004
Deo, Amitabh *C. T. Sun*	"Effect of Shape and Thickness on Properties of Short Fiber Composites"	M.S. May 2005
Harmon, Michael *S. Heister*	"Investigation of Combustible Liners for Altitude Compensation in Liquid Rocket Nozzles"	M.S. May 2005
Main, Benjamin *A. F. Grandt, Jr.*	"Evaluation of Continuing Damage from a Cracked Hole with a Failed Ligament"	M.S. May 2005
Miller, Kevin *W. E. Anderson*	"Experimental Study of Longitudinal Instabilities in a Single Element Rocket Combustor"	M.S. May 2005
Patterson, Christopher *K. C. Howell*	"Representations of Invariant Manifolds for Applications in System-to-System Transfer Design"	M.S. May 2005
Tsohas, John *S. D. Heister*	"Altitude Compensation Using Combustible Nozzle Liners"	M.S. May 2005

DOCTORAL THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree Date Granted**
Achuthan Ajit *C. T. Sun*	"Nonlinear Behavior of Ferroelectric Materials""	Ph.D August 2004
Chang, I-Ling *C. T. Sun*	"Simulation of Mechanical Behavior for Nanomaterials by Molecular Statics"	Ph.D. August 2004
Haradanahalli, Murthy N *T. N. Farris*.	"Modeling of Fretting Fatigue in Anisotropic Contacts at Elevated Temperatures and an Investigation of Lifting Schemes"	Ph.D. August 2004
Kalyanam, Sureshkumar *C. T. Sun*	"Electrical Permeability and Domain Switching Effect on Fracture Behavior of Piezoelectric Material"	Ph.D. August 2004
Long, Matthew R. *W. E. Anderson*	"Swirl Injectors for Oxidizer-Rich Stages Combustion Cycle Engines and Hypergolic Propellants"	Ph.D. August 2004
Marchand, Belinda G. *K. C. Howell*	"Spacecraft Formation Keeping Near the Libration Points of the Sun-Earth/Moon System"	Ph.D. August 2004
Crafton, Jimmy W. *J. P. Sullivan*	"The Impingement of Sonic and Sub-Sonic Jets onto a Flat Plate at Inclined Angles"	Ph.D. December 2004
Matlik, John F. *T. N. Farris*	"High-Temperature, High-Frequency Fretting Fatigue of a Single Crystal Nickel Alloy"	Ph.D. December 2004
McConaghy, Thomas T. *J. M. Longuski*	"Design and Optimization of Interplanetary Spacecraft Trajectories"	Ph.D. December 2004
Bartha, Bence *T. N. Farris*	"Modeling of Geometry Effects in Fretting Fatigue"	Ph.D. May 2005
Garcia, Daniel B. *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

COLLOQUIUM SERIES

July 2004 to June 2005

Colloquium Series – Fall 2004

DATE/TIME	TOPIC	SPEAKER
September 17, 2004 3:30 p.m. GRIS 276	"Synthesis of Virtual Environments for Acoustic Design"	**Dr. Stephen A. Rizzi** NASA Langley Research Ctr. Hampton, VA
October 7, 2004 3:30 p.m. GRIS 180	"Advanced Proper Orthogonal Decomposition Tools to Effectively Characterize Vibration and Acoustics of Finite Element Models of Coupled Structures"	**Dr. Ioannis Georgiou** School of Naval Architecture and Marine Engineering National Technical Univ. of Athens, Greece
October 14, 2004 3:00 p.m. GRIS 180	"X-43A: First Flight of a Scramjet Powered Airplane"	**Ethan Baumann, Brad Neal, and Clint St. John** NASA Dryden Flight Res. Edwards, CA
November 11, 2004*** Fowler Hall, Stewart Center 2:45 p.m.	"Powering Devices with Minimum Renewable Energy"	**Dr. Paul MacCready** Founder and Chairman of AeroVironment Inc. Simi Valley, CA
December 2, 2004 3:00 p.m. GRIS 180	"Nanoparticle Infusion into Structural Polymers and the Influence of Magnetic Flocculation"	**Hassan Mahfuz** Tuskegee Univ. Center for Advanced Materials Tuskegee, AL

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

Colloquium Series – Spring 2005

DATE/TIME	TOPIC	SPEAKER
January 27, 2005 3:00 p.m. GRIS 180	"Follow the TPS": An Analysis of What Occurred to the Thermal Protection System (TPS) During the Flight of Shuttle Columbia on STS 107	**James O. Arnold, Ph.D.** NASA Ames Center for Nanotechnology and Univ. Affiliated Res. Center
February 3, 2005 3:00 p.m. GRIS 180	"Numerical Investigations of High Speed Jet Noise"	**James N. Scott, Ph.D.** Assoc. Prof. & Section Head Ohio State University Dept. of Aerospace Engrg. Columbus, OH
February 7, 2005 3:45 p.m. MSEE B12	"On the Mechanical Behavior of Carbon Nanotubes in Hexagonal Arrays"	**R. Byron Pipes** John L. Bray Distinguished Professor of Engineering Purdue University W. Lafayette, IN
February 11, 2005 4:00 p.m. GRIS 180	"On Penetration In Porous Compressible Media"	**Oana Cazacu, Ph.D.** Department of Mechanical and Aerospace Engineering, University of Florida's Graduate Engineering and Research Center, Shalimar, FL
February 18, 2005 4:00 p.m. GRIS 276	"Hypersonic Flight Demonstrator Activities at Boeing Phantom Works"	**Shin Matsumura** Boeing Phantom Works Huntington Beach, CA
February 25, 2005** 4:00 p.m. GRIS 180	"Mechanics of the Finite Deformation Behavior of Biomacromolecular Networks"	**Mary Boyce, Ph.D.** Dept. of Mechanical Engrg. Massachusetts Inst. of Tech. Cambridge, MA
March 2, 2005 4:00 p.m. GRIS 170	"Crush of High-Density Aluminum Honeycombs: Experiment and Modeling"	**Wei-Yang Lu, Ph.D.** Sandia National Lab. Microsystems and Materials Mechanics Dept. Livermore, CA

March 3, 2005 3:00 p.m. GRIS 180	"Computational Materials: Multi-scale Modeling and Simulation of Nanostructured Materials"	**Tom Gates, Ph.D.** NASA Langley Res. Ctr. Mechanics of Structures & Materials Branch Hampton, VA
March 24, 2005 3:45 p.m. GRIS 170	"Characterization of Life-Limiting Mechanisms of Ion Thruster Discharge Cathodes"	**Alec Gallimore, Ph.D.** Professor University of Michigan Dept. of Aerospace Engrg. Ann Arbor, MI
April 7, 2005 3:00 p.m. GRIS 180	"Space Hazards: Things that go Bump in the Night"	**William H. Ailor III, Ph.D.** Principal Director Space Hazards & Operations Support Directorate The Aerospace Corporation Los Angeles, CA
April 8, 2005** 4:00 p.m. GRIS 180	"Biomechanics of Soft Biological Tissue: Structure and Modeling"	**Raymond W. Ogden, Ph.D.** Professor University of Glasgow Dept. of Mathematics Glasgow, Scotland, UK
April 21, 2005 3:00 p.m. GRIS 180	"Large-Eddy Simulation of Supersonic Cavity Flowfields Including Active Flow Control"	**Donald P. Rizzetta, Ph.D.** Air Force Research Lab. Wright-Patterson AFB, OH
April 28, 2005 3:00 p.m. GRIS 180	"Combined CO_2/H_2O Solid Oxide Electrolysis for Space Exploration"	**Christie Iacomini, Ph.D.** Aerospace & Mech. Engr. Univ. of Arizona Tucson, AZ

*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

Highlights & Awards

July 2004 to June 2005

FACULTY HIGHLIGHTS

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

Other highlights include:

- Professor William Anderson received the AIAA Liquid Propulsion Committee Best Paper Award
- Professor Weinong Wayne Chen was named ASME Fellow
- Professor James Garrison was selected to participate in the National Academy of Engineering's (NAE) 10^{th} annual Frontiers of Engineering Symposium.
- Professor Kathleen Howell was awarded the 2005 Bruhn Best Teaching Award, and the Dirk Brouwer Award from AAS
- Professor Ivana Hrbud was named to the NRC National Research Council Panel for High-Energy Power and Propulsion and In-Space Transportation
- Professor James M. Longuski 2005 A. A. Potter Best Teacher in Engineering Award.
- Professor Anastasios Lyrintzis was named University Faculty Scholar.
- Professor Mario Rotea became Program Director of NSF's Control Systems Program.
- Professor C. T. Sun was the inaugural recipient of the C.T. Sun School of Aeronautics and Astronautics Excellence in Research Award.
- Professor Terrence Weisshaar received the Structures, Structural Dynamics, and Materials Award from AIAA.
- Professor Marc Williams was awarded the School's Gustafson Outstanding Teacher 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 9th 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.

Student Awards

Congratulations to the following students who have earned top honors

Purdue Engineering Foundation Outstanding Senior Student Award –
December 2004 - Jonathan Shearer
Spring 2005 – Jayleen Guttromson

Purdue Engineering Foundation Outstanding Graduate Student Award
December 2004 – John F. Matlik
May 2005 – Kevin Miller

2005 Outstanding Senior Award –
George "Chip" Pollock

2005 Outstanding Graduate Student Award -
December 2004 – John Matlik
May 2005 – Jeremy Corpening

2005 Magoon Graduate Teaching Award - Geraldine Fritsch, Kristin Gates, Olivia Djibo, Matthew Churchfield, Masaki Kakoi, Raymond Joshua

2005 Astronaut Scholarship Foundation – Jayleen Guttromson

2005 Elmer F. Bruhn Undergraduate Research Assistantship – Laura Brower and Sachin Sree Raman

2005 Amelia Earhart Scholarship – Laura Brower

2005 David L. Filmer Scholarship – George Pollock

2005 Koerner Scholarships - Sophomores: Michael Bianco and Andrew Mundell; Juniors: Phillip Boettcher and Jillian Parent; Seniors: Lloyd Droppers and Jayleen Guttromson

2005 Purdue Forever Fellowship – James Canino and Raymond Joshua

2005 Arthur Remson Memorial Scholarship – Michael Kowalkowski

2005 John and Patricia Rich Scholarship – David Berger, John Collins, Greg Heckler, John Horst, Ryan Irwin, Jesse Jones, James Swedler, Ryan Whitley, and Garret Willis

2005 Herbert F. Rogers Scholarship – Jacqueline Jaron

2005 Marc Weaver Memorial Scholarship – Jayleen Guttromson

2005 Society of Women Engineers Awards
Jasmine Cashbaugh- Ball Aerospace & Technologies Corporation
Dawn Gordon and Jacqueline Jaron - The Boeing Company
Jayleen Guttromson – Zimmerman Family Award

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

Fall 2004 First Place Team: Ashley Brawner, Jasmine Cashbaugh, Alexandria Estes, Cynthia Fitzgerald, Daniel Gillies, and Zubin Olikara

Spring 2005 First Place Team: Dorrie Byford, Keith Fay, Oscar Guzman, Elisabeth Hanssens, Stefan Oechsner, and Alan Schwing

OUTREACH HIGHLIGHTS

The School's 9th annual Fall Space Day held on November 6, 2004 was shared with over 320 third through eighth graders and 120 plus strong volunteer crew. Astronaut **Colonel Guy Gardner** was the featured speaker. Additionally, the children participated in many interactive lessons, that reinforced basic science and math principles. Purdue Fall Space Day was sponsored by: the Indiana Space Grant Consortium; the School of Aeronautics and Astronautics; Great Lakes Chemical Corp.; Students for the Exploration and Development of Space and the Purdue Engineering Student Council (PESC).

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.

Purdue University hosted Purdue Scholars Day on December 4, 2004. Student volunteers from the School and Professor Marc Williams talked to 82 prospective high school students, which 26 had an interest in the School of Aeronautics and Astronautics.

Colonel Guy Gardner and Dr. Dan DeLaurentis were speakers for the 2005 Spring Space Forum organized by SEDS. The forum gives prominent members of the aerospace community an opportunity to provide an informative experience for Purdue and Lafayette communities.

During the summer a group of SEDS student volunteers gave local children the opportunity to learn more about aerospace by building and launching their own rockets through a Summer Educational Outreach program at the West Lafayette Library.

Curriculum & Course Offerings

July 2004 to June 2005

CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

Course Enrollments
School of Aeronautics and Astronautics
2004-2005 Academic Year

A&AE Course	Most Recent Title	Cr.	Fall 2004		Spring 2005	
			Enroll-ment	Instructor	Enroll-ment	Instructor
203	Aeromechanics I	3	127	Garrison	47	Garrison
204-1	Aeromechanics II	3	38	Imbrie	56	Chen
204-2	Aeromechanics II	3			42	Kim
204L	Aeromechanics II Lab.	1	39	Doyle	96	Doyle
241	Industrial Practice I	0	10	Williams	4	Williams
242	Industrial Practice II	0	5	Williams	5	Williams
251	Intro. Aerosp. Design	3	58	DeLaurentis	88	DeLaurentis
301	Engrg. Systems Anal.	3	90	Frazho	60	Frazho
333	Fluid Mechanics	3	108	Lyrintzis	50	Lyrintzis
333L	Fluid Mechanics Lab.	1	103	Collicott	47	Collicott
334	Aerodynamics	3	50	Williams	101	Williams
334L	Aerodynamics Lab.	1	32	Collicott	47	Collicott
340	Dynamics & Vibration	3	84	Marchand	76	Howell
341	Industrial Practice III	0	2	Williams	4	Williams
342	Industrial Practice IV	0	4	Williams	0	Williams
352	Structural Anal. I	3	93	Farris	47	Grandt
352L	Struct. Anal. I Lab.	1	46	Doyle	46	Doyle
364	Control System Analy.	3	30	Hwang	90	Hwang
364L	Control Systems Lab.	1	81	Rotea	34	Marchand
372	Jet Propl. Power Plt.	3			108	Sankaran
390	Profess. Internship	0	2	Williams	1	Williams
412	Intro. Comp. Fluid Dyn.	3	32	Blaisdell		
415	Aerodynamic Design	3	49	Sullivan		
418	Zero Gravity Flt. Exp.	3	17	Collicott		
421	Flt. Dyn. Control	3	67	Corless	44	Corless
439	Rocket Propulsion	3	92	Anderson		
440	Spacecr. Attitude Dyn.	3			51	Howell
442	Industrial Practice V	0			1	Williams
443	Industrial Prac. Sem.	0	3	Williams		
450	Spacecraft Design	3	5	Williams	47	Longuski

A&AE Course	Most Recent Title	Cr.	Fall 2004		Spring 2005	
			Enroll-ment	Instructor	Enroll-ment	Instructor
451	Aircraft Design	3	38	Sullivan	48	Andrisani
453	Matrl. Meth. Aerosp. Struct.	3			24	Doyle
454	Design Aerosp. Struct.	3	38	Grandt		
490	Special Prob. Aero.Engr.	3	20	several	46	several
490A	Flight Testing	3			28	Andrisani
490D	Intro. To Labview	3	2	Filmer		
490T	Design Build Test	3			28	Sullivan
511	Intro. Fluid Mech.	3	30	Blaisdell		
512	Comput. Aerodyn.	3			31	Merkle
514	Intermediate Aerodyn.	3			28	Lyrintzis
520	Experimental Aerody.	3			22	Schneider
520L	Exper. Aerodyn. Lab	3			22	Schneider
532	Orbit Mechanics	3	49	Howell		
537	Hypersonic Propul.	3	40	Heister		
538	Air Breath. Propul.	3	34	Merkle		
539	Adv. Rocket Propul.	3			34	Heister
546	Aero Struct Dyn Stab.	3	34	Doyle		
547	Exper. Stress Analy.	3			18	Doyle
550	Multidisc. Des. Opt.	3	75	Crossley		
550Q	Multidisc. Des. Opt.	3	74	Crossley		
553	Elasticity Aerosp. I	3	24	Sun		
554	Fatigue Struct. & Matrl.	3	40	Grandt		
555	Mech. Comp. Matrl.	3			40	Kim
555Q	Mech. Comp. Matrl.	3			4	Kim
558	Finite Element Meth. In Aerospace Structures	3	51	Kim		
559	Mech. Frict. & Wear	3			16	Farris
564	System Anal. & Synth.	3	35	Corless		
567	Intro. Appl. Stoch. Proc.	3			14	Frazho
590	Projects in Aero. Engr.	3	24	several	18	several
590A	Rocket Combuster DBT	3			31	Anderson

A&AE Course	Most Recent Title	Cr.	Fall 2004		Spring 2005	
			Enroll-ment	Instructor	Enroll-ment	Instructor
590B	Propul. Lab. Methods	3	12	Hrbud		
590D	Intro. To Labview	3	6	Filmer	9	Filmer
590E	Intro. Electric Propul.	3			22	Hrbud
590G	Intr. Satellite Nav. & Posit.	3	14	Garrison		
590M	Manufact. Adv Comp.	3			6	Pipes
590N	Fund. Aircraft Surviv.	3			12	Heister
590R	Model Predict. Contrl.	3	8	Rotea		
590T	Design Build Test	3			8	Sullivan
607	Vari. Princ. Of Mech.	3			8	Longuski
615	Aeroacoustics (meets with ME615)	3	3	Mongeau		
626	Turb. & T Model	3			23	Blaisdell
632	Adv. Orbital Dyn.	3	11	Howell		
642	Grad. Profess. Pract.	0	1	Lyrintzis	2	Lyrintzis
654	Fracture Mech.	3			25	Sun
660	Operator Meth. Control Theory	3	9	Frazho		
666	Nonlinear Dynamic System Control	3			19	Corless
690T	Lam. Turb. Transit.	3	10	Schneider		
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
Undergraduate/ Graduate Electives			
511-Intro. to Fluid Mech.	507-Basic Mechanics	536-Adv Energy Conversion	546-Struct. Dyn and Stability
512-Computational Aero	508-Optimization in Aero. Eng.	537-Hypersonic Propulsion	547-Experimental Stress Anal.
514-Intermediate Aero	531-Flight Mechanics	538-Air Breathing Propulsion	550-MDO
515-Rotorcraft Aerodynamics	532-Orbit Mechanics	539-Adv. Rocket Propulsion	551-Design Th and Methods
518-Low Gravity Fluid Mech.	564-Systems Anal. and Control	630-Stability of Free Surfaces	552-NDE of Struct and Mat.
519-Satellite Aerodynamics	565-Guidance and Control	637-Future Prop Concepts	553-Elasticity in Aero. Eng
520-Experimental Aero.	567-Intro to Stochastic Proc.		554-Fatigue in Struct. and Mat.
613-Viscous Flow Theory	574-Digital Flight Control Sys.		555-Mech. of Composite Mat.
615-Aerocoustics	590G-Satellite Nav and Pos		556-Aeroelasticity
626-Turbulence	632-Adv Orbital Dynamics		558-Finite Element Methods
	660-Operator Methods		559-Mech. of Friction & Wear
	666-Nonlinear Dynamics		646-Elastic Wave Propagation
	696-Multivariate Control		654-Fracture Mechanics
			655-Adv Topics in Composites

Required Capstone Design 450 Spacecraft Design or 451 Aircraft Design

Multidisciplinary Electives 490E-Introduction to Satellite Systems; 490F Engineering Systems Analysis; 490S-Satellite Design

Summarized Class Enrollment Statistics
for the 2004-2005 Academic Year

Semester	Statistic	Three-Credit Courses				One-Credit Laboratory Courses
		100, 200, 300, 400, Levels	500 Levels	600 Level	All Levels	
Fall of 2004	No. of classes offered	25	16	5	46	5
	Total Enrollment	1064	550	34	1648	301
	Average number of students per class	43	34	7	36	60
Spring of 2005	No. of classes offered	24	16	5	45	6
	Total enrollment	1096	313	77	1486	292
	Average number of students per class	46	20	15	33	49

(does not include AAE 698 and 699)

STAFF FOR THE 2004-2005 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