School of Aeronautics and Astronautics

Research Report
2001 – 2002
Academic Year

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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

The School received a sparkling review from ABET in part because the examiner was able to identify several examples of program improvements made explicitly as the result of feedback from our constituencies. Both the student body and the Industrial Advisory Council (IAC) were singled out as strong contributors to our assessment process.

Undergraduate enrollment increased by 18% this past year and projected enrollment for the fall of 2002 indicates that enrollment has increased by more than 150% in five years! During academic year 2001-02, 67 students earned their Bachelor of Science degree, 42 earned their Master of Science degree, and 19 earned their Doctor of Philosophy degrees. The *US News and World Report* ranked our graduate program sixth in the nation and our undergraduate program fourth amongst universities that award Ph.D.s. The School continues to appear on the list of "key schools" for the major US aerospace manufacturers.

Degrees Awarded School of Aeronautics & Astronautics					
Year	**97-98**	**98-99**	**99-00**	**00-01**	**01-02**
B.S.	40	43	43	60	67
M.S.	19	21	35	27	42
Ph.D.	14	11	9	17	19

A new course, 490F Engineering Systems Analysis, was introduced in 2001-2002. The course is in response to guidance from those that hire our students. It has received strongly positive response from our students. The School will continue expansion of a wide range of design/build/test activities. Many of these are described at http://roger.ecn.purdue.edu/~raisbeck/

A "Satellite Design" course was offered as a capstone design experience in Spring 2002 by Professor Crossley. The course was sponsored by the Center for Satellite Engineering. The mission was to design a satellite that Purdue students could build and launch. Plans are afoot to continue this work to the build stage next year this involves both undergraduate and graduate students, and industrial/government sponsors.

Purdue University's Program for Study Abroad Office currently offers more than 200 programs in over 40 countries around the world. The School of Aeronautics and Astronautics continues to develop relationships with international universities, and has student exchange agreements with: Bristol University, United Kingdom; Royal Melbourne Institute of Technology in Melbourne, Australia; University of New South Wales in Sydney, Australia; Ecole Superieure des Techniques Aeronautiques et de Construction Automobile (ESTACA) in Paris, France; and Osaka University in Japan.

Aeronautical and Astronautical Engineering students who have recently taken the opportunity of this experience are Yen Yu and James Pinyard at Bristol University, U.K. and Masaki Kakoi at ESTACA, France.

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, we are confident that our School's participation with CEE will be a benefit to all participants.

DEVELOPMENT HIGHLIGHTS

The Boeing Company, Lockheed-Martin, Northrop Grumman, Rolls-Royce, Thiokol Corporation, and TRW supported the Industrial Affiliates Program (IAP) this year. In its sixth year, the School's Industrial Advisory Council (IAC) continued its bi-annual meeting schedule, meeting both in October and April. IAC members are: Dr. William Ailor III, The Aerospace Corporation; Dr. Paul Bevilaqua, Lockheed Corporation; Mr. Bradley Belcher, Allison Advanced Development Company; Ms. Nancy Carpenter, ATK Thiokol Propulsion; Ms. Andrea Chavez, Ball Aerospace; Mr. Joseph Gernand, Boeing North American; Dr. William Kessler, Lockheed Martin Aeronautics Co.; Dr. Andrew King, Boeing Satellite Systems; 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 Commercial Airplane Group; Mr. Charles Saff, Boeing Company; Mr. Randal Secor, Northrop Grumman Corp.; and Dr. Robert Strickler, TRW Environmental Safety Systems. The IAC met September 20, 2002, and assisted the School in its Strategic Planning, and continue to help campaign for the new Engineering Master Facilities Plan.

Dr. Jürgen Weber, Chairman of the Executive Board of Deutsch Lufthansa AG, gave the 3rd William E. Boeing Distinguished Lecture at 4:00 PM on September 5, 2001 in Fowler Hall.

Annual unrestricted giving continues to increase at a modest rate. The School is active in developing a campaign for its portion of the Multidisciplinary Engineering Building. These efforts are coordinated with Carolyn Percifield and the University Development Office (UDO).

James D. Raisbeck (B.S.A.E. '61, DEA '79, OAE '99) and his wife Sherry L. Raisbeck, donated $2,000,000 to Purdue University to establish "The Raisbeck Engineering Distinguished Professorship for Engineering and Technology Integration." The School held a reception on October 25, 2001 to honor Dr. Alten F. Grandt as the

Raisbeck Distinguished Professor. Mr. Raisbeck started Raisbeck Engineering, and during his career developed the Supercritical Wing for the Sabreliner and the Mark II and Mark IV Systems for the Learjet 20 series. Raisbeck Engineering has developed and certified a number of aerodynamic improvements for business aircraft.

ALUMNI HIGHLIGHTS

The School named the following seven new Outstanding Aerospace Engineers (OAEs) in the Fall of 2001. Dr. Alon Dumanis (Ph.D. '82); Mr. Michael T. Kennedy (B.S.A.E. '70); Dr. Yasuhiro Kuroda (M.S.A.E. '53); Mr. David Mc Grath (B.S.A.A.E. '83, M.S.A.A.E. '84); Mr. G. Thomas McKane (B.S.A.E. '66); Mr. Hank Queen (B.S.A.E. '74); Mr. John L. Rich (B.S.A.T. '54); and will have an additional seven in the Fall of 2002.

Mr. Mark K. Craig (B.S.A.E. '71) was presented the Schools of Engineering Distinguished Engineering Alumnus Award on April 19, 2002. Mr. Craig is currently Deputy Director of Stennis Space Center.

Mr. Brad Belcher (B.S.A.E. '82) was awarded the 2002 Alumni Service Award. Mr. Belcher holds the position of Integrated Product Team Leader, Joint Strike Fighter F-120 Engine Program at Allison Advanced Development Company/Rolls Royce Corporation.

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2001 are given in the "Faculty Summary" section of this report. Only documents that actually appeared in print during 2001 are listed. Note that 1 book, 1 patent, 33 journal articles or book chapters, and 148 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 2001-02 academic year, 65 students were enrolled in the Cooperative Engineering Program with the 24 companies listed on the following page. This popular program is limited only by the number of industry positions available. About 31 in 110 new applicants received appointments this year. Many other students gain industrial experience through internships.

Co-Op Companies
School of Aeronautics and Astronautics
July 1, 2001-June 30, 2002

Company	Location	Number of A&AE Co-op Students
Aerospace Corporation	Los Angeles, CA	1
American Trans Air Engineering	Indianapolis, IN	0
ATA Engineering Inc.	San Diego, CA	4
Atlantic Research Corporation	Knoxville, TN	0
Ball Aerospace & Tech. Corp.	Boulder, CO	8
Boeing Satellite Systems	Los Angeles, CA	5
Delta Airlines	Atlanta, GA	0
General Electric Aircraft Engines	Cincinnati, OH	12
NASA-Ames Research Center	Moffett Field, CA	0
NASA-Dryden Flight Research Center	Edwards, CA	1
NASA-Glenn	Cleveland, OH	1
NASA-Goddard	Greenbelt, MD	1
NASA-Johnson Space Center	Houston, TX	13
NASA-Kennedy Space Center	Kennedy Space Ctr., FL	2
NASA-Langley Research Center	Hampton, VA	2
Naval Research Laboratory	Washington, DC	0
Raytheon E-Systems	Greenville, TX	0
Rockwell International Corporation	Cedar Rapids, IA	4
Rolls-Royce	Indianapolis, IN	3
Structural Analysis Engineering	Cincinnati, OH	4
United Parcel Service (Air Group)	Louisville, KY	0
United Technologies Pratt & Whitney	W. Palm Beach, FL	0
United Technologies Pratt & Whitney	East Hartford, CT	1
Wright-Patterson AFB	Dayton, OH	3

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, which 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: numerical methods in aerodynamics; computational fluid mechanics; separated flow around wings and bodies at high angles of attack; aerodynamics of rotors and propellers; boundary layers, wakes and jets in V/STOL applications and aerodynamic noise; experimental measurements using laser systems; laminar-turbulent transition in high speed 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 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. The second, which is nearing completion, will have a 9.5-inch Mach-6 quiet-flow test section. 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. **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 ***Energy Conversion Laboratory*** is housed at ASL, and is comprised of large four-function work areas. The *Propellant Area* is set up to synthesize and enrich/analyze Non-Toxic Hypergolic Miscible Fuels and Rocket Grade Hydrogen Peroxides, respectively. The *Electrochemistry Area* is designed to study the formation of hydrogen peroxide from water and electrical energy. The decomposition of hydrogen peroxide within a fuel cell is also studied in this laboratory. The *Physical Energy Conversion Area* was established to study thermoelectric and thermionic effects, as well as advanced ion thruster technologies. The *Catalysis Area* is used to synthesize and characterize heterogeneous and homogeneous substrates and additives for propulsion applications.

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.

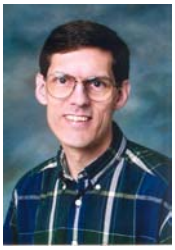
The **Tribology and Materials Processing Laboratory,** maintained jointly with the **Center for Materials Processing and Tribology** contains tribological instrumentation as well as up-to-date machines for manufacturing processes. Equipment includes a 22 kip computer-controlled electro-hydraulic test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

AERODYNAMICS

Faculty Members

S. P. Schneider, Associate 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; Graduate 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.

On the Development of Supersonic Jet Noise Prediction Methodology; (Co-investigator: A. S. Lyrintzis (Purdue, AAE); Student: E. K. Koutsavdis; Sponsor: NASA Glenn; Computer resources: NPACI (Cray T90), NCSA (SGI Origin 2000), (PUCC/IBM SP2), Purdue CS (SGI Origin 2000))

A new Computational Aeroacoustics (CAA) methodology for accurate prediction of supersonic jet noise from first principles is being developed. First, a three-dimensional Large Eddy Simulation (LES) code based on the dynamic subgrid scale model will be developed. Then Kirchhoff's or porous Ffowcs-Williams Hawhiges (FW-H) equation method will be employed for the extension of Computational Fluid Dynamics (CFD) results to the far-field. Kirchhoff's porous FW-H method allows radiating sound to be evaluated based on quantities on an arbitrary control surface, if the linear wave equation is assumed outside. The control surface is assumed to include all the nonlinear flow effects and noise sources. The solution on the control surface will be evaluated using the LES CFD code described above. The method will be enhanced to include nonlinear effects as well as refraction effects outside the Kirchhoff surface.

Modeling Diesel Engine Injector Flows (Co-investigator: Stephen D. Heister (Purdue, AAE); student: C. Xu; sponsor: Army Research Office)

This research effort will extend the development of a computational tool capable of resolving unsteady, viscous, cavitating flow fields inside diesel engine injector passages. Fully three-dimensional, unsteady calculations will be performed in order to assess the influence of injector design on the internal flow structure. In addition, a turbulence model will be added to the current laminar methodology in order to address complex processes in the wake and wall regions. Ultimately, this model will provide a tool with which engine manufacturers can evaluate design changes rapidly, thereby reducing product development times and improving engine efficiency. Moreover, the model could be useful in correlating internal flow variables with observed emissions data,

thereby providing an important link/methodology to reduce emissions through prudent injector design.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Xu, C., Blaisdell, G. A., and Heister, S. D., "Simulations of Turbulent Cavitating Internal Flows," *Proceedings of Multiphase Flow 2001*, Orlando, FL, March 2001.

Uzun, A., Koutsavdis, E. K., Blaisdell, G. A., and Lyrintzis, A. S., "Direct Numerical Simulation of 3-D Jets using Compact Schemes and Spatial Filtering," paper no. AIAA-200-2543, *15th AIAA Computational Fluid Dynamics Conference,* Anaheim, CA, June 11-14, 2001.

Eshpuniyani, B., and Blaisdell, G. A., "DNS of a Strained Turbulent Axial Vortex," *3rd AFOSR International Conference on DNS and LES,* Arlington, TX, Aug. 5-9, 2001.

Eshpuniyani, B., Qin, J. H., and Blaisdell, G. A., "Simulation of Turbulent Axial Vortices," virtual poster presentation, *Supercomputing 2001*, Denver, CO, Nov. 10-15, 2001.

STEVEN C. COLLICOTT
1991
Associate Professor

Degrees

B. S., University of Michigan, Aerospace Engineering, 1983, magna cum laude
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

Collicott, S. H., "Convergence Behavior of Surface Evolver Applied to a Generic Propellant-Management Device," *Journal of Propulsion and Power,* Vol. 17, No. 4, July-Aug. 2001, pp. 845-851.

Conference Proceedings, Presentations, Invited Lectures and Reports

Lindqvist, J. R., Collicott, S. H., and Sullivan, J. P., "Aerodynamic Losses in a Strut and Duct Flow with Lift," *39th Aerospace Sciences Meeting and Exhibit*, paper no. AIAA - 2001-0390, Reno, NV, Jan. 8-11, 2001.

Collicott, S. H., "An Undergraduate Project Course for the NASA Reduced Gravity Student Flight Opportunity Program," *39th Aerospace Sciences Meeting and Exhibit,* paper no. AIAA-2001-0585, Reno, NV, Jan. 8-11, 2001.

Chen, Y., and Collicott, S. H., "A New Design Drop Tower to Study Uncertainties in Zero-Gravity Fluids Experiments," *39th Aerospace Sciences Meeting and Exhibit,* paper no. AIAA-201-0609, Reno, NV, Jan. 8-11, 2001.

Ong, D., Yeh, C. P., Hoverman, T. J., and Collicott, S. H., "Changing Atomizer Performance with a Small Step in the Orifice," Institute for Liquid Atomization and Spray Sciences, *ILASS-Americas 2001*, Dearborn, MI, May 2001.

Collicott, S. H., "Estimation of Cavitation Inception in Spray Orifices," Institute for Liquid Atomization and Spray Sciences, *ILASS-Americas 2001*, Dearborn, MI, May 2001.

Collicott, S. H., "Corner Radius Effects on Capillary Instability in Tank Geometries," paper no. AIAA-2001-3824, *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 2001.

Feinerman, A. D., Friedman, G., Kasman, E., Montgomery, J., Megaridis, C. M., Howell, E., and Collicott, S. H., "Angle Micro-Mirrors with Three Degrees of Freedom with

Liquid MEMS Technology," *Proceedings of SPIE 2001 Annual Meeting*, Vol. 4489, San Diego, CA, July 2001.

Collicott, S. H., "Advances in Industrial Low-Gravity Fluids Engineering," seminar at Aerospace Corp., El Segundo, CA, Oct. 1, 2001.

Collicott, S. H., "Capillary-Dominated Fluids Issues Common to Spaceflight and Micro-devices," Mechanical Engrg. Fluids Colloquium Series, Purdue Univ., W. Lafayette, IN, Nov. 16, 2001.

Collicott, S. H., "Zero Gravity Fluid Dynamics in Spacecraft and Research," Back to Class, Purdue University President's Council, W. Lafayette, IN, Nov. 16, 2001.

Collicott, S. H., "Capillary-Dominated Fluids Issues Common to Spaceflight and Micro-devices," seminar at the University of Illinois, Chicago, IL, May 31, 2001.

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), Sponsor: 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; Sponsor: 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

Lyrintzis, A. S., "Transforming the Engineering Curriculum: Lessons Learned from a Summer at Boeing," (Boeing Weliver Scholars 1998, Dr. Lyrintzis was a member of the team), *ASEE Journal of Engineering Education,* Vol. 90, No. 1, Jan. 2001, pp. 143-149.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Lyrintzis, A. S., and Uzun, A., "Integral Techniques for Jet Aeroacoustics Calculations," *7th AIAA/CEAS Aeroacoustics Conference,* paper no. AIAA2001-2253, Maastricht, The Netherlands, May 28-30, 2001.

Ekici, K., and Lyrintzis, A. S., "Parallel Newton-Krylov Methods for Rotorcraft Aerodynamics," *15th AIAA Computational Fluid Dynamics Conference,* paper no. AIAA-2001-2587, Anaheim, CA, June 11-14, 2001.

Kim, H., Williams, M. H., and Lyrintzis, A. S., "An Improved Method for Rotor Wake Capturing," *15th AIAA Computational Fluid Dynamics Conference,* paper no. AIAA-2001-2669, Anaheim, CA, June 11-14, 2001.

Uzun, A., Garrison, L., Zhang, X., Lyrintzis, A. S., and Blaisdell, G. A., "Development of Low Jet Noise Aircraft Engines," virtual poster presentation, *Supercomputing 2001,* Denver, CO, Nov. 10-16, 2001.

Lyrintzis, A. S., "Integral Methods for Computational Aeroacoustics," seminar at the Trane Company, LaCrosse, WI, Jan. 2001.

Lyrintzis, A. S., "Integral Methods for Computational Aeroacoustics," seminar at the Aerospace Engrg. Dept., Ohio State Univ., Columbus, OH, Feb. 2001.

STEVEN P. SCHNEIDER
1989
Associate 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 over the last 25 years to address problems such as laminar-turbulent transition that are strongly affected by noise level. Detailed measurements of the mechanisms of transition are needed, under low noise conditions, in order to develop computational models that are grounded on the correct flow physics.

To complement the expensive quiet-flow facilities under development 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.

Publications

Schneider, S. P., "Effects of High-Speed Tunnel Noise on Laminar-Turbulent Transition," *Journal of Spacecraft and Rockets,* Vol. 38, No. 3, May-June 2001, pp. 323-333.

Ito, T., Randall, L. A., and Schneider, S. P., "Effect of Noise on Roughness-Induced Boundary-Layer Transition for Scramjet Inlet," *Journal of Spacecraft and Rockets,* Vol. 38, No. 5, Sept. Oct. 2001, pp. 692-698.

Conference Proceedings, Presentations, Invited Lectures and Reports

Schneider, S. P., "Hypersonic Laminar Instability on Round Cones Near Zero Angle of Attack," *39th Aerospace Sciences Meeting & Exhibit,* paper no. AIAA 2001-0206, Reno, NV, Jan. 8-11, 2001.

Schneider, S. P., Rufer, S. J., Randall, L., and Skoch, C., "Shakedown of the Purdue March-6 Quiet-Flow Ludwieg Tube," *39th Aerospace Sciences Meeting and Exhibit,* paper no. AIAA-2001-0457, Reno, NV, Jan. 8-11, 2001.

Schneider, S. P., and Skoch, C., "Mean Flow and Noise Measurements in the Purdue Mach-6 Quiet Flow Ludwieg Tube," *31st AIAA Fluid Dynamics Conference,* paper no. AIAA-2001-2778, Anaheim, CA, June 11-14, 2001.

Schneider, S. P., "Hypersonic Boundary-Layer Transition Research for Scramjet Forebody Design," *13th Annual Symposium on the Propulsion Engineering Research Center,* NASA Marshall Space Flight Center, AL, Oct. 2001.

Schneider, S. P., and Skoch, C., "Aerothermodynamic Prediction for Hypersonic Reentry Vehicles," presented at the NSF/Sandia meeting, Albuquerque, NM, June 2001.

Schneider, S. P., "Laminar-Turbulent Transition in the Boeing/AFOSR Mach-6 Quiet Tunnel," presented at NASA Ames, Mountain View, CA, June 27, 2001.

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., Guille, M., and Sullivan, J. P., "Accuracy of Pressure-Sensitive Paint, *AIAA Journal,* Vol. 39, No. 1, pp.103-112.

Sakaue, H., and Sullivan, J. P., "Time Response of Anodized Aluminum Pressure-Sensitive Paint," *AIAA Journal,* Vol. 39, No. 10, Oct. 2001, pp. 1944-1949.

Conference Proceedings, Presentations and Invited Lectures

Sakaue, H., Gregory, J. W., Sullivan, J. P., and Raghu, S., "Pressure Sensitive Paint for Unsteady Flow Fields," paper no. AIAA-2001-0554, *39th Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 8-11, 2001.

Lindqvist, J. R., Collicott, S. H., and Sullivan, J. P., "Aerodynamic Losses in a Strut and Duct Flow with Lift," paper no. AIAA-2001-0390, *39th Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 8-11, 2001.

Gregory, J. W., Sakaue, H., Sullivan, J. P., and Raghu, S., "Characterization of Miniature Fluidic Oscillator Flowfields using Porous Pressure Sensitive Paint," *Proceedings of ASME FEDSM-01,* 2001 ASME Fluids Engineering Division Summer Meeting, New Orleans, LA, May 29-June 1, 2001.

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.

Conference Proceedings, Presentations, Invited Lectures and Reports

Kim, H., Williams, M. H., and Lyrintzis, A. S., "An Improved Method for Rotor Wake Capturing," *15th AIAA Computational Fluid Dynamics Conference,* paper no. AIAA-2001-2669, Anaheim, CA, June 11-14, 2001.

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.

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

K. C. Howell, Professor, Ph.D., Stanford, 1983, orbit mechanics, spacecraft dynamics, control, and trajectory optimization.

DYNAMICS AND CONTROL

Faculty Members

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

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
1980
Associate Professor

Degrees

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

Interests

Estimation
Control
Dynamics
Flight Aircraft Flying Qualities

Research Areas

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

Conference Proceedings, Presentations, Invited Lectures and Reports

Norris, S. R., and Andrisani, II, D., "Longitudinal Equilibrium Solutions for Towed Aircraft and Tow Cable," paper no. AIAA-2001-4254, *AIAA Atmospheric Flight Mechanics Conference,* Montreal, Canada, Aug .6-8, 2001.

Andrisani, II, D., "Simulation Estimation of Aircraft and Target Position," presented at the *Motion Imagery Geopositioning Review and Workshop,* Purdue Univ., W. Lafayette, IN, July 24-25, 2001.

Andrisani, II, D., and Hoshizaki, T., "Aircraft Simulation Study Including Inertial Navigation System (INS) Model with Errors," presented at the *Motion Imagery Geopositioning Review and Workshop*, Purdue Univ., W. Lafayette, IN, July 24-25, 2001.

Andrisani, II, D., "Simultaneous Estimation of Aircraft and Target Position with a Control Point," presented at the *Motion Imagery Geolocation Workshop*, SAIC Signal Hill Complex, Oct. 31, 2001.

Andrisani, II, D., Bethel, J., Braun, A., Mulyana, A., and Hoshizaki, T., "Target Precision Determination and Integrated Navigation," presented at the *National Imagery and Mapping Agency (NIMA),* Bethesda, MD, Dec. 11, 2001.

Andrisani, II, D., Bethel, J., Braun, A., Mulyana, A., and Hoshizaki, T., "Target Precision Determination and Integrated Navigation," presented at the *National Imagery and Mapping Agency (NIMA),* St. Louis, MO, Dec. 12, 2001.

Andrisani, II, D., Bethel, J., Braun, A., Mulyana, A., and Hoshizaki, T., "Target Precision Determination and Integrated Navigation," presented at the *National Imagery and Mapping Agency (NIMA),* St. Louis, MO, Dec. 12, 2001.

Andrisani, II, D., Bethel, J., Braun, A., Mulyana, A., and Hoshizaki, T., "Target Precision Determination and Integrated Navigation," presented at Boeing, St. Louis, MO, Dec. 12, 2001.

MARTIN CORLESS
1984
Professor

Degrees

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

Sultan, C., Corless, M., and Skelton, R. E., "The Prestressability Problem of Tensegrity Structures: Some Analytical Solutions," *International Journal of Solids and Structures,* Vol. 38, No. 30-31, 2001, pp. 5223-5252.

Conference Proceedings, Presentations, Invited Lectures and Reports

Acikmese, A. B., and Corless, M., "Robust Constant Output Tracking for Uncertain/Nonlinear Systems with PI Controllers," *American Control Conference*, Arlington, VA, 2001.

Acikmese, A. B., and Corless, M., "Robust Tracking and Disturbance Rejection for Uncertain/Nonlinear Systems with PI Controllers," *39th Annual Conference on Communication, Control, and Computing,* Monticello, IL, 2001.

Bengea, S., DeCarlo, R., Rizzoni, G., Yurkovich, S., and Corless, M., "A Polytopic System Approach for the Hybrid Control of a Diesel Engine with VGT/EGR," *39th Annual Conference on Communication, Control, and Computing,* Monticello, IL, 2001.

ARTHUR E. FRAZHO
Professor
1980

Degrees

B.S.E., The University of Michigan, Ann Arbor,
Computer Engineering, 1973
M.S.E., The University of Michigan, Ann Arbor,
Computer Information and Control Engineering, 1974
Ph.D., The University of Michigan, Ann Arbor, Computer
Information and Control Engineering, 1977

Interests

Control systems

Research Areas

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

Publications

Frazho, A. E., "Weighted Nevanlinna-Pick Interpolation," *Operator Theory: Advances and Applications,* Vol. 122, 2001, pp. 247-274.

Foias, C., Frazho, A. E., and Kaashoek, M. A., "A Weighted Version of Almost Commutant Lifting," *Operator Theory: Advances and Applications,* Vol. 129, 2001, pp. 311-340.

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

Publications

Katzberg, S. J., and Garrison, J. L., "Surface Reflected Signals from the Global Positioning System for Ionospheric Measurements: Experimental Results in Aircraft Altitudes," *International Journal of Remote Sensing,* Vol. 22, No. 4, 2001, pp. 663-689.

Conference Proceedings, Presentations, Invited Lectures and Reports

Garrison, J. L., and Bertuccelli, L., "Empirical Model of Sea Surface Slope Statistics for Wind Vector Estimation Using Bistatic GPS Measurements," *American Geophysical Union Spring Meeting,* Boston, MA, May 29-June 2, 2001.

Garrison, J. L., Moreau, L., and Axelrad, P., "Tracking Loop Optimization for On-Board GPS Navigation in High Earth Orbit (HEO) Missions," *Institute of Navigation 57th Annual Meeting/CIGTF 20th Biennial Meeting,* Albuquerque, NM, June 11-13, 2001.

Garrison, J. L., "Simulation of Wind Speed Retrievals from an Orbiting Bistatic GPS Receiver," *IEEE 2001 International Geoscience and Remote Sensing Symposium,* Sydney, Australia, July 9-13, 2001.

Garrison, J. L., and Bertuccelli, L., "Empirical Model of Sea Surface Slope Variance for Forward Scattered GPS Measurements," AGU 2001 Fall Meeting, San Francisco, CA, Dec. 11, 2001.

KATHLEEN C. HOWELL
1982
Professor

Degrees

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

Interests

Orbit mechanics
Spacecraft dynamics, control
Trajectory optimization

Research Areas

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

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

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

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

Publications

Howell, K. C., "Families of Orbits in the Vicinity of the Collinear Libration Points," *Journal of the Astronautical Sciences*, Vol. 49, No. 1, Jan.-March 2001, pp. 107-125. (Special issue; Robert W. Farquahar, editor.)

Lo, M., Williams, B., Bollman, W., Han, D., Hahn, Y., Bell, J., Hirst, E., Corwin, R., Hong, P., Howell, K.C., Barden, B., and Wilson, R., "GENESIS Mission Design," *Journal of the Astronautical Sciences,* Vol. 49, No. 1, Jan.-March 2001, pp. 169-184. (Special issue; Robert W. Farquahar, editor.)

Conference Proceedings, Presentations, Invited Lectures and Reports

Howell, K. C., Guzman, J. J., and Anderson, J. P., "Trajectory Arcs with Lunar Encounters for Transfers to Small Amplitude L_2 Lissajous Orbits," *AAS/AIAA Spaceflight Mechanics Conference,* Santa Barbara, CA, Feb. 2001.

Folta, D., Cooley, S., and Howell, K. C., "Trajectory Design for the NGST L_2 Libration Point Mission," AAS/AIAA Spaceflight Mechanics Conference, Santa Barbara, CA, Feb. 2001.

Guzman, J. J., and Howell, K. C., "Periodic Orbits in the Vicinity of L_1 and L_2 in the Coherent Restricted Four-Body Problem," *GSFC Guidance, Navigation, and Control Center Flight Mechanics Symposium,* NASA Goddard Space Flight Center, Greenbelt, MD, June 2001.

Barden, B. T., Wilson, R. S., Howell, K. C., and Marchand, B. G., "Summer Launch Options for the Genesis Mission," *AAS/AIAA Astrodynamics Specialist Conference,* Quebec City, Canada, July 2001.

Howell, K. C., "Spacecraft Trajectory Design in Multi-Body Regimes," *5th SIAM Conference on Control and It's Applications,* San Diego, CA, July 2001.

Howell, K. C., and Anderson, J. P., "Triana Contingency Analysis: Error Analysis Based on New Goddard Upper Stage," IOM AAE-1040-001, prepared for NASA Goddard Triana Flight Project, March 2001.

Howell, K. C., "NGST: Preliminary Analysis of Bias Maneuvers," IOM AAE-0140-005, prepared for TRW, Inc., Space and Laser Programs Division, March 2001.

Howell, K. C., and Anderson, J. P., "Triana Contingency Analysis: 3σ Launch Errors and Recovery Options, IOM AAE-0140-006, prepared for NASA Goddard Triana Flight Project, May 2001.

Howell, K. C., "NGST: Bias Maneuvers in the L_2 Orbit," IOM AAE-0140-014, prepared for TRW, Inc., Space and Laser Programs Division, Dec. 2001.

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

Longuski, J. M., Fischbach, E., and Scheeres, D. J., "Deflection of Spacecraft Trajectories as a New Test of General Relativity," *Physical Review Letters,* Vol. 86, No. 14, Apr. 2, 2001, pp, 2942-2945.

Patents

Longuski, J. M., "Method for Velocity Precision Pointing in Spin-Stabilized Spacecraft or Rockets," *U. S. patent no. 6,332,591 B1*, awarded on Dec. 25, 2001.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Johnson, W. R., Longuski, J. M., and Lyons, D. T., "Attitude Control During Autonomous Aerobraking for Near-Term Mars Exploration, paper no. AAS-01-388, *AAS/AIAA Astrodynamics Specialists Conference,* Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

Okutsu, M., Debban, T. J., and Longuski, J. M., "Tour Design Strategies for the Europa Orbiter Mission," paper no. AAS-01-463, *AAS/AIAA Astrodynamics Specialist Conference,* Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

Heaton, A. F., and Longuski, J. M., "The Feasibility of a Galileo-Style Tour of the Uranian Satellites, paper no. AAS-01-464, *AAS/AIAA Astrodynamics Specialists Conference,* Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

Petropoulos, A. E., and Longuski, J. M., "A Shaped-Based Algorithm for the Automated Design of Low-Thrust, Gravity-Assist Trajectories," paper no. AAS-01-467, *AAS/AIAA Astrodynamics Specialists Conference,* Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

McConaghy, T. T., Debban, T. J., Petropoulos, A. E., and Longuski, J. M., "An Approach to Design and Optimization of Low-Thrust Trajectories with Gravity-Assists," paper no. AAE-01-468, *AAS/AIAA Astrodynamics Specialists Conference,* Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

Chen, K. J., Okutsu, M., McConaghy, T. T., and Longuski, J. M., Cyclical Visits to Mars via Astronaut Hotels," progress report no. 1, contract no. GAC-003, Global Aerospace Corp., Altadena, CA, June 2001.

Longuski, J. M., and Howell, K. C., "Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions," final report, contract no. 1211514, Jet Propulsion Laboratory, Pasadena, CA, July 2001.

Chen, K. J., Okutsu, M., McConaghy, T. T., and Longuski, J. M., "Cyclical Visits to Mars via Astronaut Hotels," progress report no. 2, contract no. GAC-003, Global Aerospace Corp., Altadena, CA, July 2001.

Chen, K. J., Okutsu, M., McConaghy, T. T., and Longuski, J. M., "Cyclical Visits to Mars via Astronaut Hotels," progress report no. 3, contract no. GAC-003, Global Aerospace Corp., Altadena, CA., Aug. 2001.

Chen, K. J., Okutsu, M., McConaghy, T. T., and Longuski, J. M., "Cyclical Visits to Mars via Astronaut Hotels," final report, contract no. GAC-003, Global Aerospace Corp., Altadena, CA, Sept. 2001.

Johnson, W. R., and Longuski, J. M., "Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions," final report Semi-Autonomous Aerobraking, contract no. 1223406, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, Oct. 2001.

Okutsu, M., Debban, T. J., and Longuski, J. M., "Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions," final report Europa Orbiter Mission Design, JPL contract no, 1211514 and 1223406, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, Oct. 2001.

Chen, K. J., Landau, D. F., McConaghy, T. T., Okutsu, M., and Longuski, J. M., "Trajectory Analysis and Design of Mars Cyclers: Preliminary Assessment," prepared for Dr. Buzz Aldrin, ShareSpace Foundation, Alexandria, VA, Dec. 2001.

MARIO A. ROTEA
1990
Professor

Degrees

Electronic Engineer 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

Advanced Algorithms for Estimation and Control

Active control systems integrate sophisticated hardware and software to provide increased performance and versatility over conventional solutions in several engineering problems. The development of an active control system requires the integration of actuators and sensors with estimation and control algorithms. These algorithms extract information from the sensors and decide how to use the actuators for best system performance. In this project we have developed theories and methodologies for the design and implementation of advanced estimation and control algorithms. These methods integrate sophisticated optimization and control theory with commercial software for the creation of high performance control systems with minimal development effort. We have successfully applied these techniques to several technology areas including active suppression of chatter in industrial machine tools and active vibration reduction in civil engineering structures, helicopter rotor systems, and turbomachinery.

Prediction and Optimization of Frequency Response Functions

The prediction and optimization of frequency response functions for systems with high modal density and low damping is of great interest to the manufacturers of modern gas turbine aeroengines. This interest is motivated in part by a need to analyze rotating parts (bladed disks) whose vibratory response is highly sensitive to real-world imperfections. Since 1998, we have been working with industry in the development of metrics and effective tools to analyze and optimize bladed disk designs. These systems typically posses a degree of spatial symmetry that can be exploited to develop improved methods and tools for analysis and design. We have developed a collection of specialized Matlab functions for structural optimization of bladed disk assemblies (SODA). We have also developed a new algorithm (LFTB) for the calculation of the

worst-case (largest) vibration amplitudes that the blades may experience when a large number of parameters are perturbed simultaneously.

Modeling and Parameter Estimation of Autonomous Parachutes

An approach that has proven successful for the modeling of air vehicles is to make use of the fundamental physical principles to derive the equations of motion of the system and then use system identification tools to extract the parameters in the equations from wind tunnel and flight test data. The goal of this project is to investigate methods for the determination of aerodynamic parameters in air vehicles that operate in highly nonlinear regimes. The project is motivated by the possibility of identifying a technique that successfully extracts aerodynamic parameters and control derivatives in guided parachute systems from short flight data records. This work is done in collaboration with the Naval Postgraduate School and the U.S. Army Yuma Proving Ground, in support of the Affordable Guided Airdrop System (AGAS), which is a low cost, high altitude, deployable airdrop system that is autonomously controlled via on-board GNC system to improve the accuracy of delivery.

Analysis and Design of Extremum Seeking Algorithms

Real-time optimization is necessary to seek optimal control parameters in many application areas such as vibration and noise attenuation, flow separation, combustion control, and control of flying formations. In these problems the control architectures that improve system operation (e.g., minimize a noise or vibration figure, minimize flow separation in an airfoil, minimize the unsteady pressure fluctuation in a combustion chamber) are known in advance. On the other hand, the optimal control parameters are not known in advance and must be determined on line. We are pursuing the design of improved real-time optimization algorithms that make use of function evaluations only to estimate optimal parameters. The technical goal is to identify algorithms that track fast variations in the optimal parameters despite the noise present in the measurements of the cost function and the modeling uncertainty that inevitable exists in real problems.

Publications

D'Amato, F. J., Rotea, J. A., Megretski, A., and Jonson, U. T., "New Results for the Analysis of Systems with Repeated Nonlinearities," *Automatica,* Vol. 37, pp. 739-747, May 2001.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Rotea, M. A., and Viassolo, D., "On Sufficient Condition for Static Output-Feedback Multimodel Control," *Proceedings American Control Conference,* Washington, DC, June 2001, pp. 3149-3152.

Viassolo, D., and Rotea, M. A., "A Methodology for the Design of Digital Periodic Controllers for Simultaneous Performance," *Proceedings IEEE Midwest Symposium on Circuits and Systems,* Aug. 2001.

Rotea, M. A., and D'Amato, F., "LFTB: An Optimized Algorithm to Bound Worst-Case Frequency Response Functions," *Proceedings 2001 American Control Conference,* Washington, DC, June 2001, pp. 3041-3048.

Rotea, M. A., and Kothandaraman, G., "Parameter Estimation for Airdrop System," contract report no. N00244-00-P-3258, Oct. 2001.

Rotea, M. A., "Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry, seminar presented United Tech. Research Center, East Hartford, CT, Jan. 2001.

Rotea, M. A., "Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry," Control Seminar Series, University of Michigan, Ann Arbor, MI, Jan. 2001.

Rotea, M. A., Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry," CDS Seminar Series, Caltech, Pasadena, CA, April 2001.

Rotea, M. A., "Optimization and Control of Complex Dynamic Systems," seminar presented National Science Foundation, Arlington, VA, April 2001.

Rotea, M. A., "Semidefinite Programming: Applications in Systems and Control," plenary talk, IX Reunion de Trabajo en Procesamiento de la Informacion y Control, Santa Fe, Argentina, Sept. 2001.

Rotea, M. A., "Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry," SMAC seminar presented Purdue Univ., Mechanical Engrg. Dept., W. Lafayette, IN, Oct. 2001.

Rotea, M. A., "Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry," MAE seminar presented at the Univ. of Virginia, Charlottesville, VA, Oct. 2001.

Rotea, M. A., "Tools for the Analysis and Optimization of Frequency Response in Systems with Symmetry," ME 681 graduate student seminar presented at Texas A & M Univ., College Station, TX, Nov. 2001.

Rotea, M. A., "Semidefinite Programming: Applications in Systems and Control," distinguished seminar series presentation, Mechanical and Industrial Engineering, Univ. of Illinois, Urbana, IL, Nov. 2001.

Rotea, M. A., "Pratt-Whitney/United Technologies Research Center Workshop on Tools for Mistuning Analysis in Turbomachinery," presentation on theory and use of LFTB (Purdue code for worst-case analysis of mistuned rotors), United Tech. Research Corp., East Hartford, CT, Dec. 2001

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 and liquid propellant injection systems.

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

Scott 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.

Conference Proceedings, Presentations, Invited Lectures and Reports

Long, M.R., Anderson, W.E, and Humble, R.W., "Bi-Centrifugal Swirl Injector Development for Nontoxic Hypergolic Bipropellants," AIAA Paper No. 2002-4026, Indianapolis, IN, July 8-10, 2002.

Mok, J.-S., Helms, J., and Anderson, W., "Decomposition and Vaporization Studies of Hydrogen Peroxide," AIAA Paper No. 2002-4028, Indianapolis, IN, July 8-10, 2002.

Fitzpatrick, S., Prater, D., and Anderson, W. "A Design, Build, Test Course in Rocket Combustors," AIAA Paper No. 2002-4186, Indianapolis, IN, July 8-10, 2002.

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., Heister, S. D., Epperson, J. T., and Sojka, P. E., "Modeling Multi-Jet Mode Electrostatic Atomization using Boundary Element Methods, *Journal of Electrostatics,* Vol. 50, 2001, pp. 91-108.

Xu, C., Bunnell, R. A., and Heister, S. D., "On the Influence of Internal Flow Structure on Performance of Plain Orifice Atomizers," *Atomization and Sprays,* Vol. VII, 2001, pp. 335-350.

Conference Proceedings, Presentations, Invited Lectures and Reports

Heister, S. D., and Blaisdell, G. A., "Modeling Diesel Engine Injector Flows," final report for ARO contract DAAG55-98-0318, Aug. 2001.

Heister, S. D., and Rotea, M. A., "Center for Satellite Engineering, progress report, June 2001.

Lim, K. H., Brodrecht, D. J., Heister, S. D., and Rusek, J. J., "Alloying Effects in an Aluminum – Hydrogen Peroxide Semi-Fuel Cell," *Proceedings of the First International Conference on Green Propellants for Space Propulsion,* European Space Agency, Noordwijk, The Netherlands, June 20-22, 2001.

Heister, S. D., "Simulating Two-Phase Flows Inside High-Speed Injectors," invited paper, *Proceedings of the First International Conference on Computational Methods in Multiphase Flow,* Orlando, FL, March 2001.

Yoon, S. S., Pham, T. L., and Heister, S. D., "Development of a Fully-Coupled Injection/Atomization Code," *Proceedings of the First International Conference on Computational Methods in Multiphase Flow,* Orlando, FL, March 2001.

Heister, S. D., and Rusek, J. J., "Development of a Design/Build/Test Course in Rocket Propulsion," *Proceedings of the 4th International Hydrogen Peroxide Propulsion Conference,* ESTEC, Noordwijk, The Netherlands, June 2001.

Xu, C., Heister, S. D., and Blaisdell, G. A., "Modeling Cavitating Flows," *Proceedings of the 13th Propulsion Engineering Research Center Annual Symposium on Propulsion,* Huntsville, AL, 2001.

Austin, B.J., Matthews, J., and Heister, S. D., "Engine/Injector Development for New Nontoxic, Storable, Hypergolic Bipropellants," *Prodeedings of the 13th Propulsion Engineering Research Center Annual Symposium on Propulsion,* Huntsville, AL, 2001.

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.

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.

Conference Proceedings, Presentations, Invited Lectures and Reports

Rusek, J. J., "Future of Hydrogen Peroxide for Space Propulsion and Power Applications," *Proceedings of the First International Conference on Green Propellants for Space Propulsion,* European Space Agency, Noordwijk, The Netherlands, June 20-22, 2001.

Pourpoint, T. L., and Rusek, J. J., "Investigation of Homogeneous and Heterogeneous Catalysis for the Propulsive Decomposition of Hydrogen Peroxide," *Proceedings of the First International Conference on Green Propellants for Space Propulsion,* European Space Agency, Noordwijk, The Netherlands, June 20-22, 2001.

Prater, D. N., and Rusek, J. J., "Systematic Examination of a Direct Peroxide Aqueous Methanol Fuel Cell," *Proceedings of the First International Conference on Green*

Propellants for Space Propulsion, European Space Agency, Noordwijk, The Netherlands, June 20-22, 2001.

Miller, D. O., and Rusek, J. J., "Electrocatalysis in Hydrogen Peroxide Fuel Cells," *Proceedings of the First International Conference on Green Propellants for Space Propulsion,* European Space Agency, Noordwijk, The Netherlands, June 20-22, 2001.

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.

STRUCTURES AND MATERIALS

Faculty Members

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.

C. T. Sun, 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 multidisciplinary 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 once 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

Williams, E. A., Crossley, W. A., and Lang, T. J., "Average and Maximum Revisit Time Trade Studies Using a Multiobjective Genetic Algorithm," *Journal of the Astronautical Sciences,* July-Sept. 2001.

Conference Proceedings, Presentations, Invited Lectures and Reports

Cook, A. M., and Crossley, W. A., "Investigating a Genetic Algorithm Approach to Place Smart Actuators for Aircraft Maneuvering," paper no. AIAA-2001-0924, *39th AIAA Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 2001.

Hassan, R. A., and Crossley, W. A., "Conceptual Design of Communication Satellites with a Genetic Algorithm," paper no. AIAA-2001-1626, *42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Seattle, WA, April 2001.

Fanjoy, D. W., and Crossley, W. A., "Using a Genetic Algorithm for Structural Topology Design of Helicopter Rotor Blades," paper no. AIAA-2001-1605, *42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Seattle, WQA, April 2001.

Crossley, W. A., Martin, E. T., and Fanjoy, D. W., "A Multiobjective Investigation of 50-Seat Commuter Aircraft Using a Genetic Algorithm," presented at the *First AIAA Aircraft Technology, Integration, and Operations Forum,* Oct. 2001.

Fanjoy, D. W., and Crossley, W. A., "Topology Design of Rotor Blades for Aerodynamic and Structural Concerns," NASA GSRP final report, no. NGT-2-52225, Jan. 2001.

Crossley, W. A., and Cook, A. M., "Actuator Placement via Genetic Algorithm for Aircraft Morphing," final summary of research, NASA grant no. NAG-1-2262, June 2001.

Crossley, W. A., and Fanjoy, D. W., "Aerodynamic Shape and Structural Topology Design of Helicopter Rotor Cross-Section using a Genetic Algorithm, final summary of research, NASA grant no. NAG-2-1403, Sept. 2001.

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) @-D Fast Fourier Transforms.

THOMAS N. FARRIS
1986
Professor and Head

Degrees

B. S., Rice University, Cum Laude, Mechanical Engineering, 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., Farris, T. N., and Slavik, D. C., "Fretting Fatigue of Ti-6A1-4V Subjected to Blade/Disk Contact Loading," *Developments in Fracture Mechanics for the New Century,* 50th Anniversary of Japan Society of Materials Science, Osaka, Japan, May 2001, pp. 41-48.

Goryacheva, I. G., Rajeev, P. T., and Farris, T. N., "Wear in Partial Slip Contact," *ASME Journal of Tribology,* Vol. 123, No. 4, pp. 848-845, 2001.

Ackroyd, B., Akcan, S., Chhabra, P., Krishnamurthy, K., Madhavan, V., Chandrasekar, S., Compton, W. D., and Farris, T. N., "Exploration of Contact Conditions in Machining," *Proceedings of the I MECH E Journal on Engineering Manufacture,* Vol. 215, No. B4, pp. 493-507, 2001.

Kompella, S., Farris, T. N., and Chandrasekar, S., "Techniques for Rapid Characterization of Grinding Wheel-Workpiece Combinations," *Proceedings of the I MECH E Journal on Engineering Manufacture,* Vol. 215, No. B10, pp. 1385-1395, 2001.

Moylan, S. P., Kompella, S., Chandrasekar, S., and Farris, T. N., "A Nano-Indentation Study of Mechanical Properties of Thin Surface Layers Affected by Manufacturing Processes," Tribology Research: From Model Experiment to Industrial Problem, A Century of Efforts in Mechanics, Materials Science and Physico-Chemistry, ed. By G. Dalmaz, A. A. Lubrecht, D. Dowson, and M. Priest, Elsevier, pp. 895-903, 2001.

Books

Small Business Innovation Research to Support Aging Aircraft: Priority Technical Areas and Process Improvements, NRC Committee, National Academy Press, 2001.

Conference Proceedings, Presentations, Invited Lectures and Reports

Rajeev, P. T., and Farris, T. N., "Two Dimensional Contact of Dissimilar/Anisotropic Materials," *Proceedings of the 41st AIAA/ASME/ASCE/ASC Structures, Structural Dynamics and Materials Conference,* (1), pp. 515-522, Seattle, WA, 2001.

Slavik, D. C., McClain R. D., Farris, T. N., and Murthy, H., "Fatigue Crack Initiation Modeling for Applications with Stress Gradients in Ti-6A1-4V, *Proceedings of the 6th National Turbine Engine High Cycle Fatigue (HCF) Conference,* CD Presentation 1, Jacksonville, FL, March 2001.

Hartle, M. S., Farris, T. N., Matlik, J. F., and Rajeev, P. T., "A Hybrid Approach to 3D Edge of Contact Stress Analysis using Singular Integral Equations," *Proceedings of the 6th National Turbine Engine High Cycle Fatigue (HCF) Conference,* CD Presentation 42, Jacksonville, FL, March 2001.

Farris, T. N., Murthy, H., Perez-Ruberte, E., and Rajeev, P. T., "Experimental Characterization of Fretting Fatigue Engine Alloys," *Proceedings of the 6th National Turbine Engine High Cycle Fatigue (HCF) Conference,* CD Presentation 19, Jacksonville, FL, March 2001.

Murthy, H., Farris, T. N., and Slavik, D. C., "Fretting Fatigue of Ti-6A1-4V Subjected to Blade/Disk Contact Loading," *Materials Science Research International Special Technical Publication 1 – Materials Science for the 21st Century,* Conference on Materials Science for the 21st Century to celebrate the 50th Anniversary of Japan Society of Materials Science, Osaka, May 2001, pp. 200-207.

Murthy, H., Rajeev, P. T., and Farris, T. N., "Fretting Fatigue in Turbine Engine Blade/Disk Contacts," Proceedings of the 13th PERC Symposium, Huntsville, AL, Oct. 2001, pp. 330-338.

Calcaterra, J., and Farris, T. N., "Analysis of Turbine Engine Attachment Fatigue Using Integral Equation Methods," Proceedings USAF Aircraft Structural Integrity Program Conference, Williamsburg, VA, Dec. 2001.

Murthy, H., Rajev, P. T., Farris, T. N., and Okane, M., "High Temperature Fretting of Turbine Materials Subjected to Engine-Type Loading," *3rd International Symposium on Fretting Fatigue,* Nagaoka, Japan, May 2001.

Matlik, J. F., and Farris, T. N., "High-Frequency Fretting Fatigue Experiments," *3rd International Symposium on Fretting Fatigue,* Nagaoka, Japan, May 2001.

Farris, T. N., "Temperature Measurements in Fretting," seminar presented at Toyama University, May 2001.

Farris, T. N., "Fretting Fatigue of Aircraft Engines," seminar presented at the University of Michigan, Nov. 2001.

Farris, T. N., "Heat Partition and Temperatures in Grinding," seminar presented at Michigan Tech., Dec. 2001.

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

Fundamental 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

Golden, P. J., Bartha, B., Grandt, Jr., A. F., and Nicholas, T., "Fatigue Crack Growth Threshold of Fretting Induced Cracks in Ti-6AL-4V, *6th National Turbine Engine HCF Conference,* Jacksonville, FL, March 5-8, 2001.

Grandt, Jr., A. E., and Watkins, W. A., "Design-Build-Test Project Teams that Incorporate Engineering and Technology Students," *American Society of Engineering Education Illinois/Indiana Sectional Conference,* Purdue Univ., W. Lafayette, IN, March 29, 2001.

Hahn, D. J., Grandt, Jr., A. F., and Park, C. Y., "A Test Protocol for Evaluating the Durability of Materials for Aircraft Joint Applications," a "Living Document" prepared for the Alcoa Technical Center, School of Aeronautics and Astronautics, Purdue Univ., W. Lafayette, IN, May 2001.

Grandt, Jr., A. F., Hahn, D. J., Park, C. Y., Yeh, J. R., Bucci, R. J., Bray G. H., and Kulak, M., "Development of Generic Protocol to Evaluate Aluminum Alloys for Joint Fatigue Applications," *12th Annual Advanced Aerospace Materials and Processes Conferences and Exposition,* Long Beach, CA, June 11-14, 2001.

Lamb, G. J., and Grandt, Jr., A. F., and Easterbrook, E. T., "Fatigue Performance of an Advanced Hole Cold Working Method," *2001 USAF Aircraft Structural Integrity Program Conference,* Williamsburg, VA, Dec. 11-13, 2001.

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. and Kedward, K.T., "Stress Analysis of Adhesive Bonded Joints Under In-Plane Shear Loading," *Journal of Adhesion,* Vol. 76, No. 1, 2001, pp. 1-36.

Conference Proceedings, Presentations, Invited Lectures and Reports

Kim, H., and Kedward, K. T., "Stress Analysis of Adhesively-Bonded Composite Joints Having Varying Bondline Thickness," *16th Annual ASC Technical Conference on Composite Materials,* Blacksburg, VA, Sept. 29-12, 2001.

Kim, H., and Keward, K. T., "Stress Analysis of In-Plane Shear Loaded Adhesively Bonded Composite Joints and Assemblies," FAA final report, DOT/FAA/AR-10-17, April 2001.

Kim, H., "Purdue University Adhesive Bonding Research Progress Update," National Institute of Aviation Research, Wichita State Univ., Wichita, KS, Nov. 28-29, 2001

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

Major research interests include the following areas:

Composite Materials and Structures -- Advanced fiber composites have gained wide application in aircraft and aerospace structures. However, our knowledge of these materials is still lacking, and a great deal of research is still needed. Our research covers a broad spectrum of mechanics and design of various composite materials and structures. Topics include low velocity impact response and damage analysis, ballistic impact and penetration of composite structures, design of new hybrid composites for improved impact resistance properties, development of theories for laminate failure prediction, inelastic behavior of composites, temperature-dependent properties, modeling of thick composite laminates, static and dynamic delamination crack propagation, intelligent tailoring of composite materials and structures and finite element simulation of forming of thermoplastic composites. Composite systems studies include carbon/epoxy composites, thermoplastic composites, metal-matrix composites, and ARALL laminates.

The McDonnell Douglas Composite Materials Laboratory is equipped with complete testing facilities. In addition, an autoclave and a hot press are available for composite specimen fabrication.

Fracture Mechanics -- Fracture mechanics is used to analyze failure in materials including fibrous composites. Behaviors of interfacial cracks between two dissimilar materials are of particular interest as they are pertinent to fiber debonding in composite materials and to delamination in composite laminates. Topics of research include separation of fracture modes for interfacial cracks and development of governing equations for dynamic motion of propagating interface cracks. Another major research effort concerns fracture criterion utilizing a combination of an extended J-integral for elastic-plastic materials and a crack front plastic work density to predict crack extension

in ductile metals. A new research topic deals with fracture mechanics issues encountered in using composite materials to repair cracked metal structure in aging aircraft.

Smart Materials and Structures -- The use of piezoceramics as actuators in adaptive structures demands these materials to perform under increasingly high electric 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 under combined mechanical and electric loading.

Publications

Roeder, B. A., and Sun, C, T., "Impact of Alumina/Aluminum Laminates: Experiments and Modeling," *International Journal of Impact Engineering,* Vol. 25, 2001, pp. 169-185.

Thiruppukuzhi, S. V., and Sun, C. T., "Models for Strain Rate-Dependent Behavior of Polymer Composites," *Composites Science and Technology,* Vol. 61, 2001, pp. 1-12.

Jiang, L. Z., and Sun, C. T., "Analysis of Indentation Cracking in Piezoceramics," *International Journal of Solids and Structures,* Vol. 38, 2001, pp. 1903-1918.

Ninan, L., Tsai, J., and Sun, C. T., "Use of Split Hopkinson Pressure Bar for Testing Off-axis Composites," *International Journal of Impact Engineering,* Vol. 25, 2001, pp. 291-313.

Tsai, J. L., Guo, C., and Sun, C. T., "Dynamic Delamination Fracture Toughness in Unidirectional Polymeric Composites," *Composites Science and Technology,* Vol. 61, 2001, pp. 87-94.

Han, C., and Sun, C. T., "Attenuation of Stress Wave Propagation in Periodically Layered Elastic Media," *Journal of Sound and Vibration,* Vol. 234, No. 4, June 2001, pp. 747-761.

Zeng, Q.-G., and Sun, C. T., "Novel Design of a Bonded Lap Joint," *AIAA Journal,* Vol. 39, No. 10, Oct. 2001, pp. 1991-1996.

Cho, J., and Sun, C. T., "Lowering Thermal Residual Stresses in Composite Patch Repairs in Metallic Aircraft Structure," *AIAA Journal,* Vol. 39, No. 10, Oct. 2001, pp. 2013-2018.

Ikeda, T., and Sun, C. T., "Stress Intensity Factor Analysis for an Interfacial Crack Between Dissimilar Isotropic Materials under Thermal Stress," *International Journal of Fracture,* Vol. 111, 2001, pp. 229-249.

Conference Proceedings, Presentations, Invited Lectures and Reports

Sun, C. T., and Achuthan, A., "Criteria for Domain Switching in Piezoelectric Materials," *SPIE's 8th International Symposium on Smart Structures and Materials,* Newport Beach, CA, March 4-8, 2001.

Hu, Huiwen, and Sun, C. T., "Moisture-temperature Equivalence in Physical Aging of Polymeric Composites," *42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and Exhibit,* paper no. AIAA-2001-1287, Seattle, WA, April 16-19, 2001.

Zeng, Q., and Sun, C. T., "Fatigue Performance of a Bonded Wavy Composite Lap Joint," *42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference and Exhibit,* paper no. AIAA-2001-1488, Seattle, WA, April 16-19, 2001.

Sun, C. T., "Design of Metal Ceramic Composites by Tailoring their Microstructures," *Optimization of Micro-structural Design and Structural Integrity of Composite Materials and Structures: Exploiting Solutions to Practical Problems,* Capri, Italy, May 20-25, 2001.

Sun, C. T., and Tsai, J. L., "Comparison of Microbuckling Model and Kink Band Model in Predicting Compressive Strengths of Composites," *Proceedings of the 13th International Conference on Composite Materials (ICCM 13),* Beijing, China, June 25-29, 2001.

Aymerich, F., Portiolo, P., Sanna, R., and Sun, C. T., "Fatigue Behavior of Stitched Composite Laminates," *Proceedings of the 13th International Conference on Composite Materials (ICCM 13),* Beijing, China, June 25-29, 2001.

Sun, C. T., "Fracture and Fatigue of Piezoceramics Under Mechanical and Electrical Loads," in Long Term Durability of Structural Materials, Durability 2000 (edited by P. J. M. Monteiro, K. P. Chomg, J. Larsen-Basse, and K. Komvopoulos), *Proceedings of Durability Workshop,* Berkeley, CA, pp. 231-244, Oct. 26-27, 2000, Elsevier, 2001.

Park, S., and Sun, C. T., "Micromechanical Modeling of Co-Continuous Ceramic Metal Composites," *Proceedings of the 16th Technical Conference,* American Society for Composites, VPI & State Univ., Blacksburg, VA, Sept. 9-12, 2001.

Sun, C. T., and Yang, Z., "K-Dominance in Delamination Cracks," *Proceedings of the 16th Technical Conference, American Society for Composites,* VPI & State Univ., Blacksburg, VA, Sept. 9-12, 2001.

Sun, C. T., and Han, C., "Dynamic Mode I Fracture Toughness Test of Composites using a Kolsky Bar," IMECE2001/AMD-25404, *ASME International Mechanical Engineering Congress and Exposition,* New York, NY, Nov. 11-16, 2001.

Sun, C. T., "Treatment of Length Scale Issues in Solid Mechanics," (key note lecture), *Proceedings of the 25th National Conference on Theoretical and Applied Mechanics,* Taichung Taiwan, pp. I-1 to I-14, Dec. 15-16, 2001.

Sun, C. T., "Smart Structures and Fracture Fatigue in Piezoceramics," invited lecture Dept. of Civil Engrg., National Univ. of Singapore, Oct. 3, 2001.

Sun, C. T., "Implications of Nanotechnology to Solid Mechanics," invited lecture National Tsing Hua Univ., Hsin-chu, Taiwan, Nov. 29, 2001.

Sun, C. T., "Piezoelectric Based Smart Structures," invited lecture National Cheng Kung Univ., Tainan, Taiwan, Nov. 30, 2001.

Sun, C. T., "Modeling Strain Rate Effect on Mechanical Behavior in Polymeric Composites," invited lecture National Chiaotung Univ., Hsin-chu, Taiwan, Dec. 5, 2001.

Sun, C. T., "Fracture and Fatigue in Piezoceramics," invited lecture National Taiwan Univ., Taiwan, Dec. 6, 2001.

Sun, C. T., "Computation and Modeling of Solids at Various Scales," invited lecture National Center for High Speed Computing, Hsin-chu, Taiwan, Dec. 12, 2001.

Sun, C. T., "Recent Development in Aerospace Structures and Materials," invited keynote lecture at Aeronautical and Astronautical Society of the Republic of China (AASRC) 2001 Annual Meeting, National Huwei Institute of Technology, Taiwan, Dec. 14, 2001.

TERRENCE A.WEISSHAAR
1980
Professor

Degrees

B. S., (highest distinction), Northwestern University, Mechanical Engineering, 1965
S. M., 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., and Duke, D. K., "Induced Drag Reduction using Aeroelastic Tailoring with Adaptive Control Surfaces," *Journal of Aircraft,* Oct. 2001.

Conference Proceedings, Presentations, Invited Lectures and Reports

Henderson, J. A., Weisshaar, T. A., and Sanders, B., "Integrated Wing Design with Adaptive Control Surfaces," *42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference,* paper no. AIAA-2001-1428, Seattle, WA, April 16-19. 2001.

Weisshaar, T. A., "Aeroelasticity's Role in Innovative UAV Design and Optimization," *41st Israel Conference on Aerospace Sciences,* Tel Aviv, Israel, Feb. 21-22, 2001.

Taylor, R. M., Weisshaar, T. A., and Sarukhanov, V., "Structural Design Process Improvement using Evolutionary Finite Element Models," paper no. AIAA-2001-1630, *42nd AIAA/ASME/ASCE/AHS Structural Dynamics and Materials Conference,* Seattle, WA, April 2001.

Weisshaar, T. A., "Aeroelastic Tailoring for Unconventional Aircraft Configuration," *International Forum on Aeroelasticity and Structural Dynamics,* Madrid, Spain, June 2001.

Weisshaar, T. A., "Aeroelastic Tailoring for Unconventional Aircraft Configurations," plenary session – *International Forum on Aeroelasticity and Structural Dynamics,* Madrid, Spain, June 7, 2001.

Weisshaar, T. A., "Aeroelasticity's Role in Innovative UAV Design and Optimization," invited plenary talk, *41st Israel Conference on Aerospace Sciences,* Tel Aviv, Israel, Feb. 21-22, 2001.

Weisshaar, T. A., "Aeroelastic Tailoring for Unconventional Aircraft Configurations," plenary session speaker, *International Forum on Aeroelasticity and Structural Dynamics,* Madrid, Spain, June 2001.

ACTIVE RESEARCH PROJECTS

July 2001 to June 2002

RESEARCH AND OTHER SCHOLARLY ACTIVITIES

In the areas of Aerodynamics, Dynamics and Controls, Propulsion, and Structures and Materials, $4.1 million in research expenditures were realized between July 1, 2001 and June 30, 2002. Several faculty were recognized for research as is detailed in the "Faculty Highlights" section. The research expenditure for the 2001-2002 year was attributed to the following sources.

SOURCE OF SPONSORED RESEARCH FOR 2001-2002	
Source	**Percentage of Total**
Department of Defense	37.9%
NASA	23.2%
National Science Foundation	4.6%
Industry	10.8%
Indiana 21st Century R & D	19.3%
Other	4.2%
Total	100.0%

SPONSORED RESEARCH PROJECTS
ACTIVE DURING THE PERIOD JULY 1, 2001 TO JUNE 30, 2002

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
NASA	Improved Preliminary Design Analysis Process for High-Pressure Rocket Combustion	12/01/01-12/31/03	$160,000	Anderson
NASA	Development of a Partial Design Database for Advanced Hydrogen Peroxide Engines	06/03/02-06/03/03	$297,063	Anderson
Orbital Sciences	Upper Stage Flight Experiment (USFE) Injector Calibration and HTP Flow-test	02/01/02-12/31/02	$10,000	Anderson
NASA	Field Test Methods for Hydrogen Peroxide Stability Margin	03/18/02-02/17/03	$100,000	Anderson
NASA	Design, Fabrication, and Testing of a Rocket Based Combined Cycle Flight Experiment	06/01/02-01/31/03	$406,560	Anderson
NASA	Indiana Space Grant Consortium Program Grant	03/01/91-02/28/02	$1,890,750	Andrisani
Rockwell Collins	Portable Data Acquisition and Control System	06/09/00-99/99/99	$30,000	Andrisani
Sarnoff Corp./DOD	Airborne Motion Imagery Modeling Study	10/01/00-04/12/02	$113,335	Co-PI: Andrisani (PI: Bethel)
Rolls-Royce	Dynamics of Engine Oil Sumps and Drains	05/01/02-04/30/03	$73,000	Collicott (Co-P.I. Heister)
NASA	Zero-Gravity Validation of Surface-Tension Propellant for Rocket-Grade Hydrogen Peroxide	06/03/02-06/03/03	$29,472	Collicott
Metrolaser Inc.	Laser-Perturbation Design	01/01/02-05/31/02	$8,154	Collicott
Rolls-Royce	Purdue Sump-Flow Research	01/01/00-05/31/02	$189,032	Collicott
United Technologies	United Technologies/Pratt & Whitney	04/01/95-99/99/99	$18,000	Collicott
University of Illinois	Liquid Huge Modeling	04/01/01-03/31/02	$6,516	Collicott
Cummins Engine	NSF Matching	01/01/97-99/99/99	$50,000	Collicott
Trask Trust Fund	Trask Trust Fund	08/15/00-06/01/02	$95,382	Collicott
Applied Optimiz.	Genetic Algorithm Approaches for Unknown Target Signature Separation	07/31/01-02/01/02	$33,000	Crossley
NASA	Design Methods and Optimization for Morphing Aircraft	08/15/01-08/14/04	$614,086	Crossley (Co-P.I.-Weisshaar)
Mide Tech. Corp.	Self Consuming Spacecraft	12/01/99-99/99/99	$2,000	Crossley

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
NASA	Improved Aircraft Conceptual Design Using A Genetic Algorithm Based Approach	07/01/98-10/30/01	$66,000	Crossley
NASA	NASA/FAA National General Aviation Design Competition Travel Award	07/14/01-08/31/01	$1,500	Crossley
NASA	Combinatorial Multiobjective Optimization Using Genetic Algorithms	04/10/01-04/09/02	$30,003	Crossley
General Elec.	Flow Solver Validation	01/08/01-03/31/02	$44,149	Crossley
General Electric Aircraft Engines	Amelioration of Fretting Fatigue of Titanium	08/16/00-12/31/01	$99,560	Farris
LSP Tech.	Fretting Fatigue Testing For LSP Technologies, Inc.	11/01/00-12/31/01	$5,550	Farris
Univ. Dayton Res. Inst.	Advanced High Cycle Fatigue Life Methodologies	04/01/99-08/31/02	$702,993	Farris (Co-P.I. Grandt)
LSP Tech.	Fretting Fatigue Testing for LSP Technologies Inc.	04/01/02-09/30/02	$20,400	Farris
General Electric Aircraft Engines	Mechanics of Blade/Disk Contacts	04/22/02-04/21/03	$50,000	Farris
Rolls-Royce	Fretting Fatigue Modeling	01/01/02-12/31/03	$70,000	Farris
NASA	Autonomous Navigation for Alternate Access to the International Space Station	05/18/01-05/17/03	$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
NASA	Model Improvement and Validation for GPS Code Tracking in High Earth Orbits (HEO)	05/01/02-12/31/02	$38,549	Garrison
ALCOA	Durability of Aircraft Joints	06/01/99-12/31/01	$210,000	Grandt
U.S. Army Space & Missiles Defense	Space and Missile Propulsion Using Advanced Propellants	04-09/02-04/08/03	$195,775	Heister (Co-P.I. Anderson)
NASA	Improved Modeling of Cavitating Venturi Flows	01/01/02-11/30/02	$60,000	Heister
Sciences Applications International	Alternative Schemes for Controlling Thrust Vector	03/01/01-03/31/03	$260,000	Heister
AFOSR	Modeling Dense Sprays in Liquid Rocket Engines	01/01/99-10/31/02	$69,717	Heister
NASA	Simulation and Visualization of Cavitating Venturi Flows	01/01/01-03/31/02	$50,000	Heister

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
ARO	Modeling Diesel Engine Injector Flows	05/20/98-08/31/01	$180,000	Heister (Co-PI: Blaisdell)
Allied-Signal	Special Program	05/01/98-99/99/99	$2,000	Heister
Allison Advanced Development Company (21st Century)	Purdue, West Lafayette Budget for Propulsion and Power Center of Excellence	03/09/01-03/09/03	$1,025,000	Heister
Army Research Office	Linux Cluster For High-Performance Parallel Computing	04/01/01-03/31/02	$111,548	Heister (Co-P.I.-Blaisdell, Crossley, Lyrintzis)
Science Applications International	Trajectory Control through Thrust Vector Rotation	03/01/01-02/28/02	$55,000	Heister
NASA	Dynamical Systems Theory, Numerical Methods, Optimization Strategies and their Application to Trajectory Design Mission Analysis Involving Lissajous and Halo Orbits	08/01/98-07/31/03	$349,347	Howell
NASA	Applications of Dynamical Systems Theory, Control Methods and Optimization Strategies to Trajectory Design & Mission Analysis Involving Formation Flying at Libration Points for GSFC Missions	04/15/02-09/30/04	$78,000	Howell
Univ. of Calif. Santa Barbara/FAA	Damage Tolerance Design of Bonded Composite Structures	12/05/01-05/31/02	$31,794	Kim
NASA	Buckling Stability of Disbonded Composite Structures	03/19/02-03/18/03	$75,000	Kim
NASA	NASA Means Business 2001 Team Award	05/15/01-05/13/02	$2,690	Longuski
JPL/NASA	Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions	11/1/99-10/31/02	$406,569	Longuski (Co-PI: Howell)
NASA	Low-Thrust Gravity-Assist Trajectory Design	8/1/00-7/31/02	$44,000	Longuski
Global Aerospace Corporation	Cyclical Visits to Mars Via Astronaut Hotels	5/1/01-8/31/01	$30,000	Longuski

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
21st Century Research and Technology Fund	Development of Low Jet Noise Aircraft Engines	3/5/01-3/5/03	$1,053,531	Lyrintzis (Co-PI's: Blaisdell, Mongeau Bolton)
Aerojet Strategic Propulsion Company	Hydrogen Peroxide Catalyst Testing	5/1/01-7/9/01	$13,332	Meyer
Aerojet	Advanced Reusable Rocket Engine Uni-Element Tri-Fluid Injector	05/01/01-12/31/02	$104,840	Meyer
Aerojet	Advanced Nontoxic Propellant Propulsion	04/22/02-12/31/02	$8,489	Meyer
Pratt & Whitney	Advanced Hydrogen Peroxide Catalyst Testing	11/01/01-10/31/02	$4,600	Meyer
NSF	Analysis and Design of Multivariable Extremum Seeking Algorithms	9/1/00-8/31/03	$196,008	Rotea
Naval Postgraduate School	Parameter Estimation for Airdrop Systems	07/30/01-06/15/02	$40,000	Rotea
United Tech. Res. Center	Robust Control Analysis and Synthesis	09/01/98-99/99/99	$37,500	Rotea
Sandia National Labs	Aerothermodynamic Predictions for Hypersonic Reentry Vehicles	09/01/99-09/01/02	$230,000	Schneider
NASA	Cold-Wire Measurements in the Body-Flap Cavity of an X-38 Model	09/24/01-09/30/02	$10,553	Schneider
NASA	Mechanisms of Boundary-Layer Transition on Reusable Launch Vehicles	02/01/02-01/31/05	$150,000	Schneider
Sandia National Labs	Effect of Roughness on Boundary-Layer Transition for Re-entry Vehicles: Quiet Tunnel Experiments	03/26/02-09/30/02	$15,000	Schneider
AFOSR	Mechanisms of Hypersonic Boundary-Layer Transition on a Generic Scramjet Forebody	11/15/99-11/14/02	$270,123	Schneider (Co-P.I.: H. Reed ASU)
AFOSR	Active Control of Secondary Flow in Engine Inlets	02/01/02-12/31/02	$70,000	Sullivan
Raisbeck Engineering	Design/Build/Test Laboratory	08/01/99-99/99/99	$75,000	Sullivan
A. T. C. Incorporated	ATC, Inc.	01/01/00-12/31/75	$16,667	Sullivan
21st Century Research and Technology Fund	Intelligent Mems-based Flow Sensors and Controllers	8/4/00-8/4/02	$815,630	Sullivan (Co. PI: Nof, Wereley)
NASA	A Laser Scanning PSP-TSP System for Propulsion Applications	7/1/01-6/30/02	$49,242	Sullivan

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
Physical Acoustics Corporation	Composite Armor Material Characterization	07/01/99-99/99/99	$39,000	Sun
ARO	Lightweight Layered Materials/Structures for Damage Tolerant Armor	09/01/96-8/31/02	$3,135,500	Sun (Co-PI's: Doyle, Espinosa, Bolton, Trumble)
ONR	Dynamic Constitutive and Failure Modeling of Composite Materials and Structures	02/01/96-08/31/02	$675,208	Sun
NSF	Fracture and Fatigue of Piezoceramics Under Combined Mechanical and Electrical Loading	09/15/98-08/31/01	$286,324	Sun
Tuskegee Univ./NSF	Interlaminar and Compressive Properties of Composites – A Subcontract to Tuskegee Univ. for the Establishment of a Center for Innovative Manufacturing of High Performance Composite Materials	09/01/97-008/31/02	$260,000	Sun
AFOSR	Development of Composites Reinforced with Short Wavy Fibers	12/01/01-11/30/02	$300,000	Sun
Ball Aerospace/ Air Force	Mixed Mode Fracture of Tubular Steel Structures	05/31/01-05/01/02	$81,999	Sun
AFOSR	Modeling and Lowering Residual Stresses in Bonded Composite Patch Repairs of Metallic Aircraft Structures	02/01/98-7/31/01	$157,482	Sun (Co-PI: Caruthers)
NASA	Modeling of Nano Materials	01/01/01 12/31/03	$165,000	Sun
Northrup Grumman/ Air Force	Analytical Study of Adaptive Control Surfaces for Drag Reduction for Sensorcraft Class	01/01/01-12/31/01	$50,000	Weisshaar
Anteon Corporations	Aero-Morphing Aircraft Concepts	2/1/01-8/30/01	$48,998	Weisshaar

GRADUATE THESES

July 2001 to June 2002

MASTER'S THESES

Student/ *Major Professor*	**Thesis Title**	**Degree** **Date Granted**
Beutien, Trisha R. *S. D. Heister*	"A Ceramic-Manganese Oxide System for the Decomposition of High Concentration Hydrogen Peroxide"	M.S. August 2001
Perez-Ruberte, Eddie *T. N. Farris*	"Elasto-Plastic Finite Element Analysis of Contacts with Applications to Fretting Fatigue	M.S. August 2001
Anderson, Jason P. *K. C. Howell*	"Earth-to-Lissajous Transfers and Recovery Trajectories Using an Ephemeris Model"	M.S. December 2001
Lim, Kok Hong *J. J. Rusek*	"Anodic Studies of the Aluminum – Hydrogen Peroxide Semi – Fuel Cell"	M.S. December 2001
Miller, Daniel Olin *S. D. Heister*	"Electrocatalysis in Hydrogen Peroxide Fuel Cells"	M.S. December 2001
Radocaj, Daniel J. *S. H. Collicott*	"Experimental Characterization of a Simple Gas Turbine Engine Sump Geometry"	M.S. December 2001
Shimo, Masayoshi *S. D. Heister*	"Modeling of Oil Film Behavior on a Seal Runner and a Sump Wall"	M.S. December 2001
Skoch, Craig R. *S. P. Schneider*	"Final Assembly and Initial Testing of the Purdue Mach-6 Quiet-Flow Ludwieg Tube"	M.S. December 2001
Valentini, Luiz F. R. *J. P. Sullivan*	"Aft-Fuselage Modification of the Gulfstream IV"	M.S. December 2001
Weinstock, Vladimir David *S. D. Heister*	"Modeling of Drop Trajectories and Drop/Wall Interactions in Gas Turbine Engine Sumps"	M.S. December 2001
Bodily, Brandon H. *C. T. Sun*	"Mechanical Properties of Single-Walled Carbon Nanotubes by Modeling as Pin-Jointed Trusses"	M.S. May 2002
Brodrecht, David J. *S. D. Heister*	"Parametric Studies of an Aluminum-Hydrogen Peroxide Semi-Fuel Cell"	M.S. May 2002
Bulathsinghala, Ivor J. *S. D. Heister*	"Trajectory Control Through Thrust Vector Rotation"	M.S. May 2002

MASTER'S THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree** **Date Granted**
Hoverman, Thomas J. *S. H. Collicott*	"Performance of a New Air-Assist/Air-Blast Atomizer for Large Liquid Mass Flows"	M.S. May 2002
Kowalkowski, Matthew Kenneth *S. D. Heister*	"Trajectory Control for Agile Landmines"	M.S. May 2002
Krautheim, Michael S. *S. H. Collicott*	"Downstream Measurements of a High Reynolds Number Horseshoe Vortex"	M.S. May 2002

DOCTORAL THESES

Student/ *Major Professor*	**Thesis Title**	**Degree** **Date Granted**
Chen, Yun *T. N. Farris*	"Analysis of Indentation Cracking in Brittle Solids"	Ph.D. August 2001
Fanjoy, David W. *W. A. Crossley*	"Aerodynamic Shape and Structural Topology Design of Helicopter Rotor Cross-Sections Using a Genetic Algorithm"	Ph.D. August 2001
Hu, Huiwen *C. T. Sun*	"Modeling Physical Aging in Polymeric Composites"	Ph.D. August 2001
Jin, Long *T. N. Farris*	"Simulation of Quenching and Tempering of Steels"	Ph.D. August 2001
Kim, Haedong *M. H. Williams*	"Computational Techniques for Blade-Vortex Interaction Prediction"	Ph.D. August 2001
Maley, Scott *C. T. Sun*	"Particulate Enhanced Damping of Sandwich Structures"	Ph.D. August 2001
Tsai, Jia-Lin *C. T. Sun*	"Dynamic Microbuckling Model for Compressive Strength of Polymeric Composites"	Ph.D. August 2001
Wang, Zeping *C. T. Sun*	"Modeling Micro-Inertia in Composite Materials Subjected to Dynamic Loading"	Ph.D. August 2001
D'Amato, Fernando J. *M. A. Rotea*	"Efficient Algorithms for the Maximization of Linear Fractional Transformations"	Ph.D. December 2001
Ekici, Kivanc *A. S. Lyrintzis*	"Parallel Computing Techniques for Rotorcraft Aerodynamics"	Ph.D. December 2001
Golden, Patrick John *A. F. Grandt*	"High Cycle Fatigue of Fretting Induced Cracks"	Ph.D. December 2001
Pakalapati, Rejeev T. *T. N. Farris*	"Fretting Contact of Dissimilar Isotropic/Anisotropic Materials"	Ph.D. December 2001
Xu, Changhai *S. D. Heister*	"Simulation of Orifice Internal Flows Including Cavitation and Turbulence"	Ph.D. December 2001

DOCTORAL THESES

Student/ *Major Professor*	**Thesis Title**	**Degree** **Date Granted**
Salyer, Terry Ray *S. H. Collicott*	"Laser Differential Interferometry for Supersonic Blunt Body Receptivity Experiments"	Ph.D. May 2002

COLLOQUIUM SERIES

July 2001 to June 2002

Colloquium Series – Fall 2001

DATE/TIME	TOPIC	SPEAKER
*September 24, 2001 7:00 p.m. West Faculty Lounge Purdue Memorial Union	Air Force Basic Research Directions and Opportunities	**Colonel Steven G. Reznick** Commander & Deputy Dir. AFOSR
October 4, 2001 1:30 p.m. Grissom 170	Mars Analog Research in the High Canadian Arctic	**Jaret Matthews** Purdue A&AE Undergraduate Collaborator on the NASA Haughton-Mars Project, & Crewmember of the Mars Arctic Research Station
October 25, 2001 3:30 p.m. Heavilon Hall G04	Hypersonic Testing with Rocket Sleds	**Birk Billingsley** Test Mgr. Hypersonic Upgrade Program U.S.A.F.
November 1, 2001 1:30 p.m. Grissom 170	Pratt & Whitney Gas Turbine Engine Instrumentation Overview	**Dr. Robert Johnston** Pratt & Whitney Technology Mgr. for the Measurement Ctr.
November 15, 2001 4:00 p.m. Stewart Ctr. 202	Air Transportation System Security	**John B. Hayhurst** Sr. Vice President The Boeing Co. President, Air Traffic Mgmt.
November 29, 2001 4:00 p.m. KNOY B044	Propulsion Technology for Next Generation Reusable Launch Vehicles and Satellites	**R. Joseph Cassady** Sr. Mgr. Of Business Dev. for the Eastern Region U.S. General Dynamics Space Propulsion Systems
**November 30, 2001 4:00 p.m. Grissom 280	Free Shear Flows of Polymers and Comments on Turbulent Drag Reduction	**Professor G. M. Homsy** Mech. & Environ. Engrg. Univ. of California Santa Barbara

December 11, 2001 1:30 p.m. Grissom 170	The Use of RANS/CFD in the Prediction of Jet Noise	**Phillip J. Morris** Boeing/A.D. Welliver Prof. of Aerospace Engrg. Penn State Univ.

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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

Colloquium Series – Spring 2002

DATE/TIME	TOPIC	SPEAKER
February 14, 2002 4:30 p.m. GRIS 170	Heterogeneous Catalysis for Space Propulsion Applications – Past, Present and Future	**Prof. Charles Kappenstein** LACCO Laboratory of Catalysis, Faculty of Sciences Univ. of Poitiers, France
March 21, 2002 4:30 p.m. GRIS 170	The Direct Simulation Monte Carlo Method – Old Problems and New Challenges	**Michael Gallis** Sandia Labs New Mexico
*March 29, 2002 4:00 p.m. GRIS 274	Control of Turbulent Boundary Layers: Success, Limitation and Issues	**Prof. John Kim** Dept. of Mechanical & Aerospace Engrg. Univ. of California
April 4, 2002 4:30 p.m. GRIS 170	Analysis of Jet Noise Mechanisms Using Direct Numerical Solutions	**Prof. Jonathan Freund** Univ. of Champaign-Urbana Champaign-Urbana, IL
April 10, 2002 3:30 p.m. ME 261	NASA's Space Launch Initiative for the Next Generation Launch System	**Dan Dumbacher** NASA George C. Marshall Space Flight Ctr.
*April 12, 2002 4:00 p.m. STEW 313	A Computational Method Based on Fast Fourier Transforms for Nonlinear Composites with Complex Microstructure	**Pierre M. Suquet** Laboratoire de Mecanique et d'Acoustique Marseille, France
May 3, 2002 11:00 a.m. GRIS 280	Studies of Contamination Mitigation for EUV Multi-layer Thin Film Optics	**Dr. Samuel Graham** Sandia National Labs. Livermore, CA

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

HIGHLIGHTS & AWARDS

July 2001 to June 2002

FACULTY HIGHLIGHTS

Our faculty continues to be feted for the outstanding work they do in the classroom and in the laboratory.

Drs. Hyonny Kim and William Anderson began assistant professorships in Fall of 2001; and Drs. Tasos Lyrintzis and Mario Rotea were promoted to Professor effective in the Fall of 2002. Several faculty continue their visible service as Editors and on various visiting committees.

Other highlights include:

- Professor Martin Corless was Plenary Speaker, Irish Signals and Systems Conference 2001, Dublin, Ireland.
- Professor John Sullivan is on sabbatical at Boeing in Seattle for the 2002 calendar year.
- Professor William Crossley is a Welliver Fellow at Boeing in St. Louis for Summer 2002, and has his research cited as a 2001 technical highlight for the NASA Langley Research Center Multidisciplinary Design Optimization Branch
- Professor James Garrison was awarded the "Early Achievement Award" by the Institute of Navigation.
- Professor C.T. Sun received the Best Paper Award from the American Society of Composites.
- Professor Tasos Lyrintzis was on a team that received the Howard Hughes Award from the American Helicopter Society.
- Professor Kathleen Howell was a finalist for the 13th Annual Discover Magazine Innovation Awards.
- Professor Mario Rotea received a Best Paper Presentation Award at the American Control Conference and gave the Plenary Talk entitled "Semidefinite Programming: Applications in Systems and Control," at IX Reunión de Trabajo en Procesamiento de la Información y Control, Santa Fe, Argentina, September 2001.
- Professor Thomas Farris was named Fellow of ASME.

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 6th annual Fall Space Day. Additionally, SEDS hosted their annual Open Forum Discussion entitled "Whose Bucks for Buck Rogers." 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

Summer 2001

NASA JSC Co-op Special Achievement Awards and Co-op Flag Awards

Out of more than 90 students who worked at JSC during summer 2001, 28 students were nominated for an award. Of those nominated, 10 received Special Achievement Awards and 15 received Flag Awards.

John Gowan and Mihailo Rutovic received a Co-op Special Achievement Award, which each included a check for $500.

Pooja Agrawal and Paul Brower received a Flag Award, which includes a certificate with a mounted flag that has flown on board an Orbiter.

Fall 2001

Out of more than 60 students who worked at JSC during fall 2001, 25 were nominated for an award, of those nominated, 10 received Special Achievement Awards and 15 received Flag Awards.

Ryan Whitely received a Co-op Special Achievement Award, which each included a check for $500.

Allison Bahsen received a Flag Award, which includes a certificate with a mounted flag that has flown on board an Orbiter.

Winners of the AAE 251 ATK Thiokol Propulsion SP.A.C.E. Awards Fall 2001

First Place Team: **Jayleen Guttromson, Jonathan Hadders, Robert Manning, Jeri Metzger, Jeremy Mikkelsen, Benjamin Phillips,** and **Brian Ventre.**

Indiana Space Grant Consortium Winners

Congratulations to **Jayleen Guttromson** and **Robert Manning** for receiving Undergraduate Research Scholarships and **Deanne Clements, Daniel Garcia** and **Talitha Selby** for receiving Graduate Research Fellowships.

Melanie Silosky a junior majoring aeronautical and astronautical engineering, has won a Scholarship awarded in fall 2001 from ***Aerospace States Association*** and has also won a ***2001 Society of Satellite Professionals International*** scholarship funded by Loral Skynet. She was cited for her project entitled "Improved Mass Center Control for Satellite Fuel Tanks."

CSMES Scholarship

Congratulations to **See-Chen Lee, James Pinyerd, Brent Robbins and Kevin Wade** who were awarded NSF CSMES scholarships.

Congratulations to **Chris Peters,** who won first place in the IronCAD student design competition for AY 2000-2001 based on the solid modeling he did for the Silarius 490 project. And to **Jeff Rodrian,** who took an honorable mention for the 2001 SURFCAM parts contest for the work on the Hyperion composite radio controlled aircraft.

2002 Clare Boothe Luce Fellowship – **Belinda Marchand**

2002 - Herbert F Rogers Scholarship - **Luca Bertucelli** and **Kristen Gates**

2002 – Koerner Scholarships **- Jayleen Guttromson, Daniel Grebow, Daniel Brophy, Douglas Crook, Elizabeth Newsome,** and **Paul Brower**

2002 – Magoon Graduate Teaching Award **- Nicholas Czapla, Jason Helms, Chris Peters,** and **Dino Smajlovic.**

2002 - Elmer F. Bruhn Undergraduate Research Assistantship **– Michael Skillen**

2002 - Outstanding Senior Award – **Luca Bertucelli**

2002 - Outstanding Graduate Student Award **- Jason Helms**

2002 Hsu Lo Fellowship – **Hai-Yang Qian**

2001 – 2002 John and Patricia Rich Scholarship – **John Gedmark**

Presentation of Awards at the 2002 National Society of Black Engineers Banquet

Congratulations to:

Olivia Djibo on the Special John Logan Memorial Award

Darryl Johnson on the merit award from Daimler-Chrysler, and the Sophomore Class Award **Conrad Golbov** on the merit award from Lockheed Martin

Presentation of Awards at the 2002 Society of Women Engineers Brunch

Congratulations to:

Jayleen Guttromson for being named the Outstanding Sophomore, Boeing Company

Heather Pawley on a merit award from the Boeing Company

Gina Pieri on a merit award from the Boeing Company

Robin Pinson on a merit award from Alcoa Foundation

Elizabeth Newsome on a merit award from Lockheed Martin

Melanie Silosky on a merit award from United Technologies

OUTREACH HIGHLIGHTS

In its sixth year, Fall Space Day '02 was a rousing success with more than 250 third through eighth graders, and 50 plus teachers and chaperones attending. Astronaut Loren Shriver was the featured speaker. Additionally, the children participated in many interactive lessons, which reinforced basic science and math principles. Students for the Exploration and Development of Space, and students in the American Institute of Aeronautics and Astronautics and Sigma Gamma Tau supported this project.

The School worked with several others on campus to spearhead the "Indiana Working Together for Aerospace Excellence" Conference held in April 2002. Over 50 representatives from industry in Indiana came together with Purdue personnel to discuss the topic.

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 2001 to June 2002

CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

Course Enrollments
School of Aeronautics and Astronautics
2001-2002 Academic Year

A&AE Course	Most Recent Title	Cr.	Fall 2001		Spring 2002	
			Enroll-ment	Instructor	Enroll-ment	Instructor
190	Intr. to Aerosp. Engrg.	2	137	Andrisani		
203-1	Aeromechanics I	3	71	Garrison	69	Garrison
203-2	Aeromechanics I	3	65	Corless		
204-1	Aeromechanics II	3	39	Imbrie	64	Kim
204-2	Aeromechanics II	3			37	Farris
204L	Aeromechanics II Lab.	1	44	Doyle	100	Doyle
251	Intro. Aerosp. Design	3	68	Sullivan	103	Crossley
333	Fluid Mechanics	3	94	Lyrintzis	38	Lyrintzis
333L	Fluid Mechanics Lab.	1	91	Collicott	36	Collicott
334	Aerodynamics	3	25	Blaisdell	86	Blaisdell
334L	Aerodynamics Lab.	1	18	Collicott	47	Collicott
340	Dynamics & Vibration	3	52	Longuski	72	Howell
352	Structural Anal. I	3	78	Weisshaar	33	Sun
352L	Struct. Anal. I Lab.	1	14	Doyle	29	Doyle
364	Control System Analy.	3	40	Frazho	76	Rotea
364L	Control Systems Lab.	1	39	Rotea	39	Rotea
372	Jet Propl. Power Plt.	3			83	Heister
412	Intro. Comp. Fluid Dyn.	3	23	Williams		
415	Aerodynamic Design	3	18	Sullivan		
416	Viscous Flows	3				
421	Flt. Dyn. Control	3	5	Andrisani	45	Corless
439	Rocket Propulsion	3	67	Heister/ Anderson		
440	Spacecr. Attitude Dyn.	3	27	Howell		
450	Spacecraft Design	3	6	Schneider	25	Longuski
451	Design I (Aircraft Design Spr. 01 Sem)	3	11	Andrisani	15	Weisshaar
453	Matr. Meth. Aerosp. Struc.	3			22	Doyle
454	Design Aerosp. Struct.	3	14	Grandt		

A&AE Course	Most Recent Title	Cr.	Fall 2001		Spring 2002	
			Enroll-ment	Instructor	Enroll-ment	Instructor
490A	Flight Testing	3			15	Andrisani
490E	Intro. Satellite Sys.	3				
490F	Engr. Syst. Analysis	3	26	Frazho	54	Frazho
490G	Zero Grav. Flt. Exper.	3				
490S	Satellite Design	3			15	Crossley
490T	Design Build Test	3				
507	Principles of Dynam.	3	32	Longuski		
508	Optimization Aerospa. Engr.	3			42	Longuski
511	Intro. Fluid Mech.	3	21	Blaisdell		
512	Computational Aerodyn.	3			35	Williams
514	Intermediate Aerodyn.	3			36	Lyrintzis
518	Low-Gravity Fluid Dyn.	3	18	Collicott		
519	Satellite Aero & Entry	3			21	Schneider
532	Orbit Mechanics	3	21	Howell		
538	Airbreathing Prop.	3	31	Lawless		
539	Adv. Rocket Prop.	3			47	Heister
539	Adv. Rocket Prop.	3			6	Heister
546	Aero Struct Dyn Stab.	3	17	Doyle		
547	Exper. Stress. Analy.	3				
552	Nondest. Eval. Struct. Matls.	3			25	Grandt
553	Elasticity Aerosp. I	3	19	Farris		
554	Fatigue Struct. & Matrl.	3	23	Grandt		
554Q	Fatigue Struct. & Matrl.	3	15	Grandt		
555	Mechanics Comp. Matl.	3			29	Sun
556	Aeroelasticity	3			18	Weisshaar
558	Finite Element Meth. in Aerospace Structures	3	32	Kim		

A&AE Course	Most Recent Title	Cr.	Fall 2001		Spring 2002	
			Enroll-ment	Instructor	Enroll-ment	Instructor
564	System Anal. & Synth.	3	19	Corless		
565	Guidance Aerospace Veh.	3			14	Andrisani
567	Intro. Appl. Stoch. Proc	3			9	Frazho
590A	Rocket Combuster DBT	3			22	Anderson
590E	Satellite Design	3			5	Crossley
590F	Des. Thes. Meth. Aerosp. Sys.	3	24	Crossley		
590G	Intr. Satellite Nav. & Posit.	3	24	Garrison		
590K	Adv. Energy Convers.	3	13	Rusek		
590T	Design Build Test	3				
615	Aeroacoustics	3				
626	Turb. & Turb. Modeling	3				
630	Stability of Free Surf.	3				
632	Adv. Orbital Dyn.	3			10	Howell
646	Elastic Wave Propagation	3			6	Doyle
654	Fracture Mechanics	3				
655	Adv. Topics Convers.	3				
666	Nonlin. Dyn. Syst. Cont.	3				
690T	Lam Turb. Trans.	3	7	Schneider		
698	M.S. Thesis Research	--				
699	Ph.D. Thesis Research	--				

Aerospace Engineering Requires a Multidisciplinary Curriculum

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

Aerodynamics	*Dynamics and Control*	*Propulsion*	*Structures and Materials*
Required Undergraduate			
333-Fluid Mechanics & Lab. 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 660-Operator Methods		558-Finite Element 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 2001-2002 Academic Year

Semester	Statistic	Three-Credit Courses				One-Credit Laboratory Courses
		100, 200, 300, 400, Levels	500 Levels	600 Level	All Levels	
Fall of 2001	No. of classes offered	18	13	1	32	5
	Total Enrollment	866	309	1	1182	204
	Average number of students per class	48	24	7	37	41
Spring of 2002	No. of classes offered	17	12	2	31	5
	Total enrollment	852	309	16	1177	251
	Average number of students per class	50	26	8	38	50

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

STAFF FOR THE 2001-2002 ACADEMIC YEAR

Administrative Assistants
L. Flack, T. Moore

Business Office
D. Horton, L. Dispennett, J. Jackson, S. Wagner

Clerical
P. Kerkhove, S. Wise

Director of Communications and Development
T. Bobillo

Communications Administrator
A. Broughton

Professional/Technical
M. Chadwell, L. Crain, I. Ellis, G. Hahn, S. Meyer, D. Reagan, E. Weaver, R. Snodgrass, J. Younts