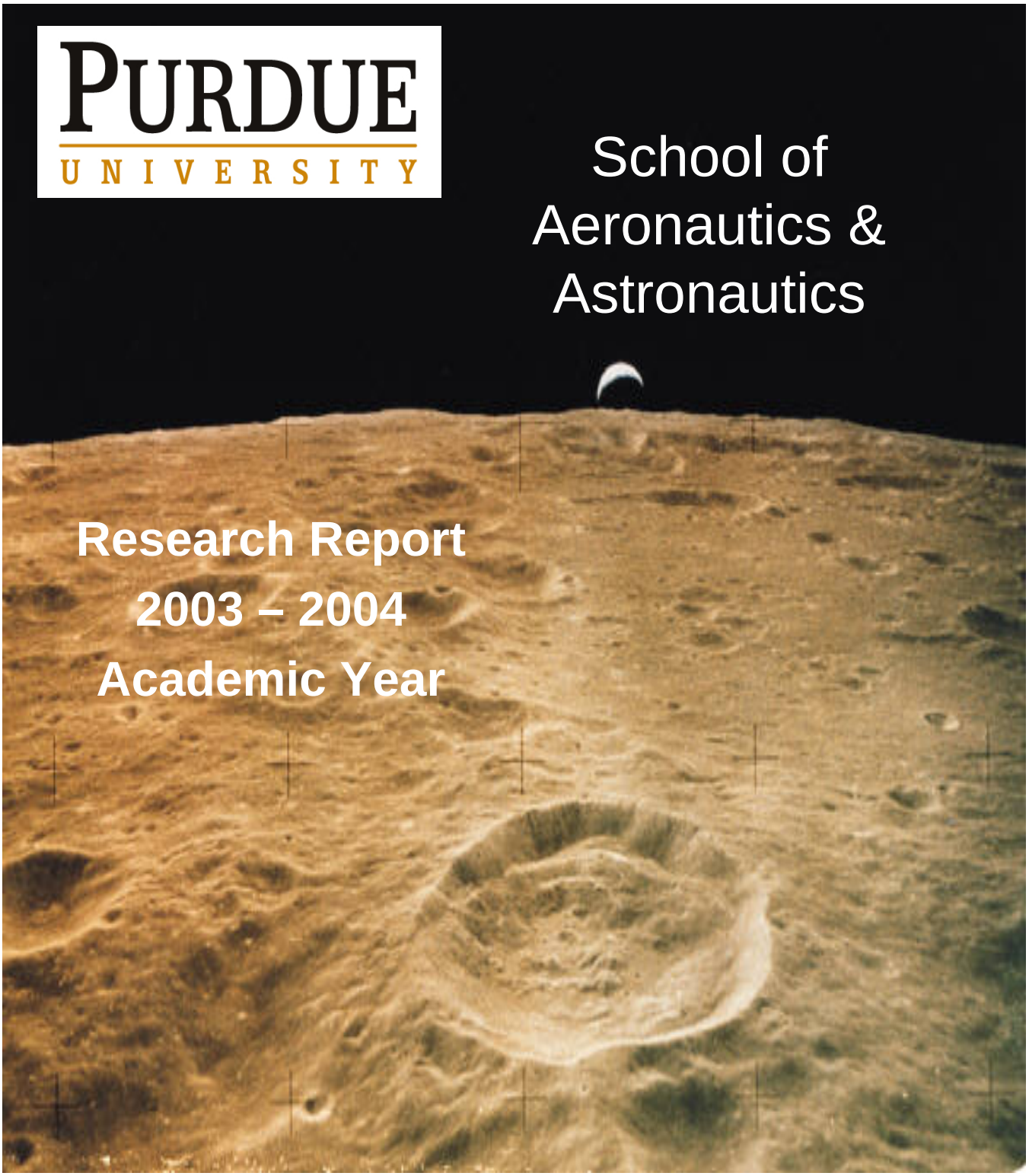

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OUR MISSION

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

ACADEMIC HIGHLIGHTS

Undergraduate enrollment was 480 for the fall of 2004, indicating that enrollment has almost tripled since 1999. During academic year 2003-04, 119 students earned their Bachelor of Science degree, 47 earned their Master of Science degree, and 11 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**
B.S.	43	60	67	95	119
M.S.	35	27	42	24	47
Ph.D.	9	17	19	10	11

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. Purdue Study Abroad will also start to offer short-term, multiple destination programs during the summer.

The School of Aeronautics and Astronautics, through Purdue University's Continuing Engineering Education (CEE) 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 CEE will be a benefit to all participants.

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 September 2003 and April 2004. 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. 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.

The School's campaign for its portion of the Millenium Engineering Building is nearing its goal. The State of Indiana's $37.7 million commitment, combined with $10 million in private gift funding, is well on its way to the $46 million goal Purdue has set to build the engineering complex, leaving Purdue $3.5 million yet to be raised.

Kenneth O. Johnson (B.S.A.A.E. '50) of Cincinnati, OH gave a lead gift of $1 million to the Millenium Engineering Building. Mr. Johnson worked for General Electric from 1966 until his retirement in 1986. While at GE's Large Gas Turbine Design Operation, he helped develop, introduce and patent the unducted fan engine, a breakthrough that led to reduced fuel consumption for commercial aircraft. He continues to perform research and development for Belcan Engineering in Cincinnati.

ALUMNI HIGHLIGHTS

The School named the following eight new Outstanding Aerospace Engineers (OAEs) to be recognized in October 2004: Mr. Bradley D. Belcher (B.S.A.A.E. 1982); Dr. John T. Betts (M.S.A.A.E. 1967, Ph.D. 1970); Mr. Lloyd E. Hackman (B.S.A.E. 1952); Ms. Anna-Maria McGowan (B.S.A.A.E. 1992); Mr. Terrence H. Murphy (B.S.A.A.E. 1980); Mr. David A. Spencer (B.S.A.A.E. 1989, M.S.A.A.E. 1991); Dr. Anthony L. Thornton (Ph.D. 1992); and Mr. Thomas L. Williams (B.S.A.A.E. 1975, M.S.A.A.E. 1976).

Mr. Hank Queen (B.S.A.E. 1974) and Dr. Christopher G. Whipple (B.S.E.S. 1970), were awarded the College of Engineering Distinguished Engineering Alumnus (DEA) Award on April 16, 2004. Mr. Queen is currently Vice President, Engineering and Product Integrity, Boeing Commercial Airplanes Group. Dr. Whipple is a Principal in Environ International's Emeryville, California office.

Mr. William J. O'Neil (B.S.A.E. 1961) was awarded the honorary doctorate degree during the May 2004 graduation ceremonies. Mr. O'Neil served as the Manager of JPL's Systems Management Office within the JPL Director's Office in the last year of his

JPL career retiring on May 1, 2001. He has been honored with NASA's highest award—the Distinguished Service Medal— for his management of Project Galileo.

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2003 are given in the "Faculty Summary" section of this report. Only documents that actually appeared in print during 2003 are listed. Note that 1 book, 37 journal articles or book chapters, and 142 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 2003-04 academic year, 48 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 9 in 58 new applicants received appointments this year. Many other students gain industrial experience through internships.

Co-Op Companies
School of Aeronautics and Astronautics
July 1, 2003-June 30, 2004

Company	Location	Number of A&AE Co-op Students
Air Force Research Lab.	Edwards AFB, CA	0
Aerospace Corporation	Los Angeles, CA	1
American Trans Air Engineering	Indianapolis, IN	0
ATA Engineering Inc.	San Diego, CA	6
Atlantic Research Corporation	Knoxville, TN	0
BAE Systems Control	Ft. Wayne, IN	0
Ball Aerospace & Tech. Corp.	Boulder, CO	12
Delta Air Lines	Atlanta, GA	0
General Electric Aircraft Engines	Cincinnati, OH	11
NASA-Dryden Flight Research Center	Edwards, CA	1
NASA-Glenn Space Center	Cleveland, OH	1
NASA-Goddard Space Center	Greenbelt, MD	1
NASA-Johnson Space Center	Houston, TX	8
NASA-Kennedy Space Center	Kennedy Space Ctr., FL	2
NASA-Langley Research Center	Hampton, VA	1
Naval Research Laboratory	Washington, DC	0
Rockwell International Corporation	Cedar Rapids, IA	4
Rolls-Royce	Indianapolis, IN	3
Structural Analysis Engineering	Cincinnati, OH	2
United Parcel Service (Air Group)	Louisville, KY	0
United Technologies Pratt & Whitney	W. Palm Beach, FL	0
United Technologies Pratt & Whitney	East Hartford, CT	0
Wright-Patterson AFB	Dayton, OH	5

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.

In addition, many workstations and personal computers are located throughout the School. High performance computing is available, using multiple IBM, Silicon Graphics, and Sun Microsystems computers. The ***High Performance Computing Cluster for Aerospace Applications*** consists of a 104-CPU Beowulf Linux cluster using 1.2 GHz AMD Athalon microprocessors allowing distributed and parallel processing. Purdue also owns a 320-CPU IBM SP supercomputer.

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 second, completed in 2001, has a 9.5-inch Mach-6 test section, but is so far quiet only at low Reynolds numbers. 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, tribology, manufacturing, wave propagation, smart materials and structures, and optimal design methods.

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 **Fatigue and Fracture Laboratory** 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 (11,000 and 22,000 lb. 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. Facilities are also available to artificially corrode specimens in connection with corrosion and/or corrosion/fatigue related research, and to perform nondestructive inspections by magnetic particle and dye penetrant methods.

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.

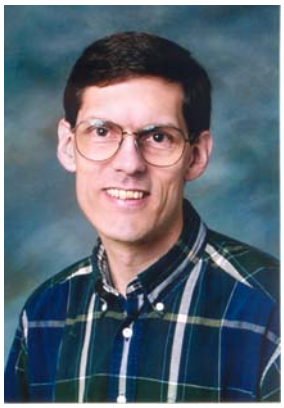
The **Tribology and Materials Processing Laboratory,** maintained jointly with the **Center for Materials Processing and Tribology** contains tribological instrumentation as well as up-to-date machines for manufacturing processes. Equipment includes a 22 kip computer-controlled electro-hydraulic test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

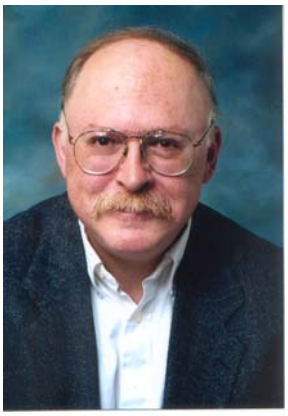
S. H. Collicott, Associate Professor, Ph.D., Stanford, 1991, experimental and low-gravity fluid dynamics, optical diagnostics, and applied optics

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

Rizzetta, D. P., Visbal, M. R., and Blaisdell, G. A., "A Time-Implicit High-Order Compact Differencing and Filtering Scheme for Large-Eddy Simulation," *International Journal Numerical Meth. Fluids*, Vol. 42, pp. 665-693, June 2003.

Uzun, A., Blaisdell, G. A., and Lyrintzis, A. S., "Sensitivity to the Smagorinsky Constant in Turbulent Jet Simulations," *AIAA Journal*, Vol. 41, No. 10, pp. 2077-2079, Oct. 2003.

Conference Proceedings, Presentations, Invited Lectures

Garrison, L. A., Dalton, W. N., Lyrintzis, A. S., and Blaisdell, G. A., "An Investigation of the Extension of the Four-Source Method for Predicting the Noise from Jets with Internal

Forced Mixers," AIAA Paper No. 2003-3165, presented by L. A. Garrison at the *9th AIAA/CEAS Aeroacoustics Conference,* Hilton Head, NC, May 2003.

Uzun, A., Blaisdell, G. A., and Lyrintzis, A. S., "3-D Large Eddy Simulation for Jet Aeroacoustics," AIAA Paper No. 2003-3322, presented by A. Uzun at the *9th AIAA/CEAS Aeroacoustics Conference,* Hilton Head, NC, May 2003.

Wright, C., Blaisdell, G. A., and Lyrintzis, A. S., "The Effects of Various Mixer Shapes on Jet Noise," AIAA Paper No. 2003-3251, presented by C. Wright at the *9th AIAA/CEAS Aeroacoustics Conference,* Hilton Head, NC, May 2003.

Zhang, X., Blaisdell, G. A., and Lyrintzis, A. S., "High-Order Compact Schemes with Filters on Multi-Block Domains," *Proceedings of the 2nd MIT Conference on Computational Fluid and Solid Mechanics,* Cambridge, MA, pp. 1212-1215, June 17-20, 2003.

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

Ong, D., Yeh, C.-P., Hoverman, T. J., and Collicott, S. H., "Effects of a Small Step in an Orifice on Liquid Jet Breakup," *Atomization and Sprays,* Vol. 13, No. 2/3, pp. 297-307, 2003.

Conference Proceedings, Presentations, Invited Lectures

Collicott, S. H., and Weislogel, M. M., "Review of Surface Evolver Validation Tests for Zero-Gravity Fluids Applications," AIAA Paper No. 2003-0999,41st AIAA Aerospace Sciences Meeting, Reno, NV, Jan. 2003.

Simmons, B., Hochstein, J., Marchetta, J., and Collicott, S. H., "An Energy Minimization Model of Magnetic Positive Propellant Positioning (MP3)," AIAA Paper No. 2003-1154, *41st AIAA Aerospace Sciences Meeting,* Reno, NV, Jan. 2003.

Tseng, K., and Collicott, S. H., "Fluidic Spray Control," *Institute for Liquid Atomization and Spray Sciences-Americas 2003,* Monterey, CA, May 2003.

Hoverman, T. J., and Collicott, S. H., "Inexpensive Air-Assist Atomization with 80,000 Orifices," *Institute for Liquid Atomization and Spray Sciences-Americas 2003*, Monterey, CA, May 2003.

Yeh, C., Tseng, K., and Collicott, S. H., "Manipulating Inlet Cavitation to Control Spray Properties," AIAA Paper No. 2003-4787, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*, Huntsville, AL, July 2003.

Collicott, S. H., "Asymmetric Propellant Positions in Symmetric Tanks and Vanes," AIAA Paper No. 2003-4892, Huntsville, AL, July 2003.

Chen, Y., and Collicott, S. H., "Investigation of the Wetting Behavior of an Asymmetrical Vane-Wall Gap in Propellant Tanks," AIAA Paper No. 2003-4893, Huntsville, AL, July 2003.

Weislogel, M. M., Collicott, S. H., Frechette, A., Sala, M., Schlitt, D., Hahs, D., and Garbacik, "Capillary Driven Flows in Complex Geometries," Symposium Microgravity Fluid Dynamics, *5th Euromech Fluid Mechanics Conference*, Toulouse, France, Aug. 2003.

Collicott, S. H., Lockheed Martin A2100 [Communications Satellite] Users Conference. Served as an on-site low-gravity fluids expert for Lockheed Martin scientists and engineers interacting with owners and operators of these $100 million satellites, Princeton, NJ, Oct. 27-28, 2003.

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 has 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.

Publications

Ekici, K., and Lyrintzis, A. S., "Newton-Krylov Methods for Unsteady Navier-Stokes Codes," *International Journal of Computational Fluid Dynamics,* Vol. 17, No. 3, pp. 225-230, June 2003.

Uzun, A., Blaisdell, G. A., and Lyrintzis, A. S., "Deficiencies of the Smagoriski Model for Turbulent Jet Simulations," *AIAA Journal*, Vol. 41, No. 10, pp. 2077-2079, Oct. 2003.

Lyrintzis, A. S., "Integral Acoustics Methods: From the (CFD) Near-Field to the (Acoustic) Far-Field," *International Journal of Aeroacoustics,* Vol. 2, No. 2, pp. 95-128, 2003.

Voutsinas, S., Lyrintzis, A., and Morino, L., (guest editors) *International Journal of Aeroacoustics,* Multi-Science Publishing Co., Vol. 2, No. 2, (127 pages) 2003.

Conference Proceedings, Presentations, Invited Lectures

Uzun, A., Blaisdell, G. A., and Lyrintzis, A. S., "3D Large-Eddy Simulations for Jet Aeroacoustics," AIAA Paper No. 2003-3322 presented at the *9th AIAA/CEAS Aeroacoustics Conference,* Hilton Head, SC, May 2003.

Wright, C., Blaisdell, G. A., and Lyrintzis, A. S., "The Effects of Various Mixer Shapes on Jet Noise," AIAA Paper No. 2003-3251 presented at the *9th AIAA/CEAS Aeroacoustics Conference,* Hilton Head, SC, May 2003.

Garrison, L., Dalton, W., Lyrintzis, A., and Blaisdell, G., "An Investigation of Extension of the Four-Source Method for Predicting the Noise from Jets with Forced Mixers," AIAA Paper No. 2003-3165 presented at the *9th AIAA/CEAS Aeroacoustics Conference*, Hilton Head, SC, May 2003.

Lyrintzis, A. S., "Aeroacoustics of Forced Mixers," presented at the *International Turbulence Workshop*, Orlando, FL, May 2003 [invited].

Zhang, X., Blaisdell, G. A., and Lyrintzis, A. S., "High-Order Compact Schemes with Filters for Multi-Block Domains, presented at the *2nd MIT Conference on Computational Fluid and Solid Mechanics*, Boston, MA, June 2003.

Uzun, A., Blaisdell, G. A., and Lyrintzis, A. S., "Application of Compact Schemes for Turbulent Jets," presented at the *2nd MIT Conference on Computational Fluid and Solid Mechanics*, Boston, MA, June 2003.

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

Experimental fluid mechanics
High-speed laminar-turbulent transition

Research Areas

High-speed laminar-turbulent transition is critical for applications including hypersonic reconnaissance vehicles, thermal protection for re-entry vehicles, drag reduction on supersonic transports, and flow noise and heat transfer above IR windows on 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 has developed quiet supersonic tunnels during the 70's, 80's, and 90's 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 grounded on the correct flow physics.

To complement the expensive quiet-flow facilities developed at NASA Langley, a low-cost 4-inch Mach 4 quiet-flow Ludwieg tube was constructed at Purdue. Quiet was demonstrated to length Reynolds numbers of 400,000 (AIAA Journal, April 1995, p. 688). Localized hot-spot disturbances were repeatably generated by a pulsed Nd:YAG laser in order to generate repeatable wave packets in the flow, and surface perturbations were generated by a glow perturber. Perturbations are measured using hot wires, high-sensitivity laser differential interferometry, and arrays of surface hot films.

A new 18-inch stainless-steel Ludwieg tube is now operational with a 9.5-inch quiet-flow Mach-6 test section. Quiet-flow operation to a length Reynolds number of 13 million is projected (AIAA Paper 98-0547), although quiet-flow has so far been achieved only at low Reynolds numbers. Modern digital and optical instrumentation will enable

efficient use of the 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.

Conference Proceedings, Presentations and Invited Lectures

Schneider, S. P., Matsumura, S., Rufer, S., Skoch, C., and Swanson, E., "Hypersonic Stability and Transition Experiments on Blunt Cones and a Generic Scramjet Forebody," AIAA Paper No. 2003-1130, presented at the *2003 AIAA Meeting*, Reno, NV, Jan. 2003.

Matsumura, S., Schneider, S. P., "Streamwise-Vortex Instability and Transition on a Generic Scramjet Forebody," AIAA Paper No. 2003-3592, presented at the *2003 AIAA Meeting*, Orlando, FL, June 2003.

Schneider, S. P., Skoch, C., Rufer, S., and Swanson, E., "Hypersonic Transition Research in the Boeing/AFOSR Mach-6 Quiet Tunnel," AIAA Paper No. 2003-3450, presented at the *AIAA Fluid Dynamics Meeting*, Orlando, FL, June 2003.

Matsumura, S., Schneider, S. P., Berry, S. A., "Flow Visualization Measurement Techniques for High-Speed Transition Research in the Boeing/AFOSR Mach-6 Quiet Tunnel," AIAA Paper No. 2003-4583, presented at the *AIAA Ground Testing Conference*, Huntsville, AL, July 2003.

Schneider, S. P., "Development of the Boeing/AFOSR Mach-6 Quiet Tunnel at Purdue University," presented at *ONERA Chalais-Meudon*, France, July 9, 2003.

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

Publications

Liu, T.S. and Sullivan, J.P., "In Situ Calibration Uncertainty of Pressure-Sensitive Paint," *AIAA Journal*, Vol. 41, No. 11, Nov 2003, pp. 2300-2302.

Conference Proceedings, Presentations and Invited Lectures

Gregory, J. and. Sullivan, J., "Characterization of Hartmann Tube Flow with Porous Pressure-Sensitive Paint," AIAA Paper 2003-3713, *33rd AIAA Fluid Dynamics Conference and Exhibit*, Orlando, FL, June 23-26, 2003.

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

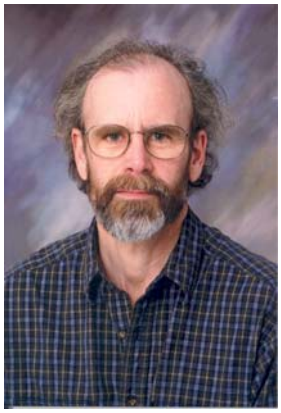
DYNAMICS AND CONTROL

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

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

Ryu, S., and D. Andrisani II, D., "Longitudinal Flying Qualities Prediction for Nonlinear Aircraft," *Journal of Guidance, Control and Dynamics,* Vol. 26, No. 3, pp. 474-482, May-June 2003.

Conference Proceedings, Presentations, Invited Lectures

Hoshizaki, T., Andrisani II, D., Braun, A., Mulyana, A., and Bethel, J., "Optical Navigation Systems," AAIA Paper No. 2003-5353, presented at the *AIAA Guidance, Navigation, and Control Conference,* Austin Texas, August 11-14, 2003.

Garman, K. and Andrisani II, D., "A Portable Data Acquisition System for Flight Testing Light Aircraft," AAIA Paper No. 2003-5618, presented at the *AIAA Atmospheric Flight Mechanics Conference,* Austin, TX, August 11-14, 2003.

Hoshizaki, T., Andrisani II, D., Braun, A., Mulyana, A., and Bethel, J.,"Performance of Integrated Electro-Optical navigation Systems," presented at *Institute of Navigation GPS/GNSS Conference,* Session F1, Paper 7, September 9-12, 2003.

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

Book

Corless, M. J., and Frazho, A. E., Linear Systems and Control: An Operator Perspective, Marcel Dekker, New York, NY, 2003.

Conference Proceedings, Presentations, Invited Lectures and Reports

Li, X., DeCarlo, R., and Corless, M. J., "Sliding Manifold Design for a Class of Uncertain Time Delay Systems," *2003 American Control Conference*, Denver, CO, 2003.

DANIEL DELAURENTIS
2004
Assistant Professor

Degrees

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

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

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

Research Interests

Design Methods:

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

Aerospace Systems and Flight Vehicles:

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

Conference Proceedings, Presentations, Invited Lectures and Reports

DeLaurentis, D.A., Lewe, J.H., Schrage, D.P., "Abstraction and Modeling Hypothesis for Future Transportation Architectures," paper no. AIAA-2003-2514 (invited paper) *Proceedings of the AIAA/ICAS International Air & Space Symposium and Exhibition (Centennial of Flight),* Dayton, OH, July 14-17, 2003.

Pfaender, H., DeLaurentis, D., Mavris, D., "An Object-Oriented Approach for Conceptual Design Exploration of UAV-based System-of-Systems," paper no. AIAA-2003-6521, *Proceedings of 3rd AIAA Unmanned Unlimited Conference,* San Diego, CA, Sept. 15-18, 2003.

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.

Book

Corless, M.J., and Frazho, A.E., Linear Systems and Control: An Operator Perspective, Dekker, New York, NY, 2003, 368 pages.

Publications

C. Foias, A.E. Frazho, and M.A. Kaashoek, "The Distance to Intertwining Operators, Contractive Liftings and a Related Optimality Result," *Integral Equations and Operator Theory*, 25 (2003), 71–89.

Conference Proceedings, Presentations, Invited Lectures

C. Foais, A.E. Frazho and M.A. Kaashoek, "The Commutator and Contractive Liftings," *International Workshop on Operator Theory and Applications*, Cagliari, Italy, June 24-27, 2003, abstract.

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

Cardellach, E., Ruffini, G., Pino, D., Ruis, A., Komjathy, A., and Garrison, J. L., Mediterranean Balloon Experiment: Ocean Wind Speed Sensing From the Stratosphere Using GPS Reflections," R*emote Sensing of Environment*, Vol. 88, pp. 351-362, 2003.

Conference Proceedings, Presentations, Invited Lectures

Garrison, J. L., "Anisotropy in Reflected GPS Measurements of Ocean Winds," *2003 IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

You, H., Heckler, G., Garrison, J. L., and Zavorotny, V. U., "Stochastic Model and Experimental Measurements of Ocean Scattered GPS," *2003 IEEE International Geoscience and Remote Sensing Symposium*, Toulouse, France, July 21-25, 2003.

Zeidan, N., and Garrison, J. L., "Bit Synchronization and Doppler Frequency Removal at Very Low Carrier to Noise Ratio Using a Combination of the Viterbi Algorithm with an Extended Kalman Filter," *ION-GPS/GNSS 2003*, Portland, OR, Sept. 9-12, 2003.

You, H., Heckler, G., Garrison, J. L., Zavorotny, V. U., "Stochastic Model and Experimental Measurement of Ocean-Scattered GPS Signal Statistics," presented at the *2003 Workshop on Oceanography with GNSS Reflections*, Barcelona, Spain, July 17-18, 2003.

Thompson, D. R., Gasparovic, R. F., Garrison, J. L., and Elfouhaily, T. M., "TPS Oceanography Utility Assessment," presented at the *2003 Workshop on Oceanography with GNSS Reflections*, Barcelona, Spain, July 17-18, 2003.

Garrison, James L., "Aniostropy in Reflected GPS Measurements of Ocean Winds", *presentation at: 2003 Workshop on Oceanography with GNSS Reflections*, Barcelona, Spain, July 17-18, 2003.

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.

Conference Proceedings, Presentations, Invited Lectures

Howell, K. C., and Marchand, B. G., "Control Strategies for Formation Flight in the Vicinity of a Libration Point Orbit," AAS Paper No. 03-113, *AIAA 13th AAS/AIAA Space Flight Mechanics Meeting,* Ponce, Puerto Rico, Feb. 9-13, 2003.

Marchand, B. G., and Howell, K. C., Formation Flight Near L2 in the Sun-Earth/Moon Ephemeris System Including Solar Radiation Pressure," AAS Paper No. 03-596, *AAS/AIAA Astrodynamics Conference*, Big Sky, MT, Aug. 2003.

Howell, K. C., and Marchand, B. G., "Design and Control of Formations Near Libration Points in the Sun-Earth/Moon Ephemeris System," *Flight Mechanics Symposium*, Mission Engineering and Systems Analysis Division, NASA Goddard Space Flight Center, Greenbelt, MD, Oct. 28-30, 2003.

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

Conference Proceedings, Presentations, Invited Lectures and Reports

Hwang, I, Hwang, J., and Tomlin, C., "Flight-Mode-Based Conflict Detection using a Residual-Mean Interacting Multiple Model," *NASA Joint University Program,* Stanford, CA, March 2003.

Hwang, I., Balakrishnan, H., Kim, J., and Tomlin, C., "Flight-Mode-Based Conflict Detection using a Residual-Mean Interacting Multiple Model," *DARPA Software Enabled Control Meeting,* Stanford, CA, April 2003.

Hwang, I., Balakrishnan, H., and Tomlin, C., "Hybrid Estimation Algorithm and Related Work," *MURI meeting,* Stanford, CA, June 2003.

Balakrishnan, H., Hwang, I., and Tomlin, C., "Inference Methods for Stochastic Hybrid Systems," *MURI-ONR meeting,* Stanford, CA, July, 2003.

Hwang, I., Hwang, J., and Tomlin, C., "Flight-Mode-Based Aircraft Conflict Detection using a Residual-Mean Interacting Multiple Model Algorithm," *Proceedings of the AIAA Guidance, Navigation, and Control Conference,* Austin, Texas, August 2003.

Hwang, I., Balakrishnan, H., and Tomlin, C., "Observability Criteria and Estimator Design for Stochastic Linear Hybrid Systems," *Proceedings of the IEE European Control Conference,* Cambridge, UK, September 2003.

Stipanovic, D.M., Hwang, I., and Tomlin, C., "Computation of an Over-Approximation of the Backward Reachable Set using Subsystem Level Set Functions," *Proceedings of the IEE European Control Conference*, Cambridge, UK, September 2003.

Hwang, I., Balakrishnan, H., Roy, K., and Tomlin, C., "Multiple-Target Tracking and Identity Management Algorithm for Air Traffic Control," *NASA Joint University Program*, UCLA, CA, September 2003.

Hwang, I., Balakrishnan, H., Roy, K., Shin, J., Guibas, L., and Tomlin, C., Multiple-"Target Tracking and Identity Management Algorithm for Air Traffic Control," *Proceedings of the 2nd IEEE Sensors*, Toronto, Canada, October 2003.

Hwang, I., Balakrishnan, H., and Tomlin, C., "Performance Analysis of Hybrid Estimation Algorithms," *Proceedings of the 42nd IEEE Conference on Decision and Control*, Maui, Hawaii, December 2003.

Oishi, M., Hwang, I., and Tomlin, C., "Immediate Observability of Discrete Event Systems with Applications to User-Interface Design," *Proceedings of the 42nd IEEE Conference on Decision and Control*, Maui, Hawaii, December 2003.

JAMES M. LONGUSKI
1988
Professor

Degrees

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

Interests

Spacecraft Dynamics
Orbit Mechanics
Control
Orbit decay and reentry

Awards and Major Appointments

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

Research Areas

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

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

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

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

In 4) the feasibility of using tethers for aerobraking has been demonstrated. The basic idea is to connect an orbiter and a probe together by a long tether, for missions to planets with atmospheres. The probe enters the atmosphere and is used to reduce the

hyperbolic speed of the orbiter to capture speed, thus eliminating the large retro maneuver normally required. New issues being addressed include analysis of the flexible tether, tether guidance and control, and spacecraft (endpoint) attitude control.

Publications

Johnson, W. R., Longuski, J. M., and Lyons, D. T., "Pitch Control During Autonomous Aerobraking for Near-Term Mars Exploration," *Journal of Spacecraft and Rockets,* Vol. 40, No. 3, pp. 371-379, May-June 2003.

McConaghy, T. T., Debban, T. J., Petropoulos, A. E., and Longuski, J. M., "Design and Optimization of Low-Thrust Trajectories with Gravity-Assist," *Journal of Spacecraft and Rockets,* Vol. 40, No. 3, pp. 380-387, May-June 2003.

Heaton, A. F., and Longuski, J. M., "Feasibility of a Galileo-Style Tour of the Uranian Satellites," *Journal of Spacecraft and Rockets,* Vol. 40, No. 4, pp. 591-596, July-Aug. 2003.

Johnson, W. R., Longuski, J. M., and Lyons, D. T., "Nondimensional Analysis of Reaction-Wheel Control for Aerobraking," *Journal of Guidance, Control, and Dynamics,* Vol. 26, No. 6, pp. 861-868, Nov.-Dec. 2003.

Conference Proceedings, Presentations, Invited Lectures

Park, R. S., and Scheeres, D. J., Giampieri, G., Longuski, J. M., and Fischbach, E., "Estimating General Relativity Parameters from Radiometric Tracking of Heliocentric Trajectories," Paper AAS 03-205, *AAS/AIAA Spaceflight Mechanics Meeting,* Ponce, Puerto Rico, Feb. 9-13, 2003.

McConaghy, T. T., Yam, C. H., Landau, D. F., and Longuski, J. M., "Two-Synodic-Period Earth-Mars Cyclers with Intermediate Earth Encounter," AAS Paper No. 03-509, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Chen, K. J., McConaghy, T. T., Landau, D. F., and Longuski, J. M., "A Powered Earth-Mars cycler with Three Synodic-Period Repeat Time," AAS Paper No. 03-510, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Landau, D. F., and Longuski, J. M., "Comparative Assessment of Human Missions to Mars," AAS Paper No. 03-513, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Landau, D. F., Longuski, J. M., and Penzo, P. A., "Parking Orbits for Human Missions to Mars," AAS Paper No. 03-514, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Javorsek, II, D., and Longuski, J. M., "Extension of Satellite Lifetime via Precision Pointing of Orbit Transfer Maneuvers," AAS Paper No. 03-515, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Javorsek, II, D., and Longuski, J. M., "Effect of Thrust Profile on Velocity Pointing Errors of Spinning Spacecraft," AAS Paper No. 03-516, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Jokic, M., and Longuski, J. M., "Artificial Gravity and Abort Scenarios via Tethers for Human Missions to Mars," AAS Paper No. 03-536, *AAS/AIAA Astrodynamics Specialist Conference,* Big Sky, MT, Aug. 3-7, 2003.

Park, R. S., Rischbach, E., Giampieri, G., Longuski, J. M., and Scheeres, D. J., "Test of General Relativity: Estimating PPN Parameters γ and β from Spacecraft Radiometric Tracking Data," Poster Presentation and Proceedings, SPACEPART '03, the *2nd International Conference on Particle and Fundamental Physics in Space,* Washington, DC, Dec. 10-12, 2003.

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

Kothandaraman, G., and Rotea, M. A., "SPSA Algorithm for Parachute Parameter Estimation," AIAA Paper No. 2003-2118, *17th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar,* Monterey, CA, May 2003.

Lana, C., Rotea, M. A., and Viassolo, D. E., "Characterization of Color Printers Using Robust Parameter Estimation," *IS&T/SID's 11th Color Imaging Conference,* Scottsdale, AZ, Nov. 4-7, 2003.

Rotea, M. A., Lana, C., and Viassolo, D., "Robust Estimation Algorithm for Spectral Neugebauer Models," *42nd IEEE Conference on Decision and Control,* Maui, Hawaii, Dec. 2003.

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.

Awards and Major Appointments

Best Paper Award, "Design and Ground Testing of a Hydrogen Peroxide/Kerosene Combustor for RBCC Application," 39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Huntsville, Alabama, 20-23 July 2003.

Conference Proceedings, Presentations, Invited Lectures

Sisco, J. C., Austin, B. L., Mok, J-S., and Anderson, W. E., "Ignition Studies of Hydrogen Peroxide and Kerosene Fuels," AIAA Paper No. 2003-0831, *41st Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 6-9, 2003.

Miller, K. J., Sisco, J. C., Austin, Jr., B. L., Martin, T. N., and Anderson, W. E., "Design and Ground Testing of a Hydrogen Peroxide/Kerosene Combustor for a RBCC Application," AIAA Paper No. 2003-4477, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Martin, T. M., Miller, K. J., Gedmark, J. M., Yu, Y., Pourpoint, T., and Anderson, W. E., "A Design, Build, Test Course in Rocket Combustors," AIAA Paper No. 2003-4499, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Long, M. R., Bazarov, V. G., and Anderson, W. E., "Main Chamber Injectors for Advanced Hydrocarbon Booster Engines," AIAA Paper No. 2003-4599, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Mok, J.-S., Sisco, J. C., and Anderson, W. E., "Analysis and Experiments of Hydrogen Peroxide Vaporization and Decomposition," AIAA Paper No. 2003-4621, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Pearson, N. S., Pourpoint, T., and Anderson, W. E., "Vaporization and Decomposition of Hydrogen Peroxide Drops," AIAA Paper No. 2003-4642, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Sung, I.-K., Northcutt, B. G., Rubel, K. R., and Anderson, W. E., "A Subscale-Based Life Prediction Methodology for Rocket Engine Combustors," AIAA Paper No. 2003-4900, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Sisco, J. C., Mok, J.-S., and Anderson, W. E., "Autoignition of Kerosene by Decomposed Hydrogen Peroxide in a Dump Combustor Configuration," AIAA Paper No. 2003-4921, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 21-23, 2003.

Ali, S. T., and Anderson, W. E., "Field Test Method for Hydrogen Peroxide Stability Margin, AIAA Paper No. 2003-4642, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*, Huntsville, AL, July 21-23, 2003.

Anderson, W. E., Sisco, J. C., and Sung, I.-K., "Rocket Combustor Experiments and Analyses," *Thermal Fluids Analysis Workshop*, Hampton, VA, Aug. 19, 2003.

Anderson, W. E., "Combustor Scaling," *2003 Thermal-Fluids Analysis Workshop,* NASA Langley Research Center, Aug. 19, 2003.

Anderson, W.E., Sisco, J.C., and Sung, I.-K., "Rocket Combustor Experiments and Analyses," *Thermal Fluids Analysis Workshop*, Hampton, VA, Aug. 19, 2003.

Anderson, W. E., "Combustor Scaling," *2003 Thermal-Fluids Analysis Workshop,* NASA Langley Research Center, August 19, 2003.

Anderson, W.E., Sisco, J.C., and Sung, I.-K., "Subscale Test Methods for Combustion Devices," *5th International Symposium on Liquid Space Propulsion,* Chattanooga, TN, October 28-30, 2003.

Miller, K. J., Sisco, J. C., Austin Jr., B. L., Martin, T. N., Anderson, W. E., and Palumbo, N.M. "Direct-Connect Simultaneously Mixing and Combusting Ducted Rocket Build and Test," *39th JANNAF Combustion Subcommittee Meeting,* Colorado Springs, CO, Dec. 1-5, 2003.

STEPHEN D. HEISTER
1990
Professor

Degrees

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

Interests

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

Sponsored Research Summaries

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

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

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

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

Publications

Yoon, S. S., and Heister, S. D., "Categorizing Linear Theories for Atomizing Jets," *Atomization and Sprays,* Vol. 13, 2003.

Conference Proceedings, Presentations, Invited Lectures

Corpening, J., Heister, S. D., Palmer, K., and Rusek, J. J., "Combustion of Advanced Non-Toxic Hybrid Propellants," AIAA Paper No. 2003-4595, *39th AIAA Joint Propulsion Conference,* Huntsville, AL, 2003.

Shimo, M., Heister, S. D., Ji, J., and Gore, J., "Performance Mapping of Cyclic PDE using Various Fuels," AIAA Paper No. 2003-4823, *39th AIAA Joint Propulsion Conference,* Huntsville, AL, 2003.

Matsutomi, Y., Heister, S. D., and Meyer, S. E., "Impulse Measurements of a Cyclic Pulse Detonation Engine," AIAA Paper No. 2003-4824, *39th AIAA Joint Propulsion Conference,* Huntsville, AL, 2003.

Xu, C., Heister, S. D., and Field, R., "Cavitating Flow Modeling Including Energy Interchange Effects," AIAA Paper No. 2003-4925, *39th AIAA Joint Propulsion Conference,* Huntsville, AL, 2003.

Shimo, M., Meyer, S., Heister, S., Gore, J., and Ji, J., "Performance Mapping of a Cyclic PDE using Ethylene/Air," *Proceedings of the Third Joint Meeting of the U. S. Sections of the Combustion Institute,* Chicago, IL, 2003.

Park, H., Yoon, S. S., and Heister, S. D., "A Fully Nonlinear Atomization Model for High-Speed Jets," *16th ILAS Americas Conference,* Monterey, CA, 2003.

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

Conference Proceedings, Presentations, Invited Lectures and Reports

Ivana Hrbud, Melissa Van Dyke, Mike Houts, Keith Goodfellow, "Non-Nuclear NEP System Testing", *Proceedings of the Space Technology and Applications International Forum (STAIF),* February 2003, Albuquerque, NM.

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

Venkateswaran, S., Merkle, C.L., Zeng, X and Li, D., "Influence of Initial Conditions on Pre-Conditioned Solutions at Low Speeds," *AIAA Journal,* Sept. 2003.

Conference Proceedings, Presentations, Invited Lectures and Reports

Merkle, C. L., "A Generalized Fluid Formulation for Turbomachinery Computations," (invited) AIAA Paper No. 2003-3999, *33rd AIAA Fluid Dynamics Conference and Exhibit,* Orlando, FL, June 23-26, 2003.

Li, D., Keefer, D., Rhodes, R., and Merkle, C. L., "Analysis of MHD Generator Power Generation," AIAA Paper No. 2003-5050, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, 2003.

Li, D., Xia, G., and Merkle, C. L. "Analysis of Real Fluid Flows in Converging Diverging Nozzles," AIAA Paper No. 2003-4132, *33rd AIAA Fluid Dynamics Conference and Exhibit,* Orlando, FL, June 23-26, 2003.

Venkateswaran, S., and Merkle, C. L., "Artificial Dissipation Control for Viscous and Unsteady Computations," AIAA Paper No. 2003-3695, *16th AIAA Computational Fluid Dynamics Conference,* Orlando, FL, June 23-26, 2003.

Tsuei, H., Groschel, E., Xia, G., and Merkle, C. L., "Characterization of Thrust Augmentation by Unsteady Ejectors," AIAA Paper No. 2003-4970, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, 2003.

Lindau, J., and Kunz, R., Venkateswaran, S., and Merkle, C. L., "Computation of Compressible Multiphase Flows," AIAA Paper No. 2003-1285, *41st Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 2003.

Zeng, X., Venkateswaran, S., and Merkle, C. L., "Designing Dual-Time Algorithms for

Steady-State Calculations," AIAA Paper No. 2003-3707, *16th AIAA Computational Fluid Dynamics Conference,* Orlando, FL, June 23-26, 2003.

Xia, G., Li, D., and Merkle, C. L., "Effects of a Needle on Hartmann-Sprenger Tube Flows," AIAA Paper No. 2003-3888, *33rd AIAA Fluid Dynamics Conference and Exhibit,* Orlando, FL, June 23-26, 2003.

Venkateswaran, S., Li, D., and Merkle, C. L., "Influence of Stagnation Regions on Preconditioned Solutions at Low Speeds," AIAA Paper No. 2003-435, *41st Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 2003.

Lindau, J., Venkateswaran, S., Kunz, R., Merkle, C. L., "Multiphase Computations for Underwater Propulsive Flows," AIAA Paper No. 2003-4105, *16th AIAA Computational Fluid Dynamics Conference,* Orlando, FL, June 23-26, 2003.

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.

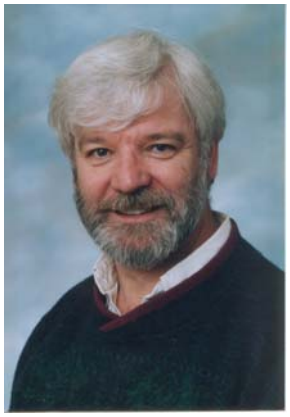
From 1993 to 1998 Mr. Meyer worked at Arnold Engineering Development Center in Tullahoma, Tennessee as a project engineer in the Propulsion Wind Tunnel Facility. There he directed multi-million dollar propulsion integration wind tunnel tests for contractors on the F-22 and F/A-18 fighter aircraft and 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. 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

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

Hassan, R. A., and Crossley, W. A., "Multi-Objective Optimization for Communication Satellites with a Two-Branch Tournament Genetic Algorithm," *Journal of Spacecraft and Rockets*, Vol. 40, No. 2, pp. 266-272, Mar.-Apr. 2003.

Conference Proceedings, Presentations, Invited Lectures

Hassan, R. A., and Crossley, W. A., "Comparison of Sampling Techniques for Reliability-Based Optimization of Communication Satellites Using Genetic Algorithms, AIAA Paper No. 2003-1332, *41st Aerospace Sciences Meeting and Exhibit*, Reno, NV, Jan. 6-9, 2003.

Roth, B., and Crossley, W. A., "Application of Optimization Techniques in the Conceptual Design of Morphing Aircraft," AIAA Paper No. 2003-6733, *3rd AIAA ATIO Forum*, Denver, CO, Nov. 17-19, 2003.

Crossley, W. A., "Mission Development Studies and Morphing as an Independent Variable," *DARPA Morphing Aircraft Structures (MAS) Kick-Off Meeting*, Tucson, AZ, Jan. 26-28, 2003.

Crossley, W. A., "The Future of Aerospace Structures: Education," presented as part of "The Future of Aerospace Structures," panel session at the *44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, Norfolk, VA, Apr. 2003.

Crossley, W. A., "Optimization to Support Morphing Aircraft Design," NASA Langley Research Center, Hampton, VA, Aug. 11, 2003.

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.

Conference Proceedings, Presentations, Invited Lectures and Reports

Doyle, J. F., "Force Identification for Nonlinear Structures," *Proceedings 7th International Conference on Recent Advances in Structural Dynamics,* ISVR, Southampton, July 2003.

Choi, S-W., and Doyle, J. F., "Impact and Penetration of Ductile Materials: Finite Element and Simplified Modeling," *Proceedings of the 7th International Conference on Recent Advances in Structural Dynamics,* ISVR, Southampton, July 2003.

THOMAS N. FARRIS
1986
Professor and Head

Degrees

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

Interests

Tribology
Manufacturing processes
Fatigue and fracture

Awards and Major Appointments

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

Research Areas

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

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

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

Publications

Murthy, H., Rajeev, P.T., Okane, M., Farris, T.N., "Development of Test Methods for High Temperature Fretting of Turbine Materials Subjected to Engine-Type Loading," *ASTM STP 1425, Fretting Fatigue: Advances in Basic Understanding and Applications*, Y. Mutoh, S.E. Kinyon and D.W. Hoeppner, Eds. pp 273-288 (2003).

Matlik, J.F. and Farris, T.N., "Development of Test Methods for High Frequency Fretting Fatigue," *ASTM STP 1425, Fretting Fatigue: Advances in Basic Understanding and Applications*, Y.Mutoh, S.E. Kinyon and D.W. Hoeppner, Eds. pp 251-272 (2003).

Moylan, S.P., Kompella, S., Chandrasekar, S. and Farris, T.N., "A New Approach for Studying Mechanical Properties of Thin Surface Layers Affected by Manufacturing Processes," *ASME Journal of Manufacturing Science and Engineering*, **125**, pp 310-315 (2003).

Chang, S-H., Farris, T.N. and Chandrasekar, S., "Experimental Characterization of Superfinishing," *Proceedings of the I MECH E Journal on Engineering Manufacture*, **217**(B7) pp 941-951 (2003).

Hwang, J., Kompella, S., Chandrasekar, S. and Farris, T.N., "Measurement of Temperature Field in Surface Grinding using Infra-Red (IR) Imaging System," *ASME Journal of Tribology*, **125**, pp 377-383 (2003).

Farris, T.N., Murthy, H., and Matlik, J.F. "Fretting Fatigue," *Comprehensive Structural Integrity Fracture of Materials from Nano to Macro; Volume 4: Cyclic Loading and Fatigue,* ed by R.O. Ritchie and Y. Murakami, pp 281-326 (2003).

Conference Proceedings, Presentations, Invited Lectures and Reports

Narayanan, V., Krishnamurthy, K., Hwang, J., Kompella, S., Chandrasekar, S., Farris, T.N., and Madhavan, V., "Measurement of Temperature Field at the Tool-Chip Interface," *Proc. Of NSF Workshop on Research Needs in Thermal Aspects of Material Removal Processes*, Ed R. Komanduri, Stillwater, OK*, pp 63-69, June 2003.

Hwang, J., Kompella, S., Hanna, I., Chandrasekar, S. and Farris, T.N., "Analysis and Measurement of Grinding Temperatures," *Proc. Of NSF Workshop on Research Needs in Thermal Aspects of Material Removal Processes*, Ed R. Komanduri, Stillwater, OK, pp 202-212, June 2003.

Murthy, H. and Farris, T.N., "Elevated Temperature Fretting of Turbine Materials Subjected to Engine Type Loading," in *Proc. of 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*, Norfolk, VA, April 2003.

Matlik, J.F. and Farris, T.N., "High Temperature, High Frequency Fretting Fatigue Investigations," in *Proc. of 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*, Norfolk, VA, April 2003 [Outstanding Student Paper].

Farris, T.N., Murthy, H. and Matlik, J.F., "Fretting Fatigue of Contacts between Engine Alloys of Dissimilar Elastic Properties," *Proc. of the 8th National Turbine Engine High Cycle Fatigue (HCF) Conference*, Monterey, CA, April 2003.

Whittle, 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," (abstract only) MRS Annual Meeting, 2003.

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.).

Conference Proceedings, Presentations, Invited Lectures and Reports

Grandt, Jr., A. F., and Gustafson, W. A., "History of Aerospace Education and Research at Purdue University: 1910-2002," AIAA Paper No. 2003-0234, *41st Aerospace Sciences Meeting and Exhibit,* American Institute of Aeronautics and Astronautics, Reno, NV, Jan. 2003.

Grandt, Jr., A. F., "Review of Crack Paths by L. P. Pook," *Applied Mechanics Reviews*, Vol. 56, No. 2, pp. B25-B26, March 2003.

Garcia, D. B., and Grandt, Jr., A. F., "Fractographic Characteristics Associated with Fretting Fatigue Cracks in Turbomachinery Alloys," AIAA Paper No. 2003-1682, *44th AIAA/ASME/AHS Structures, Structural Dynamics, and Materials Conference*, Norfolk, VA, April 7-10, 2003.

Farris, T. N., Grandt, Jr., A. F., Murthy, H., Matlik, J. F., and Garcia, D. B., "Characterization of Fretting Fatigue of Nickel-Based Alloys," *8th National Turbine Engine HCF Conference*, Monterey, CA, April 14-16, 2003.

Grandt, Jr., A. F., and Kim, J., "Characterization of Fatigue Crack Growth in Unitized Construction," final report prepared for The Alcoa Technical Center, April 2003.

Grandt, Jr., A. F., and Park, C. Y., "Analysis of Fatigue Crack Growth from Countersunk Fastener Holes," *FAA Materials and Structures R&D Workshop,* FAA William J. Hughes Technical Center, NJ, June 3 – 5, 2003.

Grandt, Jr., A. F., "Review of Models and Phenomena in Fracture Mechanics by L. I. Slepyan," *Applied Mechanics Reviews*, Vol. 56, No. 4, p. B56, July 2003.

Grandt, Jr., A. F., and Kim, J., "Stress Intensity Factor Testing for Unitized Construction," *5th Boeing Unitized Structure Technical Interchange*, New Orleans, LA, Sept. 11, 2003.

PETER K. IMBRIE
Freshman Engineering
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., Kedward, K. T., and Welch, D. A., "Experimental Investigation of High Velocity Ice Impacts on Woven Carbon/Epoxy Composite Panels," Composites Part A, Vol. 34, No. 1, pp. 25-41, 2003.

Kim, H., "The Influence of Adhesive Bondline Thickness Imperfections on Stresses in Composite Joints," *Journal of Adhesion,* Vol. 79, No. 2, pp. 621-642, 2003.

Conference Proceedings, Presentations, Invited Lectures

Kim, H., and Lee, J., "Adhesive Nonlinearity and the Prediction of Failure in Bonded Composite Lab Joints," *ASTM D30 Symposium on the Joining and Repair of Composite Structures,* Kansas City, MO, March 17-18, 2003.

Kim, H., Kwon, H., and Keune, J., "Buckling Initiation and Disbonded Growth in Adhesively Bonded Composite Flanges," *44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials (SDM) Conference,* Norfolk, VA, Apr. 7-10, 2003.

Kim, H., and Kwon, H., "Buckling-Driven Disbonding of Composite Joint Flanges," *ASME Mechanics and Materials Conference,* Scottsdale, AZ, June 17-20, 2003.

Kim, H., "Disbonded Growth Initiation in Post-Buckled Composite Joint Flanges," *Proceedings of the 18th Annual ASC Technical Conference on Composite Materials,* Gainesville, FL, Oct. 20-22, 2003.

Kwon, H., and Kim, H., "Experimental Measurement of Buckling and Disbond Growth in Adhesively Bonded Composite Splice Joint Flanges," *Proceedings of the 18th Annual ASC Technical Conference on Composite Materials,* Gainesville, FL, Oct. 20-22, 2003.

Kim, H., "Flexural Instability of Hollow Foam-Filled Thin-Walled Composite Cylinders," *ASME International Mechanical Engineering Congress and RD&D Exposition,* Washington, DC, Nov. 15-21, 2003.

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

Degrees

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

Interests

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

Research Areas

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

Publications

Pipes, R. B., and Hubert, P., "Scale Effects in Carbon Nanostructures: Self-Similar Analysis," *Nano Letters*, Vol. 3, No. 2, (2003), pp 239-243.

Pipes, R. B., Frankland, S-J., Hubert, P. and Saether, E., "Self-Consistent Properties of the SWCN and Hexagonal Arrays as Composite Reinforcements," *Composites Science and Technology*, Vol. 63, No. 10, (2003), pp. 1349-1358.

Pipes, R. B., and Hubert, P., "Helical Carbon Nanotube Arrays: Thermal Expansion," *Composites Science and Technology*, Vol. 63, No. 11, (2003), 1571-79.

Saether, E., Pipes, R. B., and Frankland, S-J, "Nanostructured Composites: Effective Mechanical Properties Determination of Nanotube Bundles," *Composites Science and Technology*, Vol. 63, No. 11, (2003), pp. 1543-50.

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

Sun, C.T. and Zhang H., "Size-dependent Elastic Moduli of Platelike Nanomaterials," *J. Applied Physics,* Vol. 93, No. 2, pp. 1212-1218, Jan. 2003.

Zhu, C., and Sun, C. T., "Micromechanical Modeling of Fiber Composites Under Off-Axis Loading," *Journal of Thermoplastic Composite Materials,* Vol. 16, No. 4, pp. 333-344, July 2003.

Zhu, R. P., and Sun, C. T., "Effects of Fiber Orientation and Elastic Constants on Coefficients of Thermal Expansion in Laminates," *Mechanics of Advanced Materials and Structures,* Vol. 10, No. 2, pp. 99-108, 2003.

Bodily, B. H., and Sun, C. T., "Structural and Equivalent Continuum Properties of Single-Walled Carbon Nanotubes," *International Journal of Materials and Product Testing,* Vol. 18, No. 4/5/6, pp. 381-397, 2003.

Aymerich, F., Priolo, P., and Sun, C. T., "Static and Fatigue Behavior of Stitched Graphite/Epoxy Composite Laminates," *International Journal of Fracture,* Vol. 63, pp. 907-917, 2003.

Guo, C., and Sun, C. T., "Stationary and Moving Interface Cracks with Contact in Anisotropic Bimaterials," *The Chinese Journal of Mechanics* - Series A, Vol. 19, No. 1, pp. 207-215, 2003.

Hu, H., and Sun, C. T., "The Equivalence of Moisture and Temperature in Physical Aging Polymeric Composites," *Journal Composite Materials,* Vol. 37, No. 10, pp. 913-928, 2003.

Cho, J., and Sun, C. T., "Modeling Thermal Residual Stresses in Composite Patch Repairs During Multi-temperature Bonding Cycles," *Journal of Aircraft,* pp. 1200-1205, Nov.-Dec. 2003.

Conference Proceedings, Presentations, Invited Lectures

Sun, C.T., "Testing and Modeling Rate Dependent Properties of Polymeric Composites Using Off-Axis Specimens," (abstract only) *Composites Testing and Model Identification,* Chalons en Champagne, France, Jan. 28-30, 2003.

Maley, S., and Sun, C. T., "Quantifying Particulate Damping in Sandwich Structures," Proceedings of the 6th *International Conference on Sandwich Structures,* Fort Lauderdale, FL, pp. 976-995, March 31-April 2, 2003.

Turaga, U.V.R.S., and Sun, C. T., "An Investigation of Adhesive Single-lap Joints with Attachments," *33rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference,* Norfolk, VA, April 7-10, 2003.

Sun, C. T., and Zhang, H., "Size-Dependent Elastic Constants of Materials at Nano Scale," (abstract only) presented at the *9th International Conference on the Mechanical Behavior of Materials,* Geneva, Switzerland, May 26-30, 2003.

Sun, C. T., and Turaga, U. V. R. S., "An Improved Method for Joining Composites," *Proc. of the 14th International Conference on Composite Materials (ICCM-14),* San Diego, CA, July 14-18, 2003.

Tsai, J., and Sun, C. T., "Strain Rate Effect on In-plane Shear Strength of Unidirectional Polymeric Composites," *Proc. of the 14th International Conference on Composite Materials (ICCM-14),* San Diego, CA, July 14-18, 2003.

Sun, C. T., and Jin, Z.-H., "Cohesive Laws in Cohesive Fracture Model," *2003 Mechanics and Materials Conference,* Scottsdale, AZ, June 17-20, 2003.

Chang, I., and Sun, C. T., "Misfit Dislocation Modeling of Thin Film by Molecular Methods," *2003 Mechanics and Materials Conference*, Scottsdale, AZ, June 17-20, 2003.

Sun, C. T., "A Critical Review of Applications of Fracture Mechanics in Composites," (a plenary lecture) at the *18th Technical Conference, American Society for Composites,* Gainesville, FL, Oct. 20-22, 2003.

Subramaniyan, A. K., Bing, Q., Nakaima, D., and Sun C. T., "Effect of Nanoclay on Compressive Strength of Glass Fiber Composites," *Proc. of the 18th Technical Conference, American Society for Composites,* Gainesville, FL, Oct. 20-22, 2003.

Shigeki, A., Shrotri, K., and Sun, C. T., "Static and Fatigue Strengths in a Notched Hybrid Composite Laminate," *Proc. of the 18th Technical Conference, American Society for Composites,* Gainesville, FL, Oct. 20-22, 2003.

N. Gorenstein, A. Friedman, M. Ladisch, C.T Sun, H. Mahfuz, A. Adnan, V.K. Rangari, S. Jeelani, 'Synthesis, Processing, and Mechanical Characterization of Epoxy-Protein Nanocomposites," *Proc. of the 18th Technical Conference, American Society for Composites*, Gainesville, Florida, Oct. 20 -22, 2003.

Sun, C. T., and Achuthan, A., "Domain Switching in Polycrystalline Ferroelectrics Based on Microstructures," *International Symposium on Macro- Meso- Micro- and Nano-Mechanics of Materials (MM2003),* Hong Kong, Dec. 8-20, 2003.

Sun, C. T., and Wang, Z., "Modeling Micro-inertia in Heterogeneous Solids Under Dynamic Loading, presented at the *ASME International Engineering Congress & Exposition*, Washington, DC, Nov. 16-21, 2003.

Sun, C. T., "Implications of Nanotechnology to Solid Mechanics," a William Mong Distinguished Lecture presented at the University of Hong Kong, Dec. 12, 2003.

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.

Publications

Weisshaar, T. A., Livine, E., and Sanders, B. L., "Aeroelasticity of Nonconventional Airplane Configurations – Past and Future," *Journal of Aircraft,* Vol. 40, No. 6, pp. 1047-1065, Nov. – Dec. 2003.

Conference Proceedings, Presentations, Invited Lectures

Weisshaar, T. A., "Changing the Shape of Aeronautics – the Case for Autonomous Morphing Aircraft," Keynote, *SPIE,* San Diego, CA, March 2003.

Weisshaar, T. A., "Making the Case for Morphing Aircraft," Keynote, *AIAA SDM*, Norfolk, VA, April 2003.

Weisshaar, T. A., "Reconfigurable Space Systems – Vision for the Future," U. S. Air Force Space Command, Colorado Springs, CO, Oct. 2003.

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.

Publications

Wu, J., Rajwa, B., Filmer, D. L. Hoffmann, C.M., Yuan, B., Chiang, C., Sturgis, J., Voytik-Harbin, S., and Robinson, J. P., "Automated Quantification and Reconstruction of Collagenmatrix from 3D Confocal Datasets," *Journal of Microscopy*, 210 (2003) 158-165.

Wu, J., Rajwa, B., Filmer, D.L., Hoffmann, C.M., Yuan, B., Chiang, C., Sturgis, J., and Robinson, J. P., "Analysis of Orientations of Collagen Fibers by Novel Fiber-tracking Software,"*Microscopy & Microanalysis*, 9 (2003) 574-580.

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 2003 to June 2004

RESEARCH AND OTHER SCHOLARLY ACTIVITIES

Between July 1, 2003 and June 30, 2004, approximately $5.1 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 2003-2004 year was attributed to the following sources.

SOURCE OF SPONSORED RESEARCH FOR 2003-2004	
Source	**Percentage of Total**
Department of Defense	45.1
NASA	23.8
National Science Foundation	3.6
FAA	3.5
Industry	10.7
Indiana 21st Century R & D	7.8
Other	5.5
Total	100.0%

SPONSORED RESEARCH PROJECTS
ACTIVE DURING THE PERIOD JULY 1, 2003 TO JUNE 30, 2004

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
InSpace LLC.	Innovative Ignition System for Non-Toxic Storable Propellants – Phase 1 – Experimental Design	03/01/04-05/31/04	$20,000	Anderson
NASA	Improved Preliminary Design Analysis Process for High-Pressure Rocket Combustion	12/01/01-12/31/03	$135,000	Anderson
NASA	Risk Reduction for the ORSC Main Chamber Injectors and Cooling	01/08/03-09/30/04	$512,003	Anderson Co-PI's: Gore, Heister, Sojka
NASA	Ignition and Performance Tests of a Rocket-Based Combined Cycle	10/15/03-06/30/04	$29,996	Anderson
ERC, Inc./AFRL	Fundamental Studies of Peroxide Decomposition	09/12/02-12/31/03	$30,000	Anderson
InSpace LLC	Thermal Decomposition Studies	08/28/03-02/28/04	$40,000	Anderson
Sierra Engrg.	Longitudinal Stability Tester Development Support	09/02/03-12/10/03	$20,000	Anderson Co-PI: Meyer
Metron, Inc.	Intent Inference Algorithm	06/25/03-09/17/04	$105,645	Andrisani
United Negro College Fund	GM Sullivan Faculty Fellowship	07/01/02-12/31/75	$10,000	Andrisani
Rockwell Collins	Portable Data Acquisition and Control System	06/09/00-12/31/75	$30,000	Andrisani
E-Enterprise Ctr. @ Discovery Pk.	Air Traffic Management Research for the 21st Century and Beyond	08/01/01-08/31/04	$32,100	Andrisani
Rockwell Collins	Remotely Piloted Giant-Scale Aircraft	07/01/03-12/31/75	$25,000	Andrisani
Rolls Royce Allison	Dynamics of Engine Oil Sumps & Drains	05/01/02-05/31/05	$210,526	Collicott (Co-P.I. Heister)
Star Technologies	Zero-Gravity Wicking of Biofluids	06/07/04-09/30/04	$25,060	Collicott
NASA	Design Methods and Optimization for Morphing Aircraft	08/15/01-08/14/04	$236,890	Crossley
AFRL	Improved Methodology for Advanced Aircraft Design	09/29/00-05/31/04		Crossley (Co-P.I.-Weisshaar)
Nextgen Aeronautics	Genetic Algorithm Approaches for Sizing, Shape and Topology	02/01/04-07/31/04	$14,990	Crossley
Mide Tech. Corp.	Self Consuming Spacecraft	12/01/99-12/31/75	$2,000	Crossley

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
NSF	Micro-Scale Characterization of Machining Interfaces	08/15/01-07/31/04	$41,237	Co-PI: Farris with Chandrasekar
General Electric Aircraft Engines	Mechanics of Blade/Disk Contacts	07/01/03-12/31/03	$49,999	Farris
NSF	Innovation Realization Lab – A New Educational Model	08/01/01-07/31/04	$137,384	Co-PI: Farris with Kovenock
Pratt & Whitney	SSME Single Crystal Cracking Contact Fatigue Test	06/18/02-12/30/04	$150,000	Farris
WPAFB	Fretting Fatigue Testing of Aluminum	09/06/02-01/05/06	$248,000	Farris Co-PI: Grandt
General Electric Co.	High-Temperature Fretting Fatigue Feature Testing	09/05/03-09/05/04	$125,294	Farris
21st Century R&D	Low Cost Carbon-Carbon Technology for Pervasive Economic Growth	03/05/01-03/31/04	$184,565	Co-PI: Farris & Sun with Siegmund
Multi-sponsor	Materials Processing and Tribology Research Group	06/17/98-12/31/75	$137,700	Farris
Rolls-Royce	Fretting Fatigue Modeling	01/01/02-12/31/03	$70,000	Farris
NASA	Model Function Development for the Retrieval of Ocean Surface Properties from Scattered GPS Signals	09/15/02-09/14/05	$345,704	Garrison
NASA	Autonomous Navigation for Alternate Access to the International Space Station	05/18/01-12/31/04	$49,283	Garrison
NASA	Investigation of the Fundamental Properties of Forward Scattered GPS Signals for Oceanographic Remote Sensing	03/01/02-02/28/05	$412,805	Garrison
Boeing Co.	Study to Compare Predicted Versus Experimental Crack Shape Changes as Crack Progresses Through Structure	09/11/03-07/31/05	$74,783	Grandt
Ohio State Univ.	AFRL Visiting Scientist Proposal	05/01/03-04/30/04	$83,660	Grandt
FAA	Analysis of Fatigue Crack Growth from Countersunk Fastener Holes	07/01/02-06/30/05	$382,218	Grandt
ALCOA	Durability of Aircraft Joints	06/01/99-12/31/01	$210,000	Grandt
AFOSR	Modeling Liquid Rocket Engine Atomization and Swirl/Coaxial Injectors	02/01/03-12/31/04	$167,336	Heister
Edwards AFB	Non-Catalytic Ignition of Advanced Monopropellants	09/11/03-06/11/04	$50,000	Heister
National Reconnaissance	Altitude Compensation using Combustible Nozzle Liners	11/24/03-11/24/04	$192,000	Heister Co-PI: Meyer

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
Allison Advanced Development Co.	Propulsion & Power Center of Excellence	03/09/01-05/30/04	$821,899	Heister Co-PI: Gore
University of Alabama/NASA	Combustion Instability and Film Cooling Studies for Hydrocarbon Engines	01/31/03-08/09/05	$119,538	Heister Co-PI's: Anderson, Farris
NASA	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	Howell
NASA	Stationkeeping Analysis in Support of the Terrestrial Planet Finder (TPF) Mission	03/15/04-09/01/04	$10,000	Howell
NASA	Mission Design and Analysis Involving Formation Flying Near Libration Point Orbits	07/01/03-06/30/04	$75,000	Howell Co-PI: Rotea
Boeing Co.	Hail Ice Impact Damage on Stiffened Composite Panels	05/01/04-10/31/04	$20,000	Kim
NASA	Buckling-Driven Disbond Growth in Composite Structures	01/01/04-12/31/04	$75,000	Kim
Odyssian Technology	Multi-functional Composite Structures	02/15/03-02/15/05	$337,500	Kim Co-PI's: Crossley Sun Weisshaar
United Technologies/ Pratt&Whitney	Modeling Hail Ice Impacts on Aero-Engine Structures	08/27/02-12/31/04	$33,789	Kim
JPL	Interplanetary Mission Design	05/14/03-11/30/04	$156,510	Longuski
21st Century R&D	Development of Low Jet Noise Aircraft Engines	03/05/01-12/30/03	$1,053,531	Lyrintzis Co-PI's: Blaisdell Bolton Mongeau
Northrop Grumman	Purdue University's High Pressure Facility	04/17/03-11/30/04	$79,412	Meyer
Northrop Grumman	5K Thrust Chamber Assembly Testing	04/15/03-11/30/04	$155,500	Meyer
Swift Enterprises	72% Monoprop Hydrogen Peroxide Gas Generator Testing	08/05/02-12/30/03	$252,450	Meyer

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
N.S. Gowadia	Static and Free Jet Inlet Testing	11/15/02-12/31/04	$123,556	Meyer
Babcock and Wilcox	Pulse Detonation Testing for Diamond Power Specialty Company	05/14/04-12/31/04	$41,262	Meyer Co-PI: Merkle
General Kinetics	GK Cavitating Venturi Calibration Testing	09/17/03-12/31/04	$5,475	Meyer
Discovery Park	Center for Security of Large Scale Systems	03/25/04-08/24/05	$1,027,984	Co-PI: Rotea with Wasynczuk, Revankar, Ong, Sullivan, Hoffman, Coyle, Downar, Skvarenia, Gotham
Fleet & Industrial Supply	Parameter Estimation for Airdrop Systems	12/12/02-12/31/03	$26,867	Rotea
United Technologies Research Center	Robust Control Analysis and Synthesis	09/01/98-12/31/75	$40,000	Rotea
Xerox Corp.	Xerox Corporation	07/07/01-12/31/75	$66,000	Rotea
NSF	Analysis and Design of Multivariable Extremum Seeking Algorithms	9/1/00-8/31/04	$209,488	Rotea
Sandia National Lab.	Collaborative Research: Mechanisms of Hypersonic Boundary-Layer Transition on Reentry Vehicles	08/01/03-09/30/05	$40,000	Schneider
AFOSR	Mechanisms of Hypersonic Boundary Layer Transition on Two Generic Vehicle Geometries	12/15/02-12/14/04	$260,229	Schneider
NASA	Mechanisms of Boundary-Layer Transition on Reusable Launch Vehicles	02/01/02-01/31/05	$125,000	Schneider
NASA	Unsteady Pressure Measurement in Turbomachinery Using Porous Pressure-Sensitive-Paint	08/01/02-07/31/04	$48,000	Sullivan
USDA	Technology Development, Transfer, and Marketing of Industrial Products for Rural Communities	09/15/01-09/30/04	$107,095	Co-PI: Sullivan with Gibson, Tao, Okos, Swain
21st Century R&D	Materials Processing for Accelerometer and Sensor Manufacture	03/05/01-03/05/04	$95,884	Co-PI: Sullivan with Bowman, King, Slamovich
Raisbeck Engineering	Design/Build/Test Laboratory	08/01/99-99/99/99	$97,000	Sullivan

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P.I.
A.T.C. Incorporated	ATC, Inc.	01/01/00-12/31/75	$16,667	Sullivan
Physical Acoustics Corporation	Composite Armor Material Characterization	07/01/99-99/99/99	$39,000	Sun
AFOSR	Development of Composites Reinforced with Short Wavy Fibers	12/01/01-11/30/04	$300,000	Sun
ONR	Dynamic Constitutive and Failure Modeling of Composite Materials and Structures	02/01/96-11/30/04	$675,208	Sun
ONR	Applications of Nanomaterials in Polymeric Composites for Marine Structures	12/01/02-11/30/04	$200,000	Sun
Tuskegee Univ./NSF	Modeling of Nanocomposites	09/01/03-08/31/04	$40,000	Sun
AFOSR	Prediction of Ductile Fracture of Thin-Walled Cylinders Subjected to Localized Intense Heat	06/01/03-09/30/04	$199,000	Sun
NASA	Modeling of Nano Materials	01/01/01 08/31/04	$250,000	Sun
DARPA	IPA Agreement	08/12/02-08/11/06	$634,649	Weisshaar

GRADUATE THESES

July 2003 to June 2004

MASTER'S THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree** **Date Granted**
Sisco, James C. *W. Anderson*	"Autoignition of Kerosene by Decomposed Hydrogen Peroxide in a Dump Combustor Configuration"	M.S. August 2003
Ali, Syed Tabrez *W. Anderson*	"Heterogeneous Decomposition of Hydrogen Peroxide and its Stability Margin"	M.S. December 2003
Anathula, Vikram *G. Blaisdell*	"Computations of an Axial Vortex Using Turbulence Models"	M.S. December 2003
Garrison, Loren A. *A. Lyrintzis*	"Jet Noise Models for Forced Mixer Noise Predictions"	M.S. December 2003
Gnanamanickam, E. P. *J. Sullivan*	"Piezoelectric Ceramics for High Temperature Aerospace Applications"	M.S. December 2003
Lana, Carlos *M. Rotea*	"Characterization of Color Printers Using Robust Parameter Estimation"	M.S. December 2003
Matsumura, Shin *S. Schneider*	"Streamwise-Vortex Instability and Transition on the Hyper-2000 Scramjet Forebody"	M.S. December 2003
Matsutomi, Yu S. Heister	"Impulse Measurement and Modeling of Cyclic Pulse Detonation Engines"	M.S. December 2003
Mok, Jong Soo *W. Anderson*	"Investigation of Simultaneous Vaporization and Decomposition of Hydrogen Peroxide Using Multiple Jets in Crossflow"	M.S. December 2003
Stein, William B. *S. Heister &* *J. Rusek*	"An Investigation for Developing a Theoretical Basis for Electrokinetic Propulsion"	M.S. December 2003
Child, David R. *A. F. Grandt, Jr.*	"Experimental Validation of Mode I Stress Intensity Factors for the Single-Cracked Pin-Loaded Lug"	M.S. May 2004
Corpening, Jeremy *S. D. Heister*	"Experiments on Combustion of Advanced Hybrid Rocket Fuels Using Hydrogen Peroxide Oxidizer"	M. S. May 2004
Edwards, Jonathan M. *S. D. Heister*	"Impulse Measurements of Momentum Exchange Propulsion for Mobility Applications"	M. S. May 2004

Gean, Matthew *H. Kim*	"Finite Element Analysis of the Mechanics of Blade Disk Contacts"	M. S. May 2004
Keune, John *H. Kim*	"Development of a Hail Ice Impact Model and the Dynamic Compressive Strength Properties of Ice"	M.S. May 2004
Lew, Phoi-Tack *A. Lyrintzis*	"Effects of Inflow Forcing on Jet Noise Using 3-D Large Eddy Simulation"	M.S. May 2004
Niemczura, Jaroslaw *S. Heister*	"Evaluation of Positive Displacement Pump Types for Small Scale, Scroll Driven Propellant Feed Systems"	M.S. May 2004
Wright, Charles *A. Lyrintzis*	"Investigating Correlations Between Reynolds Averaged Flow Fields and Noise for Forced Mixed Jets"	M.S. May 2004

DOCTORAL THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree** **Date Granted**
Chen, Yongkang *S. Collicott*	"A Study of Capillary Flow in a Vane-Wall Gap in Zero Gravity"	Ph.D August 2003
Eshpuniyani, Brijesh *G. Blaisdell*	"Flow Physics of Strained Turbulent Axial Vortices"	Ph.D. December 2003
Funk, John *S. Heister*	"Effects of Impingement and Shear Upon the Ignition of Hypergolic Rocket Bipropellants"	Ph.D. December 2003
Hoshizaki, Takayuki *D. Andrisani, II*	"Tactical Strategies for Improving Accuracy in Optical Targeting Systems"	Ph.D. December 2003
Park, Chul Young *A. F. Grandt, Jr.*	"Durability of Countersunk Fastener Holes"	Ph.D. December 2003
Sakaue, Hirotaka *J. Sullivan*	"Anodized Aluminum Pressure Sensitive Paint for Unsteady Aerodynamic Applications"	Ph.D. December 2003
Uzun, Ali *A. Lyrintzis*	"3-D Large Eddy Simulation for Jet Aeroacoustics"	Ph.D. December 2003
Cho, Sung-Man *J. F. Doyle*	"Algorithms for Nonlinear Identification Problems Using Whole-Field Data"	Ph.D. May 2004
Hassan, Rania *W. A. Crossley*	"Genetic Algorithm Approaches for Conceptual Design of Spacecraft Systems Including Multi-Objective Optimization and Design Under Uncertainty"	Ph.D. May 2004
Yagci, Baris *A. E. Frazho*	"Sinusoid Estimation in Non-Stationary Noise and Applications in Structural Vibrations"	Ph.D. May 2004
Zhang, Haitao *C. T. Sun*	"Mechanical Behavior of Nanomaterials: Modeling and Simulation"	Ph.D. May 2004

COLLOQUIUM SERIES

July 2003 to June 2004

Colloquium Series – Fall 2003

DATE/TIME	TOPIC	SPEAKER
September 4, 2003*** 4:00 p.m. Fowler Hall	Gas Turbines Developments – Past, Present and Future	**Dr. Mike Howse** Director-Engrg. & Tech. Rolls-Royce plc United Kingdom
September 11, 2003 3:00 p.m. GRIS 180	Pulsed Detonation Engine (PDE) Research at Wright-Patterson AFB	**Dr. Fred Schauer** Head, PDBE Air Force Research Lab WPAFB, OH
September 16, 2003 3:00 p.m. GRIS 180	Materials Challenges of Liquid Rocket Engines	**John A. Halchak** Rocketdyne Propulsion & Power, The Boeing Company Canoga Park, CA
September 25, 2003 3:00 p.m. GRIS 180	Future Directions at Boeing	**Ray Cosner** Sr. Technical Fellow The Boeing Company
October 2, 2003 3:00 p.m. GRIS 180	The Boeing 7E7 – A New Airplane for a New World	**Roy Eggink** Manager, Aerodynamics Engrg. for Product Develop. Boeing Comm. Airplanes Everett, WA
October 9, 2003 3:00 p.m. GRIS 180	Systems Research in Advanced Air Traffic Management	**Yiyuan J. Zhao** Aerospace Engrg. & Mech. Univ. of Minnesota
October 10, 2003** 2:30 p.m. ME 256	Modeling and Numerical Simulation of the Bio-Fluid-Dynamics of Red Blood Cells	**Dr. Costas Pozrikidis** Univ. of California San Diego, CA
October 10, 2003 10:30 a.m. MSEE B012	Raisbeck Learjet Drag Reduction Program: How Things are really done in the Outside World	**James Raisbeck** CEO and Board Chairman Raisbeck Engineering Seattle, WA

October 23, 2003 3:00 p.m. GRIS 180	Capillary-Driven Flow in Liquid Filaments Connecting Orthogonal Microfluidic Channels	**Dr. Jeffrey Allen** NASA John H. Glenn Research Center Lewis Field Cleveland, OH
November 3, 2003 3:00 p.m. GRIS 180	The Jupiter Icy Moons Orbiter: NASA's Bold New Interplanetary Explorer	**Joe Cassady** Eastern Regional Mgr. Business Development Aerojet, Redmond Operations
November 13, 2003 3:00 p.m. GRIS 180	Challenges and Issues in the Computational Modeling of a Jet in Cross-Flow with Ground Effect	**Dr. Venke Sankaran** Purdue University W. Lafayette, IN

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

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

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

Colloquium Series – Spring 2004

DATE/TIME	TOPIC	SPEAKER
January 15, 2004 3:00 p.m. GRIS 180	Development and Applications of General CFD Code	**Dr. Ding Li** University of Tennessee
January 22, 2004 5:00 p.m. GRIS 280	Mars Exploration Rover Entry and Landing Loads Analysis	**Dr. Doug Adams** Spacecraft Struct. & Dyn. Group NASA JPL
February 12, 2004* 3:00 p.m. GRIS 180 and 7:00 p.m. GRIS 180	Morphing Aerospace Structures – Connecting Points in the Sky and the Universe	**Dr. Terrence Weisshaar** DARPA Program Mgr.
February 17, 2004 3:00 p.m. GRIS 180	System of Systems – A View from Industry	**Barbara M. Grant** Director, Horizontal Integration Support Lockheed Martin Corp.
February 19, 2004 3:00 p.m. GRIS 180	Measures of Cohesiveness in Single Walled Carbon Nanotube Arrays	**Dr. Byron Pipes** Goodyear Endowed Professor Polymer Engineering Academic Center University of Akron Akron, OH
March 4, 2004 3:00 p.m. GRIS 180	Fluidic Jets, Sprays and Mixing Devices	**Dr. Surya Raghu** Advanced Fluidics Ellicott City, MD
March 25, 2004 3:00 p.m. GRIS 180	Design Optimization for Reliability and Robustness	**S. Mahadevan** Vanderbilt University
April 1, 2004 3:00 p.m. GRIS 180	High Lift Systems for Commercial Airplanes	**Rob Hoffenberg** Boeing Commercial Airplanes Everett, WA

April 2, 2004* 3:30 p.m. GRIS 160	The Mobility of Phase Boundaries	**Rohan Abeyaratne** Quentin Berg Prof. of ME MIT Cambridge, MA
April 6, 2004 2:00 p.m. STEW 320	JSF Steam Ingestion Program: The Lakehurst Jan. 03 Catapult Sled Tests	**John T. Spyropoulos** Naval Air System Command Paxtuxent River, MD JSF Program Office Washington, DC
April 8, 2004 3:00 p.m. GRIS 180	STOVL Propulsion Control and Development Challenges of Step Changes in System Architecture	**Dr. Gonzalo J. Rey** Pratt & Whitney E. Hartford, CT
April 13, 2004 3:00 p.m. GRIS 180	Fracture Mechanics and Computer Vision for Measurements in Experimental Mechanics: recent studies and developments	**Dr. Michael A. Sutton** Carolina Distinguished Professor Dept. of Mechanical Engrg. Univ. of South Carolina
April 15, 2004 3:00 p.m. GRIS 180	Buffet Experiences Over 46 Years and Continuing	**Professor Marty Furman** Parks College of Engineering & Aviation St. Louis, MO
April 22, 2004 10:30 a.m. STEW 320	Overview of the Aerothermodynamics Analyses Conducted in Support of the STS-107 Accident Investigation	**Charles H. Campbell** NASA Johnson Space Ctr. Houston, TX
April 22, 2004 3:00 p.m. GRIS 180	Impact Dynamics Analyses at Pratt & Whitney Bird-Strike and Blade Containment	**Dr. Thomas Vasko, PE** Pratt & Whitney East Hartford, CT

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

Highlights & Awards

July 2003 to June 2004

FACULTY HIGHLIGHTS

The School welcomed three new faculty in fall 2004. In the dynamics and control area, Dr. Dan DeLaurentis joined our School as Assistant Professor from Georgia Institute of Technology; and Dr. Inseok Hwang joined our faculty as Assistant Professor from Stanford University. Dr. R. Byron Pipes joined our faculty, as well as the Materials Engineering and Chemical Engineering faculty, as the John L. Bray Distinguished Professor of Engineering.

Professor Terrence Weisshaar continues his sabbatical at DARPA where he directs the Morphing Program.

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

Other highlights include:

- Professor James Longuski was awarded the 2003 Bruhn Best Teaching Award.
- Professor Kathleen Howell was named Hsu Lo Professor of Aeronautical and Astronautical Engineering
- Professor Charles Merkle was named the Reilly Professorship of Engineering
- Professor Steven Collicott flew on NASA's KC-135 aircraft (a.k.a. "Vomit Comet)
- Professor Mario Rotea was awarded the Best Poster Interactive Paper Award, 42nd IEEE Conference on Decision and Control, December 2003
- Professor Martin Corless was awarded the 2004 Gustafson Teaching Award.
- Professor Steven Schneider was promoted to the rank of Professor of Aeronautical and Astronautical Engineering.
- Professor John Sullivan was named director of Purdue University Center for Advanced Manufacturing

STUDENT HIGHLIGHTS

There are four 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). AIAA, SGT, and SEDS conducted the 8th annual Fall Space Day. SGT hosted "Professor Pizzas," an opportunity for students to interact one-on-one with an AAE professors and visiting dignitaries. Several student groups continue to perform well in national design competitions.

Student Awards

Congratulations to the following students who have earned top honors

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

Fall 2003 First Place Team: Greg Wilson, Jimmy Chiu, Garrett Willis and David Stinson

Spring 2004 First Place Team: Ryan Abbott, Philipp Boettcher, Marques Fulford, Yusaku Yamashita, and Tatsuya Kotegawa

Purdue Engineering Foundation Outstanding Student Award –
December 2003 - Jennifer Watson
Spring 2004 - Wade McMillan

2004 - Herbert F. Rogers Scholarship - Whitney Jackson, Brian Schoening, and Brian Ventre

2004 - Koerner Scholarships - Sophomores: Philipp Boettcher and Dheer Lashkari; Juniors: Laura Brower and Joshi Manasi; Seniors: Debanik Barua and Michael Spuzzillo

2004 - Magoon Graduate Teaching Award - Lee Kuan Chiew, Masaki Kakoi, Fong Loon Pan, William B. Stein, and Stephanie VanY

2004 - Elmer F. Bruhn Undergraduate Research Assistantship - Manasi Joshi, Tyler Wilhelm and Rebecca Dale

2004 - Outstanding Senior Award -
December 2003 – Jennifer Watson
May 2004 – Wade McMillan

2004 - Outstanding Graduate Student Award -
December 2003 – William (Ben) Stein
May 2004 – Jeremy Corpening

2004 - Hsu Lo Fellowship - Hai-Yang Qian

2004 - John and Patricia Rich Scholarship - David Berger, John Collins, Gregory Heckler, John Horst, Ryan Irwin, Jesse Jones, Ryan Whitley, James Swedler, and Garrett Willis

Presentation of Awards at the 2004 Society of Women Engineers Brunch

Congratulations to:

Allison Bahnsen - Ball Aerospace & Technologies Corporation
Jasmine Cashbaugh - Lockheed Martin
Jayleen Guttromson - merit award from Alumnae
Whitney Jackson - Donald C. Cook America Electric Power
Jackie Jaron - The Boeing Company
Angela Long - merit award from Alumnae
Jeri Metzger - merit award from Alumnae
Niccole Pattee - Lockheed Martin
Elizabeth Wolf - Vought Aircraft Industries, Inc.
Leah Wyman - Miller-Bush

ASTM Student Paper Competition Award 2003 - Bence Bartha
Best Poster Interactive Paper Award 2003 - Carlos Lana
1st Place National Student Paper Competition 2004 - James Gregory
2004 - 47th Purdue Grand Prix Winner - Clayton Smith

OUTREACH HIGHLIGHTS

In its eighth year, Fall Space Day '03 was a great success with more than 300 third through eighth graders, and 85 plus strong volunteer crew attending. Astronaut **Colonel John Blaha** 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.; the American Institute of Aeronautics and Astronautics; and the Students for the Exploration and Development of Space.

Several faculty gave presentations to local schools. The inherent excitement of aerospace leads to these invitations and generates great responses from the students.

Curriculum & Course Offerings

July 2003 to June 2004

CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

Course Enrollments
School of Aeronautics and Astronautics
2003-2004 Academic Year

A&AE Course	Most Recent Title	Cr.	Fall 2003		Spring 2004	
			Enroll-ment	Instructor	Enroll-ment	Instructor
203-1	Aeromechanics I	3	166	Garrison	45	Corless
204-1	Aeromechanics II	3	57	Farris	64	Kim
204-2	Aeromechanics II	3			59	Imbrie
204L	Aeromechanics II Lab.	1	54	Doyle	122	Doyle
241	Industrial Practice I	0	4	Williams	5	Williams
242	Industrial Practice II	0	1	Williams	3	Williams
251	Intro. Aerosp. Design	3	67	Sullivan	123	Williams
301	Engrg. Systems Anal.	3	80	Frazho	43	Frazho
333	Fluid Mechanics	3	104	Lyrintzis	53	Lyrintzis
333L	Fluid Mechanics Lab.	1	106	Collicott	50	Collicott
334	Aerodynamics	3	50	Williams	91	Blaisdell
334L	Aerodynamics Lab.	1	31	Collicott	51	Collicott
340	Dynamics & Vibration	3	88	Longuski	63	Howell
341	Industrial Practice III	0	2	Williams	6	Williams
342	Industrial Practice IV	0	12	Williams	1	Williams
352-1	Structural Anal. I	3	41	Sun	49	Sun
352-2	Structural Anal. I	3	42	Kim		
352L	Struct. Anal. I Lab.	1	25	Doyle	50	Doyle
364	Control System Analy.	3	75	Frazho	102	Yagci
364L	Control Systems Lab.	1	75	Rotea	51	Rotea
372	Jet Propl. Power Plt.	3			99	Sankaran
412	Intro. Comp. Fluid Dyn.	3	37	Blaisdell		
415	Aerodynamic Design	3	40	Sullivan		
421	Flt. Dyn. Control	3	43	Corless	53	Corless
439	Rocket Propulsion	3	84	Anderson		
440	Spacecr. Attitude Dyn.	3			53	Howell
442	Industrial Practice V	0			4	Williams
443	Industrial Practices Sem.	0	4	Williams	1	Williams
450	Spacecraft Design	3	14	Schneider	42	Longuski
451	Aircraft Design	3	32	Andrisani II	29	Crossley

A&AE Course	Most Recent Title	Cr.	Fall 2003		Spring 2004	
			Enroll-ment	Instructor	Enroll-ment	Instructor
453	Matr. Meth. Aerosp. Struc.	3			26	Doyle
454	Design Aerosp. Struct.	3	31	Grandt		
490A	Flight Testing	3			22	Andrisani II
490T	Design Build Test	3			26	Sullivan
507	Principles of Dynam.	3	31	Longuski		
508	Optimiz. Aerosp. Engr	3			45	Longuski
511	Intro. Fluid Mech.	3	27	Blaisdell		
512	Comput. Aerodyn.	3			28	Merkle
514	Intermediate Aerodyn.	3			32	Lyrintzis
518	Low-Gravity Fluid Dyn.	3	6	Collicott		
520	Experimental Aerody.	3			19	Schneider
532	Orbit Mechanics	3	33	Howell		
539	Adv. Rocket Prop.	3			38	Heister
538	Air Breath. Propul.	3	30	Fleeter		
546	Aero Struct Dyn Stab.	3	21	Doyle		
550	Multidisciplinary Des. Opt.	3	41	Crossley		
551	Des. Theo. Meth. Aero. Syst.	3			36	Crossley
552	Nondes. Eval. Struct. Matrls.	3			33	Grandt
552Q	Nondes. Eval. Struct.	3			10	Grandt
553	Elasticity Aerosp. I	3	40	Doyle		
554	Fatigue Struct. & Matrl.	3	21	Grandt		
554Q	Fatigue Struct. & Matrl.	3	63	Grandt		
555	Mechanics Comp. Matl.	3			31	Sun
558	Finite Element Meth. In Aerospace Structures	3	38	Kim		

A&AE Course	Most Recent Title	Cr.	Fall 2003		Spring 2004	
			Enroll-ment	Instructor	Enroll-ment	Instructor
564	System Anal. & Synth.	3	30	Corless		
565	Guidance Aerospace Veh.	3			8	Andrisani II
567	Intro. Appl. Stoch. Proc.	3			22	Frazho
590A	Rocket Combuster DBT	3			13	Anderson
590D	Intro. to Labview	3	4	Filmer		
590E	Intro. Electric Propul.	3			36	Hrbud
590G	Intr. Satellite Nav. & Posit.	3	12	Garrison		
590R	Model Predict. Contrl.	3	9	Rotea		
590T	Design Build Test	3			6	Sullivan
607	Vari. Princ. Of Mech.	3				Longuski
613	Viscous Flow Theory	3	7	Schneider		
628	Future Propul. Concpt.	3	17	Rusek		
630	Stability of Free Surf.	3	10	Heister		
646	Elastic Wave Propag.	3			14	Doyle
690G	Astro. Nav. & Guidance	3	6	Howell		
690S	Adv. Satellite Nav.	3			5	Garrison
698	M.S. Thesis Research	--				
699	Ph.D. Thesis Research	--				

Aerospace Engineering Requires a Multidisciplinary Curriculum

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

Aerodynamics	*Dynamics and Control*	*Propulsion*	*Structures and Materials*
Required Undergraduate			
333-Fluid Mechanics & Lab. 334-Aerodynamics and Lab	340-Dynamics and Vibrations 364-Controls and Lab 421-Flight Dynamics or 440-Spacecraft Att. Dynamics	372-Jet Propulsion or 439-Rocket Propulsion	204-Aeromech. II (Str of Mat.) and lab 352-Structural Analysis & Lab
Undergraduate Electives			
412-Intro to CFD 414-Compressible Aero 416-Viscous Flows	421-Flight Dynamics or 440-Spacecraft Att. Dynamics 490A Flight Testing	372-Jet Propulsion or 439-Rocket Propulsion	453-Matrix Methods in Struct.
415-Aerodynamic Design	490R-Control Systems Design	590C Propulsion Design	454-Structural Design

Required Capstone Design 450 Spacecraft Design or 451 Aircraft Design

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

Summarized Class Enrollment Statistics
for the 2003-2004 Academic Year

Semester	Statistic	Three-Credit Courses				One-Credit Laboratory Courses
		100, 200, 300, 400, Levels	500 Levels	600 Level	All Levels	
Fall of 2003	No. of classes offered	23	16	5	45	5
	Total Enrollment	1074	445	41	1560	251
	Average number of students per class	47	28	8	35	50
Spring of 2004	No. of classes offered	24	14	3	41	5
	Total enrollment	1066	457	21	1444	186
	Average number of students per class	44	18	7	35	37

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

STAFF FOR THE 2003-2004 ACADEMIC YEAR

Administrative Assistants
Linda Flack, Terri Moore

Business Office
Stephanie Stewart, Joan Jackson, Michelle Kidd, Sherry Wagner

Clerical
Karen Johnson, Paula Kerkhove

Director of Communications and Development
Tim Bobillo

Communications Administrator
Ann Broughton

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