School of Aeronautics and Astronautics

Purdue University

Research Report
2000 - 2001
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 of Aeronautics and Astronautics continued its push for excellence with a year that was successful by any measure. AAE maintains a commitment to be a world-class leader in aerospace engineering education and research. Our faculty is dedicated to preparing young men and women to be leaders in aerospace engineering, and our students and graduates are proving that our goal is being achieved. Others observe our success, as well. The *U.S News and World Report* ranked our graduate program sixth in the Spring 2001 in the nation and our undergraduate program fifth in Fall 2000.

Undergraduate enrollment rose by 23% this past year and projected enrollment for the Fall of 2001 indicates that we have *doubled in four years*. During the academic year 2000-2001, 60 students earned their Bachelor of Science degree, 27 earned their Master of Science degree, and 17 earned their Doctor of Philosophy degrees. Again, this year, the School and its faculty served as an aerospace resource to local, state and national media. During the academic year, nearly two dozen stories highlighting our faculty and students appeared in local and state media – Professor Steven Collicott's student efforts with low gravity flight experiments, Professor James Longuski's design class proposing a mission to Mars, student success in the AGATE national design competition, Professor John Rusek's research with fuel cells, and Purdue as a focus of *Aviation Week and Space Technology* and *space.com* publications on aerospace job opportunities to name a few.

The faculty continued efforts to augment the Astronautics portion of the curriculum. The Center for Satellite Engineering again offered the interdisciplinary course entitled "Introduction to Satellite Engineering" involving professors from AAE, ECE, ME and Biology. Professor Kathleen Howell's AAE 440 course entitled "Spacecraft Attitude Dynamics" was approved as a required course for our students specializing in Astronautics. Professors Steve Heister and John Rusek established a "Propulsion System Design" course, Professor William Crossley introduced a "Satellite Design" course and Professor James Garrison introduced a course entitled "Introduction to Satellite Navigation and Positioning."

Other curriculum highlights are that Professor William Crossley taught AAE 590G, Multidisciplinary Design Optimization as part of the Purdue Continuing

Engineering Education Program for the 2000-2001 academic year. In 2001-2002, Professor A. F. Grandt, Jr. will teach AAE 554, Fatigue of Structures and Materials in CEE during the Fall and Professor Stephen D. Heister will teach AAE 539, Advanced Rocket Propulsion in CEE during the spring.

Also, following the request from many constituents that we teach our students systems engineering, the curriculum committee developed an outline for a course entitled "Engineering Systems Analysis" that will be taught for the first time in the Fall of 2001.

We continue to develop relationships with international universities. The formal exchange program with Bristol University is working well with students exchanging in both directions and a new agreement with Ecole Superior de Techniques Aerospatial et Construction Automobile (ESTACA) in Paris will involve exchanges this Fall.

ENROLLMENT AND DEGREES AWARDED

The School had 292 undergraduate students (excluding freshmen) beginning the Fall of 2000 representing a 23% increase over 1999. Graduate enrollment was 144, with 76 students in the M.S. Program and 68 in the Ph.D. program. A summary of degrees awarded is given below for the past five years. Master's and Ph.D. theses published during the 2000-01 academic year are summarized in the Graduate Theses section.

Purdue University remains an attractive destination for international students. This past school year saw Purdue lead all public research institutions in total number of international students enrolled. This trend is evident at AAE, also, with international students comprising 15% of undergraduates, 40% of Master's level, and 73% of Ph.D. level students.

Degrees Awarded
School of Aeronautics & Astronautics

Year	96-97	97-98	98-99	99-00	00-01
B.S.	48	40	43	43	60
M.S.	30	19	21	35	27
Ph.D.	17	14	11	9	17

DEVELOPMENT HIGHLIGHTS

AlliedSignal (now Honeywell), The Boeing Company, Hughes Space and Communications Company (now Boeing), Lockheed-Martin, Northrop Grumman, Rolls-Royce, Thiokol Corporation and TRW supported the Industrial Affiliates Program (IAP) this year. In its fifth year, the School's Industrial Advisory Council

(IAC) continued its bi-annual meeting schedule, meeting both in October and April. The IAC is pleased with the Engineering (EMFP) and President Jischke's plans. They look forward to assisting the School in its Strategic Planning.

The 2nd William E. Boeing Distinguished Lecture was given by General Roy D. Bridges, Director of NASA Kennedy. The 3rd Lecture was given by Dr. Jurgen Weber, Chairman of the Executive Board of Deutsch Lufthansa AG at 4:00 p.m. on September 5, 2001, in Fowler Hall.

Several planned gifts were made to the School this academic year including large gifts from 1999 OAEs Dick Freeman and Mike Hua. 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.

The School named seven OAEs in the Fall of 2000: Mark K. Craig (B.S.A.E. '71), Edward G. Dorsey (B.S.A.E. '49), Leslie A. Hromas (M.S.A.E. '53, Ph.D. '57), Kenneth O. Johnson (B.S.A.E. '50), Kenneth G. Miller B.S.A.E. '66), Daniel P. Raymer (B.S.A.E. '76, M.S.A.E. '76), and Charles R. Saff (B.S.A.E. '71).

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2000 are given in the "Faculty Summary" section of this report. Only documents that actually appeared in print during 2000 are listed. Note that 1 book, 50 journal articles or book chapters, and 110 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 2000-01 academic year, 92 students were enrolled in the Cooperative Engineering Program with the 25 companies listed below. This popular program is limited only by the number of industry positions available. About 40 in 142 new applicants received appointments this year. Many other students gain industrial experience through internships.

Co-Op Companies
School of Aeronautics and Astronautics
July 1, 2000-June 30, 2001

Company	Location	Number of A&AE Co-op Students
Aerospace Corporation	Los Angeles, CA	1
Airborne Express	Wilmington, OH	4
American Trans Air Engineering	Indianapolis, IN	0
ATA Engineering Inc.	San Diego, CA	2
Atlantic Research Corporation	Knoxville, TN	0
Ball Aerospace & Tech. Corp.	Boulder, CO	8
Boeing Satellite Systems	Los Angeles, CA	6
Delta Airlines	Atlanta, GA	8
General Electric Aircraft Engines	Cincinnati, OH	10
NASA-Ames Research Center	Moffett Field, CA	0
NASA-Dryden Flight Research Center	Edwards, CA	4
NASA-Glenn	Cleveland, OH	1
NASA-Goddard	Greenbelt, MD	2
NASA-Johnson Space Center	Houston, TX	16
NASA-Kennedy Space Center	Kennedy Space Ctr., FL	2
NASA-Langley Research Center	Hampton, VA	1
Naval Research Laboratory	Washington, DC	0
Raytheon E-Systems	Greenville, TX	0
Rockwell International Corporation	Cedar Rapids, Iowa	4
Rolls-Royce	Indianapolis, IN	4
Structural Analysis Engineering	Cincinnati, OH	5
Structural Dynamics Research Center	Milford, OH	9
United Parcel Service (Air Group)	Louisville, KY	0
United Technologies Pratt & Whitney	W. Palm Beach ,FL	2
Wright-Patterson AFB	Dayton, OH	3

FACULTY FOR THE 2000-01 ACADEMIC YEAR

Aerodynamics

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, applied optics.

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

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

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

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

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

Dynamics and Control

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

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

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

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

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

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

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

Propulsion

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

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

Structures & Materials

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

J. F. Doyle, Professor, Ph.D., Illinois, 1977, structural dynamics, experimental mechanics, photomechanics, 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, aging aircraft.

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

C. T. Sun, Professor, Ph.D., Northwestern, 1967, composites, fracture and fatigue, structural dynamics.

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

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 also currently is 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 RS/6000, Silicon Graphics, and Sun Microsystems computers. Cluster computing, using single and dual Intel Pentium Pro and Pentium II systems, is a recent addition, complementing the main Sun Microsystems compute servers. Purdue also owns a 272 node IBM SP-2.

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 Grissom Hall and at two major remote campus facilities: the Maurice Zucrow Laboratory (MZL), and the Aerospace Sciences Laboratory (ASL).

The ***Aerospace Post-Processing and Visualization Laboratory*** contains a variety of high-end computational assets. Several Silicon Graphics workstations are available for general computing, graphical visualizations, and digitization of images

on videotape. In addition, a cluster of dual-chip Pentium machines running in a LINUX environment provides a resource for parallel computations of a significant scale.

The ***Propulsion and Power 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 will be outfitted to conduct turbine flow measurements using simulated PV drivers and catalytic chamber effluent. In local proximity is a dedicated oxidizer storage building, and a dedicated explosive/propellant storage bunker, rated for Class 1.1 materials.

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 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.

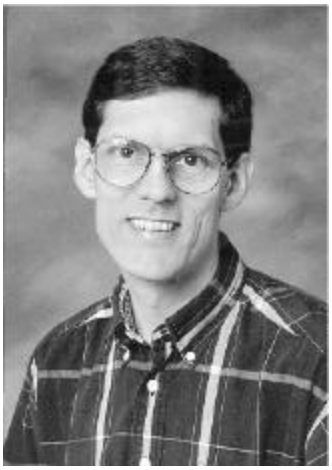
The **Structural Dynamics Laboratory** has the latest equipment for recording ultra-dynamic events. Major equipment includes Norland and Nicolet digital recorders, a one-million-frame-per-second dynamic camera, impact gun, and various computer peripherals for data acquisition. The primary research interest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

FACULTY SUMMARY

AERODYNAMICS



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.

Publications

Koutsavdis, E. K., Blaisdell, G. A., and Lyrintzis, A. S., "On the Use of Compact Schemes with Spatial Filtering in Computational Aeroacoustics," *AIAA Journal*, Vol. 38, No. 4, Apr. 2000, pp. 713-716.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Lyrintzis, A. S., Blaisdell, G. A., and Koutsavdis, E. K., "On the Development of a Jet Noise Prediction Methodology," Second Year Progress Report, NASA Glenn Research Center Grant NAG3-2095, March 2000, 89 pages.

Blaisdell, G. A., "The Effect of Filtering on Large Eddy Simulation of Decaying Isotropic Turbulence," Final Report, AFRL Summer Research Program, Oct. 20, 2000, 20 pages.

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

Schmisseur, J. D., Collicott, S. H., and Schneider, S. P., "Laser Generated Localized Free Stream Perturbations in Supersonic/Hypersonic Flows," *AIAA Journal,* Vol. 38, No. 4, Apr. 2000, pp. 666-671.

Henry, M., and Collicott, S. H., "Visualization of Internal Flow in a Cavitating Slot Orifice," *Atomization and Sprays,* Vol. 10, No. 6, Nov./Dec. 2000, pp. 545-562.

Ambrose, J., Yendler, B., and Collicott, S. H., "Modeling to Evaluate a Spacecraft Propellant Gauging System," *Journal of Spacecraft and Rockets,* Vol. 37, No. 6, Nov./Dec. 2000, pp. 833-835.

Conference Proceedings, Presentations, Invited Lectures and Reports

Salyer, T. R., Collicott, S. H., and Schneider, S. P., "Feedback Stabilized Laser Differential Interferometry for Supersonic Blunt Body Receptivity Experiments," AIAA paper 2000-0846, *38th AIAA Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 2000, 11 pages.

Collicott, S. H., "Initial Experiments on Reduced-Weight Propellant Management Vanes," AIAA paper 2000-3442, *36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,* Huntsville, AL, July 2000, 11 pages.

Li, H., Bunnell, R., Collicott, S. H., and Heister, S. D., "Internal Flow Visualization and CFD in High-Pressure Diesel Fuel Injectors," *9th International Symposium on Flow Visualization,* Edinburg, Scotland, Aug. 2000, 10 pages.

ANASTASIOS S. LYRINTZIS
1994
Associate 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.

On the Development of Supersonic Jet Noise Prediction Methodology, Principal Investigators: G. A. Blaisdell and A. S. Lyrintzis; Sponsor NASA Lewis

A new Computational Aeroacoustics (CAA) methodology for accurate prediction of supersonic jet noise from first principles will be developed. First, a three-dimensional Large Eddy Simulation (LES) code based on the dynamic subgrid scale model will be developed. Then Kirchhoff's method will be employed for the extension of Computational Fluid Dynamics (CFD) results to the far-field. Kirchhoff's 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.

Parallel Computing Techniques for Rotorcraft CFD Codes, Prinicipal Investigator, Anastasios Lyrintzis; Sponsor: Purdue Research Foundation

We are working on the modification of unsteady Navier Stokes codes for application on massively parallel and distributed computing environments. In our previous work we have worked with the Euler mode of the Navier-Stokes code TURNS (Transonic Unsteady Rotor Navier Stokes) that has been used for an accurate description of rotorcraft aerodynamics. For the efficient implementation of TURNS (Navier Stokes mode) on massively parallel and distributed computing systems, several algorithmic changes should be developed. We propose here:

1) Modification of the implicit operator LU-SGS to a parallel version for the Navier Stokes equations.

2) Implementation of a Newton-Krylov method with the use of preconditioned conjugate gradient-type (Krylov subspace) methods for the solution of the linear systems resulting from the linearization (Newton's step) at each time step. The modified parallel LU-SGS from step 1 will be used as a preconditioner.

3) Extension of the methodology for overset grids using the state-of-the-art OVERFLOW code.

Since the MPI (Message Passing Interface) environment will be used we expect that our algorithms will be portable several parallel and distributed environments. We expect that efficient parallel processing will make TURNS and OVERFLOW more attractive for the rotorcraft industry. The parallel algorithms proposed would be easily implemented in other Navier Stokes codes as well.

Publications

Lyrintzis, A. S., Jameson, J. R., and Koutsavdis, E. K., "A Study of Rotorcraft Blade-Tip Shape Noise Characteristics," Journal of the American Helicopter Society, Vol. 45, No. 1, Jan. 2000, pp. 54-57.

Koutsavdis, E. K., Blaisdell, G. A., and Lyrintzis, A. S., "On the Use of Compact Schemes with Spatial Filtering in Computational Aeroacoustics," *AIAA Journal*, Vol. 38, No. 4, Apr. 2000, pp. 713-716.

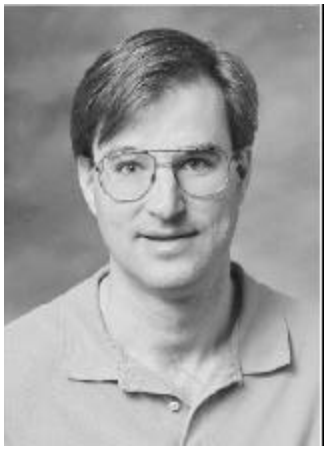
Caradonna, F., Kitaplioglu, C., McCluer, M., Baeder, J., Leishman, G., Berezin, C., Visintainer, J., Bridgeman, J., Burley, C., Epstein, R., Lyrintzis, A., Koutsavdis, E., Rahier, G., Delrieux, Y., Rule, J., and Bliss, D., "A Review of Methods for the Prediction of BVI Noise," *Journal of the American Helicopter Society*, Vol. 45, No. 4, Oct. 2000, pp. 303-320.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Ekici, K., and Lyrintzis, A. S., "Parallel Computing Techniques for Rotorcraft Aerodynamics," AIAA paper 2000-2617, presented at the *AIAA Fluids 2000 Meeting*, Denver, CO, June 2000.

Lyrintzis, A. S., “Integral Methods for Jet Aeroacoustic Predictions,” presented at the *Jet Noise Workshop*, NASA Glenn Research Center, Nov. 2000.

Lyrintzis, A. S., Blaisdell, G. A., and Koutsavdis, E. K., “On the Development of a Jet Noise Prediction Methodology,” Second Year Progress Report, NASA Glenn Research Center Grant NAG3-2095, March 2000, 89 pages.



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 has been constructed at Purdue. Quiet flow has been demonstrated to length Reynolds

numbers of 400,000 (AIAA Journal, April 1995, p. 688). Localized hot-spot disturbances are repeatably generated by a pulsed Nd:YAG laser in order to generate repeatable wave packets in the flow, and surface perturbations are being generated by a glow perturber. Perturbations are being measured using hot wires, high-sensitivity laser differential interferometry, and arrays of surface hot films.

A new 18-inch stainless-steel Ludwieg tube has been completed for use with an 9.5-inch quiet-flow Mach-6 test section, operations began in April 2001. Quiet-flow operation to a length Reynolds number of 13 million is projected (AIAA Paper 98-0547), although no quiet-flow has yet been achieved. 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 will enable testing with larger models and thicker boundary layers.

Publications

Schmisseur, J. D., Collicott, S. H., and Schneider, S. P., "Laser Generated Localized Free Stream Perturbations in Supersonic/Hypersonic Flows," *AIAA Journal*, Vol. 38, No. 4, Apr. 2000, pp. 666-671.

Schneider, S. P., "Laminar-flow Design for a Mach-6 Quiet-Flow Wind Tunnel Nozzle," *Current Science,* Vol. 79, No. 6, Sept. 25, 2000, pp. 790-799.

Conference Proceedings, Presentations, Invited Lectures and Reports

Ito, T., Randall, L. A., and Schneider, S. P., "Effect of Freestream Noise on Roughness-Induced Boundary-Layer Transition for a Scramjet Inlet," *38th Aerospace Sciences Meeting and Exhibit,* AIAA paper 2000-0284, Jan. 10-13, 2000, Reno, NV.

Schneider, S. P., "Fabrication and Testing of the Purdue Mach-6 Quiet-Flow Ludwieg Tube," *38th Aerospace Sciences Meeting and Exhibit,* AIAA paper 2000-0295, Jan. 10-13, 2000, Reno, NV.

Salyer, T. R., Collicott, S. H., and Schneider, S. P., "Feedback Stabilized Laser Differential Interferometry for Supersonic Blunt Body Receptivity Experiments," AIAA paper 2000-0846, *38th AIAA Aerospace Sciences Meeting and Exhibit,* Jan. 2000, Reno, NV, 11 pages.

Schneider, S. P., "Initial Shakedown of the Purdue Mach-6 Quiet-Flow Ludwieg Tube," *21st AIAA Aerodynamic Measurement Technology and Ground Testing Conference,* AIAA paper 2000-2592, June 19-22, 2000, Denver, CO.

Schneider, S. P., "Effects of High-Speed Tunnel Noise on Laminar-Turbulent Transition," *21st AIAA Aerodynamic Measurement Technology and Ground Testing Conference,* AIAA paper 2000-2205, June 19-22, 2000, Denver, CO.

Ito, Takeshi and Schneider, S. P., "Supersonic Boundary Layer Transition Research in Purdue Ludwieg Tube," presented at the 32nd Fluid Dynamics Symposium, (in Japanese) Fukuoka, Japan 2000.

Schneider, S. P., "Development of a Mach-6 Quiet-Flow Wind Tunnel for Transition Research," *Proceedings of the IUTAM Symposium on Laminar-Turbulent Transition*, Springer-Verlag, Berlin, 2000, pp. 427-432.

Schneider, S. P., "Hypersonic Laminar-Turbulent Transition: The Need for NATO Cooperation," presented at the DLR, Goettingen, Germany, May 8, 2000.

Schneider, S. P., "Hypersonic Laminar-Turbulent Transition at Purdue University," presented at the Institute for Aerodynamics and Gasdynamics, Univ. of Stuttgart, Germany, May 12, 2000.

Schneider, S. P., "The Purdue Mach-6 Quiet-Flow Ludwieg Tube: A Facility for Research in Laminar-Turbulent Transition," presented at Notre Dame University, Nov. 3, 2000.

Schneider, S. P., "Laminar-Turbulent Transition in Hypersonic Boundary Layers: Development of a High-Reynolds Number Mach-6 Quiet-Flow Testing Capability," final report, AFOSR DURIP Grant F49620-98-1-0284, AFRL-SR-BL-TR-00-0025, Feb. 2000, 9 pages, AD-B251202.

JOHN P. SULLIVAN
1975
Professor

Degrees

B. S., University of Rochester, Mechanical & Aerospace Sciences (with honors), 1967
M. S., Massachusetts Institute of Technology, Aeronautical Engineering, 1969
Sc.D., Massachusetts Institute of Technology, Aeronautical Engineering, 1973

Interests

Experimental aerodynamics
Laser instrumentation
Luminescent sensors for temperature and pressure measurements

Research Areas

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

1. High lift systems
2. Suction/blowing airfoils

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

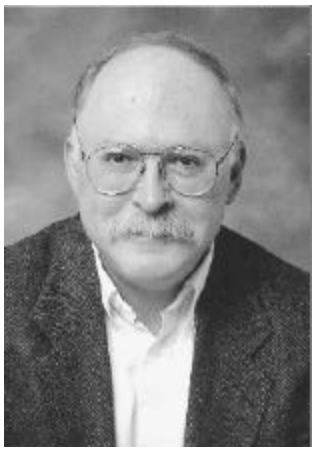
1. Wind tunnels - low speed to hypersonic
2. Gas turbine engines
3. Flight tests

Conference Proceedings, Presentations and Invited Lectures

Sakaue, Hirotaka, and Sullivan, J. P., "Fast Response Time Characteristics of Anodized Aluminum Pressure Sensitive Paint," presented at the *38th Aerospace Sciences Meeting and Exhibit,* AIAA paper #200-0506, Reno, NV, Jan. 11-14, 2000.

Sullivan, J. P., and Watkins, W., "A Design/Build/Test Environment for Aerospace Education," presented at the *38th Aerospace Sciences Meeting and Exhibit,* AIAA paper # 2000-0052, Reno, NV, Jan. 11-14, 2000.

Gregory, J. W., Sakaue, H., Sullivan, J. P., and Raghu, S., "Porous Pressure Sensitive Paint for Unsteady Flow Fields," *8th Pressure Sensitive Paint Workshop,* NASA Langley Research Center.



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

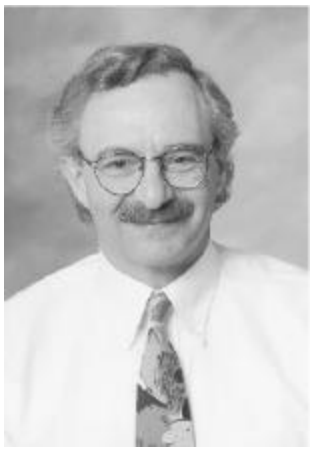
The determination of aeroelastic stability and forced response characteristics of flight vehicles requires methods for predicting the unsteady aerodynamic loads that are induced by structural deformation and/or free stream disturbances. Current research is directed at developing such methods for transonic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

Publications

Gick, R. A., Williams, M. H., and Longuski, J. M., "Periodic Solutions for Spinning Asymmetric Rigid Bodies with Constant Principal-Axis Torque," *Journal of Guidance, Control, and Dynamics,* Vol. 23, No. 5, Sept.-Oct. 2000, pp. 781-788.

DYNAMICS & CONTROL



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

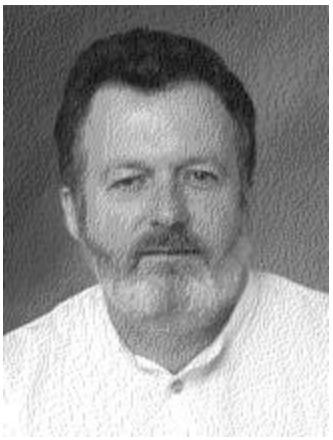
Extensive experience in experimental methods in the study of vehicle dynamics and control has focused teaching and research on practical and important aerospace problems in four areas. First is the area of estimation theory, where new estimation algorithms have been developed using the partitioning approach. 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

Ryu, S., and Andrisani, II, D., "Longitudinal Flying Qualities Prediction for Nonlinear Aircraft," *AIAA Atmospheric Flight Mechanics Conference*, AIAA paper #2000-3989, Denver, CO, Aug. 14-17, 2000.

Ryu, S., and Andrisani, II, D., ”Controller Design for Longitudinal Flying Qualities Improvement in Nonlinear Aircraft,” *AIAA Atmospheric Flight Mechanics Conference,* AIAA paper #2000-3988, Denver, CO, Aug. 14-17, 2000.

Andrisani, II, D., “Progress Report for the Indiana Space Grant Consortium for the period 11/01/99 – 05/31/01,” NASA Grant NTG5-40043, Dec. 15, 2000.



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

Corless, M., and Leitmann, G., "Analysis and Control of a Communicable Disease," Nonlinear Analysis: Theory, Methods and Applications, Vol. 40, No. 1-8, 2000, pp. 145-172.

Sultan, C., Corless, M., and Skelton, R. E., "A Tensegrity Flight Simulator," *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 23, No. 6, 2000, pp. 1055-1064.

Conference Proceedings, Presentations, Invited Lectures and Reports

Pancake, T., Corless, M., and Brockman, M., "Analysis and Control of Polytopic Uncertain/Nonlinear Systems in the Presence of Bounded Disturbance Inputs," *American Control Conference*, Chicago, IL, June 28-30, 2000.

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

Smith, M. J., and Frazho, A. E., "On Interpolation Problems in the Complex Right Half Plane," *Operator Theory: Advances and Applications*, Vol. 115, 2000, pp. 255-267.

Conference Proceedings, Presentations, Invited Lectures and Reports

Frazho, A. E., "State Space Methods, Nevanlinna-Pick Interpolation and Dilation Theory," seminar presented at the Vrije Universiteit, Amsterdam, Sept. 2000.

Frazho, A. E., "State Space Methods for Positive Real Interpolation Problems," seminar presented at the International Workshop on Operator Theory and Applications, Furo, Portugal, Sept. 2000.

Frazho, A. E., “State Space Algorithmns for Tangential Nevanlinna-Pick Interpolations,” seminar presented at Vrije Universiteit, Amsterdam, for the conference associated with the Honorary Doctorate for Professor Foias, Oct. 2000.

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

Garrison, J. L., and Katzberg, S. J., "The Application of Reflected GPS Signals to Ocean Remote Sensing," *Remote Sensing of Environment*, Vol. 73, 2000, pp. 175-187.

Komjathy, A., Zavorotny, V., Axelrad, P., Born, G., and Garrison, J. L., "GPS Signal Scattering from Sea Surface: Wind Speed Retrieval Using Experimental Data and Theoretical Model," *Remote Sensing of Environment*, Vol. 73, 2000, pp. 162-175.

Moreau, M., Axelrad, P., Garrison, J. L., and Long, A., "GPS Receiver Architecture and Expected Performance for Autonomous Navigation in High Earth Orbits," *Navigation*, Vol. 47, No. 3, Fall 2000, pp. 191-204.

Conference Proceedings, Presentations, Invited Lectures and Reports

Garrison, J. L., Katzberg, S. J., Zavorotny, V. U., and Masters, U., "Comparison of Sea Surface Wind Speed Estimates from Reflected GPS Signals with Buoy Measurements," *IEEE 2000 International Geoscience and Remote Sensing Symposium*, Honolulu, HI, July 24-28, 2000.

Zavorotny, V. U., Voronovich, A. G., Katzberg, S. J., Garrison, J. L., and Komjathy, A., "Extraction of Sea State and Wind Speed from Reflected GPS Signals: Modeling and Aircraft Measurements," *IEEE 2000 International Geoscience and Remote Sensing Symposium*, Honolulu, HI, July 24-28, 2000.

Long, A., Kelbel, D., Lee, T., Garrison, J., and Carpenter, J. R., "Autonomous Navigation Improvements for High-Earth Orbiters Using GPS," *15th International Symposium Spaceflight Dynamics*, Biarritz, France, June 26-30, 2000.

Garrison, J. L., Ruffini, G., Ruis, A., Cardellach, E., Masters, D., Armatys, M., and Zavorotny, V. U., "Preliminary Results from GPS-Reflections Mediterranean Balloon Experiment (GPSR-MEBEX)," *6th International Conference on Remote Sensing for Marine and Coastal Environments*, Charleston, SC, May 1-3, 2000.

Katzberg, S. J., and Garrison, J. L., "Wind Speed Retrieval of GPS Surface Reflection Data Using a Matched Filter Approach," *6th International Conference on Remote Sensing for Marine and Coastal Environments*, Charleston, SC, May 1-3, 2000.

Armatys, M., Masters, D., Komjathy, A., Axelrad, P., and Garrison, J. L., "Exploiting the GPS Signal for Application as an Oceanographic Remote Sensing Tool," *Institute of Navigation: National Technical Meeting 2000*, Anaheim, CA, Jan. 26-28, 2000.

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

Ely, T. A., and Howell, K. C., "East-West Stationkeeping of Satellite Orbits with Resonant Tesseral Harmonics," *Acta Astronautica,* Vol. 46, No. 1, Jan. 2000, pp. 1-15.

Conference Proceedings, Presentations, Invited Lectures and Reports

Howell, K. C., Marchand, B. G., and Lo, M. W., "Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems," *AAS/AIAA Space Flight Mechanics Conference,* Clearwater, FL, Jan. 2000, (best paper award for the Conference).

Williams, K. E., Barden, B. T., Howell, K. C., Lo, M. W., and Wilson, R. S., "GENESIS Halo Orbit Stationkeeping Design," *International Symposium, Spaceflight Dynamics,* Biarritz, France, June 2000.

Howell, K. C., and Guzman, J. J., "Spacecraft Trajectory Design in the Context of a Coherent Restricted Four-Body Problem with Application to the MAP Mission," *IAF 51st International Astronautical Congress,* Rio de Janeiro, Brazil, Oct. 2000.

Howell, K. C., "Formation Flight Near Libration Points: State-of-the-Art," NASA Working Group, Jet Propulsion Laboratory, Pasadena, CA, May 2000.

Howell, K. C., "Flying Formations Near Quasihalo Orbits," *SIAM Pacific Rim Dynamical Systems Conference,* Maui, Hawaii, Aug. 2000.

Howell, K. C., "The Lagrange Points and the Exploration of Space: Fundamental Dynamics," special NASA working group, presentation to NASA Headquarters Personnel, Jet Propulsion Laboratory, Pasadena, CA, Oct. 2000.

Howell, K. C., "Fundamental Motions in Multi-Body Regimes with Application to Spacecraft Trajectories," Engineering Colloquium, NASA Goddard Space Flight Center, Greenbelt, MD, Nov. 2000.

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

Tragesser, S. G., and Longuski, J. M., "Modeling Issues Concerning Motion of the Saturnian Satellites," *Journal of the Astronautical Sciences*, Vol. 47, Nos. 3 and 4, July-Dec. 1999 (distribution 2000), pp. 275-294.

Sims, J. A., Longuski, J. M., and Patel, M. R., "Aerogravity-Assist Trajectories to the Outer Planets and the Effect of Drag," *Journal of Spacecraft and Rockets*, Vol. 37, No. 1, Jan.-Feb. 2000, pp. 49-55.

Javorsek, II, D., and Longuski, J. M., "Velocity Pointing Errors Associated with Spinning Thrusting Spacecraft," *Journal of Spacecraft and Rockets*, Vol. 37, No. 3, May-June 2000, pp. 359-365.

Gick, R. A., Williams, M. H., and Longuski, J. M., "Periodic Solutions for Spinning Asymmetric Rigid Bodies with Constant Principal-Axis Torque," *Journal of Guidance, Control, and Dynamics*, Vol. 23, No. 5, Sept.-Oct. 2000, pp. 781-788.

Bonfiglio, E. P., Longuski, J. M., and Vinh, N. X., "Automated Design of Aerogravity-Assist Trajectories," *Journal of Spacecraft and Rockets*, Vol. 37, No. 6, Nov.-Dec. 2000, pp. 768-775.

Petropoulos, A. E., Longuski, J. M., and Bonfiglio, E. P., "Trajectories to Jupiter via Gravity Assists from Venus, Earth, and Mars," *Journal of Spacecraft and Rockets*, Vol. 37, No. 6, Nov.-Dec. 2000, pp. 776-783.

Patents (pending)

Longuski, J. M., and Javorsek, II, D., "Method for Velocity Precision Pointing in Spin-Stabilized Spacecraft or Rockets," U. S. patent application #09/935,225, Aug. 9, 2000.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Johnson, W. R., and Longuski, J. M., "Design of Aerogravity-Assist Trajectories," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4031, Denver, CO, Aug. 14-17, 2000.

Vinh, N. X., Johnson, W. R., and Longuski, J. M., "Mars Aerocapture using Bank Modulation," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4424, Denver, CO, Aug. 14-17, 2000.

Okutsu, M., and Longuski, J. M., "Mars Free Returns via Gravity Assist from Venus," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4030, Denver, CO, Aug. 14-17, 2000.

Strange, N. J., and Longuski, J. M., "A Graphical Method for Gravity-Assist Trajectory Design," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4030, Denver, CO, Aug. 14-17, 2000.

Heaton, A. F., Strange, N. J., Longuski, J. M., and Bonfiglio, E. P., "Automated Design of the Europa Orbiter Tour," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4034, Denver, CO, Aug. 14-17, 2000.

Petropoulos, A. E., and Longuski, J. M., "Automated Design of Low-Thrust Gravity-Assist Trajectories," *AIAA/AAS Astrodynamics Specialist Conference,* AIAA paper #2000-4033, Denver, CO, Aug. 14-17, 2000.

Petropoulos, A. E., and Longuski, J. M., "Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions," progress report #1, Low-Thrust Gravity-Assist Study, Jet Propulsion Laboratory, JPL contract no. 1211514, California Institute of Technology, Pasadena, CA, Dec. 2000.

Longuski, J. M., "Adventures at Jupiter," presented to Purdue Retirees Program Participants, June 5, 2000.

MARIO A. ROTEA
1990
Associate 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

Estimation and Control Algorithms (sponsored by NSF, United Technologies Corporation, the Boeing Company, and GE.)

Active control systems integrate diverse hardware and software to provide increased performance and versatility over passive solutions. The development of an active control system requires the integration of actuators, sensors, and estimation and control algorithms. The estimation and control algorithms get information from the sensors and decide how to use the actuators for best system performance. In this project we develop theory, methodology, and software, for the design and implementation of estimation and control algorithms with multiple actuators and sensors. Our methods and tools integrate sophisticated theory with commercial and public domain software for the creation of algorithms with minimal development effort. These advanced methods are part of the graduate curriculum at Purdue University. We have successfully applied these techniques to several emerging technology areas including active suppression of chatter in industrial machine tools, active vibration reduction in civil engineering structures and helicopter rotor systems, and flutter suppression in turbomachinery.

Fast Algorithms for Prediction of Worst-Case Frequency Response Functions (sponsored by NSF and United Technologies Corporation)

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 and optimize vibratory responses in new compressor rotor designs which, to realize weight and aerodynamic benefits, are becoming more and more structurally flexible and exhibit large number of vibration modes in the operating envelope. In applications one is interested in calculating the largest, or worst-case, frequency response that results when several parameters are perturbed simultaneously. Technically, the problem is that of maximizing a nonlinear function of unknown parameters or perturbations given a model of the system. Due to the large number of parameters, on the order of hundreds for real rotors, general-purpose algorithms are computationally expensive and do not run in practical times. This research is aimed at developing improved algorithms to calculate the worst-case frequency response. We have recently shown that utilization of the underlying problem structure leads to an algorithm whose cost is O(N) smaller than the cost of general-purpose algorithms, where N is the number of parameters. This result indicates a cost reduction proportional to N, which for problems with hundreds of parameters is substantial.

Analysis and Design of Extremum Seeking Algorithms (sponsored by NSF and the Xerox Corporation)

On-line optimization is necessary to seek optimal control parameters in many application areas such as active 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 have recently obtained new funding from NSF to design improved on-line optimization algorithms. The technical goal of this work is the derivation of 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 most real problems. The Xerox Corporation is also partially funding this effort to help us develop advanced on-line optimization algorithms to improve image quality in modern printing systems.

Parameter Estimation in Air Vehicles (sponsored by U.S. Army YPG and NASA)

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 focus is on Prediction Error Methods for parameter estimation. The project is motivated by the possibility of identifying a technique that successfully extracts aerodynamic parameters from flight test data in guided parachute systems.

Publications

Rotea, M. A., "Design of Static Cascade Compensators using Generalized Singular Values," *AIAA Journal of Guidance, Navigation, and Control*, Vol. 23, No. 2, March-April 2000, pp. 200-205.

Conference Proceedings, Presentations, Invited Lectures, and Reports

Rotea, M. A., "Analysis of Multivariable Extremum Seeking Algorithms," Proceedings 2000 American Control Conference, Chicago, IL, June 2000, pp. 433-437.

Rotea, M. A., and D'Amato, F. J., "Structural Optimization on Bladed-Disk Assemblies," Matlab Toolbox User's Guide, Version 1.0, June 2000, 107 pages.

Rotea, M. A., and D'Amato, F. J., "Structural Optimization on Bladed-Disk Assemblies," Matlab Toolbox User's Guide, Version 1.0, June 2000, 107 pages.

Heister, S., and Rotea, M., "Center for Satellite Engineering—Progress Report," June 2000, 17 pages.

PROPULSION

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

Bunnell, R. A., and Heister, S. D., "Three-Dimensional Unsteady Simulation of Cavitating Flows in Injector Passages," *Journal of Fluids Engineering*, Vol. 122, No. 4, 2000, pp. 791-797.

Wernimont, E. J., and Heister, S. D., "Combustion Experiments in a Hydrogen Peroxide/Polyethylene Hybrid Rocket with Catalytic Ignition," *Journal of Propulsion and Power*, Vol. 16, No. 2, 2000, pp. 318-326.

Schoonover, P. L., Crossley, W. A., and Heister, S. D., "Application of a Genetic Algorithm to the Optimization of Hybrid Rockets," *Journal of Spacecraft and Rockets*, Vol. 37, No. 5, 2000, pp. 622-629.

Yoon, S. S., and Heister, S. D., "Analytic Solution for Fluxes at Interior Points for 2-D Laplace Equation," *Engineering Analysis with Boundary Element*, Vol. 24, 2000, pp. 155-160.

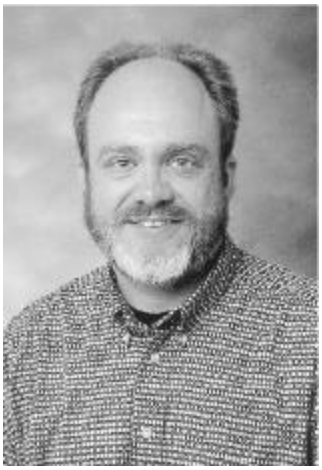
Conference Proceedings, Presentations, Invited Lectures and Reports

Pham, T. L., and Heister, S. D., "A Computational Tool for Spray Modeling using Lagrangian Droplet Tracking in a Homogeneous Flow Model," *ICLASS-2000*, Pasadena, CA, 2000.

Xu, C., Bunnell, R. A., Heister, S. D., and Pham, T. L., "On the Influence of Internal Flow Structure on Performance of Plain-Orifice Atomizers," *ICLASS-2000*, Pasadena, CA, 2000.

Heister, S., and Rotea, M., "Center for Satellite Engineering—Progress Report," June 2000, 17 pages.

Li, H., Bunnell, R., Collicott, S. H., and Heister, S. D., "Internal Flow Visualization and CFD in High-Pressure Diesel Fuel Injectors," *9th International Symposium on Flow Visualization*, Edinburg, Scotland, Aug. 2000, 10 pages.



JOHN J. RUSEK
1998
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

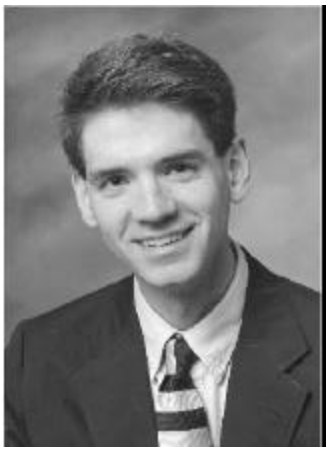
- 1998 William B. McLean Prize, United States Navy Air Technology Medal
- 1998 USN Rear Admiral Commendation for Young Astronauts Program
- 2000 Distinguished Alumnus – Loyola Academy
- Who's Who in the World
- Who's Who in America

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.

STRUCTURES & MATERIALS



WILLIAM A. CROSSLEY
1995
Assistant 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

Jones, B. R., Crossley, W. A., and Lyrintzis, A. S., "Aerodynamic and Aeroacoustic Optimization of Airfoils via a Parallel Genetic Algorithm," *AIAA Journal of Aircraft*, Vol. 37, No. 5, Nov.-Dec. 2000, pp. 1088-1096.

Schoonover, P. L., Crossley, W. A., and Heister, S. D., "Application of a Genetic Algorithm to the Optimization of Hybrid Rockets," *Journal of Spacecraft and Rockets*, Vol. 37, No. 5, 2000, pp. 622-629.

Crossley, W. A., and Williams, E. A., "Simulated Annealing and Genetic Algorithm Approaches for Discontinuous Coverage Satellite Constellation Design," *Engineering Optimization,* Vol. 32, 2000, pp. 353-371.

Ross, T. E., and Crossley, W. A., "A Method to Assess Commercial Aircraft Technologies," *Journal of Aircraft,* Vol. 37, No. 4, Jul.-Aug. 2000, pp. 570-579.

Ely, T. A., Crossley, W. A., and Williams, E. A., "Satellite Constellation Design for Zonal Coverage Using Genetic Algorithms," *Journal of the Astronautical Sciences,* Vol. 47, Nos. 3 and 4, Jul.-Dec. 1999, pp. 207-228 (the Jul.-Dec. 1999 issue was not published until February 2000).

Conference Proceedings, Presentations, Invited Lectures and Reports

Williams, E. A., Crossley, W. A., and Lang, T. J., "Average and Maximum Revisit Time Trade Studies for Satellite Constellations using a Multiobjective Genetic Algorithm," *AAS/AIAA Space Flight Mechanics Meeting,* AAS paper #00139, Clearwater, VL, Jan. 2000.

Cook, A. M., and Crossley, W. A., "Genetic Algorithm Approaches to Smart Actuator Placement for Aircraft Flight Control," *41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* AIAA paper #2000-1582, Atlanta, GA, Apr. 2000.

Fanjoy, D. W., and Crossley, W. A., "Overcoming the Obstacles to using a Genetic Algorithm for Topology Design of Planar Cross-Sections," *41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* AIAA paper #2000-1824, Atlanta, GA, Apr. 2000.

Fanjoy, D. W., and Crossley, W. A., "Using a Genetic Algorithm to Design Beam Cross-Sectional Topology for Bending, Torsion, and Combined Loading," *41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* AIAA paper #2000-1583, Atlanta, GA, Apr. 2000.

Smith, C. F., and Crossley, W. A., "Investigating Response Surface Approaches for Drag Optimization of a Subsonic Turbofan Nacelle," *8th AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization,* AIAA paper #2000-4797, Long Beach, CA, Sept. 2000.

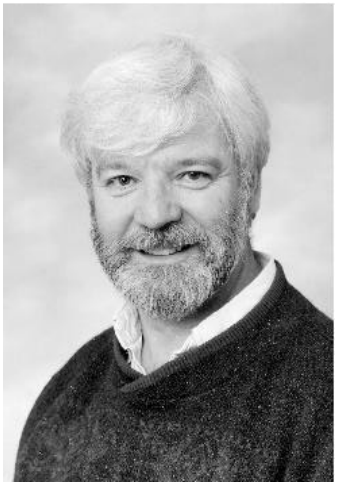
Fanjoy, D. W., Beaver, A. K., and Crossley, W. A., "Population Size Studies for a Multiobjective Genetic Algorithm," *8th AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization,* AIAA paper #2000-4892, Long Beach, CA, Sept. 2000.

Roth, G. L., and Crossley, W. A., "Investigation of Number of Children, Number of Parents, Tournament Size, and Elitism in Genetic Algorithms," *8th AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization*, AIAA paper #2000-4846, Long Beach, CA, Sept. 2000.

Crossley, W. A., Fanjoy, D. W., and Beaver, A. K., "Structural Design Applications of the Two-Branch Tournament Genetic Algorithm," presented at the *Symposium on Multidisciplinary Structural Optimization, ASME International Mechanical Engineering Conference and Exhibit (IMECE)*, Orlando, FL, Nov. 5-10, 2000.

Crossley, W. A., "A Computational Investigation on Approximation Techniques for Engineering Design Optimization," presentation *NASA Langley Research Center*, Hampton, VA, Aug. 9, 2000.

Crossley, W. A., and Cook, A. M., "Genetic Algorithm Approaches for Actuator Placement," final summary of research, NASA Grant NAG1-2119, Sept. 2000.



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.

Books

Doyle, J. F., Static, *Dynamic, and Stability Analysis of Thin-Walled Structures,* Springer-Verlag, New York, 2000.

Conference Proceedings, Presentations, Invited Lectures and Reports

Adams, R., and Doyle, J. F., "Force Identification on Complex Structures," *Proceedings of the SEM IX International Congress on Experimental Mechanics,* Orlando, FL, June 5-8, 2000, pp. 272-275.

Webster, E. M., and Doyle, J. F., "A Dynamic View of Static Instabilities," *Proceedings of the 7th International Conference*, Southampton, England, July 27, 2000, pp. 87-99.

Adams, R., and Doyle, J. F., "A General Force Identification Method," *Proceedings of the 7th International Conference,* Southampton, England, July 27, 2000, pp. 225-236.

Webster, E. M., and Doyle, J. F., "A Dynamic View of Static Instabilities," ICTAM 2000, Abstract Book of the *20th International Congress of Theoretical and Applied Mechanics*, Chicago, IL, Aug. 27-Sept. 2, 2000, p. 138.

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

Szolwinski, M. P., Harish, G., McVeigh, P. A., and Farris, T. N., "Experimental Study of Fretting Crack Nucleation in Aerospace Alloys with Emphasis on Life Prediction," *ASTM STP 1367, Fretting Fatigue: Current Technologies and Practices,* D. W. Hoeppner, V. Chandrasekaran and C. B. Elliot, Eds., 2000, pp. 267-281.

Harish, G., Szolwinski, M. P., Farris, T. N., and Sakagami, T., "Evaluation of Fretting Stresses through Full-Field Temperature Measurements," *ASTM STP 1367, Fretting Fatigue: Current Technologies and Practices,* D. W. Hoeppner, V. Chandrasekaran and C. B. Elliot, Eds., 2000, pp. 423-435.

Farris, T. N., Szolwinski, M. P., and Harish, G., "Fretting in Aerospace Structures and Materials," *ASTM STP 1367, Fretting Fatigue: Current Technologies and Practices*, D. W. Hoeppner, V. Chandrasekaran and C. B. Elliott, Eds., 2000, pp. 523-537.

Chang, S.-H., Farris, T. N., and Chandrasekar, S., "Contact Mechanics of Superfinishing," *ASME Journal of Tribology,* Vol. 122, No. 2, 2000, pp. 388-393.

Szolwinski, M. P., and Farris, T. N., "Linking Riveting Process Parameters to the Fatigue Performance of Riveted Aircraft Structures," *AIAA Journal of Aircraft*, Vol. 37, No. 1, 2000, pp. 130-137.

Madhavan, V., Chandrasekar, S., and Farris, T. N., "Machining as a Wedge Indentation," *ASME Journal of Applied Mechanics,* Vol. 67, No. 1, 2000, pp. 128-139.

Farris, T. N., Harish, G., Tieche, C., Sakagami, T., Szolwinski, M. P., "Experimental Tools for Characterizing Fretting Contacts," *JSME International Journal Series A-Mechanics and Material Engineering*, Vol. 43, No. 4, 2000, pp. 374-383.

Book Chapters

Bulsara, V. H., Chandrasekar, S., and Farris, T. N., "Scratch Testing," ASM Handbook, Vol. 8, Mechanical Testing and Evaluation, 2000, pp. 317-324.

Conference Proceedings, Presentations, Invited Lectures and Reports

Farris, T. N., Harish, G., McVeigh, P. A., and Murthy, H., "Prediction and Observation of Fretting Fatigue of Ti-6Al-4V Subjected to Blade/Disk Type Contacts," *Proceedings of the 5th National Turbine Engine High Cycle Fatigue (HCF) Conference on CD*, Session 13, 11 pages, Chandler, AZ, March 2000.

Murthy, H., Harish, G., and Farris, T. N., "Influence of Contact Profile on Fretting Crack Nucleation in a Titanium Alloy," *Proceedings of 41st AIAA/ASME/ASCE/ASC Structures, Structural Dynamics, and Materials Conference*, CD-ROM, Atlanta, GA, April 2000.

Hammond, J., Moylan, S. P., Chhabra, P. N., Chandrasekar, S., Compton, W. D., and Farris, T. N., "Quantitative Characterization of Surface Mechanical Properties and Microstructures in Hard Metal by Nanoindentation," *Proceedings 27th Leeds-Lyon Symposium on Tribology: Tribology Research: from Model Experiment to Industrial Problem: A Century of Efforts in Mechanics, Materials Science and Physico-Chemistry*, Lyon, France, Sept. 2000.

Goryacheva, I. G., Rajeev, P. T., and Farris, T. N., "Wear in Partial Slip Contacts," *IUTAM Congress*, Chicago, IL, Aug.-Sept. 2000.

Farris, T. N., "Fretting Fatigue of Aerospace Structures," presented Georgia Tech., GA, April 2000.

Harish, G. and Farris, T.N., "Coupled Thermoelastic Evaluation of Fretting Stresses: Application to Life Prediction," IUTAM Congress, Chicago, IL, Aug.-Sep, 2000.

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

Basic research is directed at developing methodology to analyze and design damage tolerant aerospace structures and materials or to evaluate the remaining safe operating life of "aging" aircraft. Emphasis is placed on employing both experimental and numerical approaches to predict the initial growth of preexistent cracks and subsequent fracture due to cyclic and/or static loads. The influence of corrosion on structural life is also of interest.

Current research is focusing on problems related to ensuring the structural integrity of older aircraft. Deterministic and probabilistic approaches are being employed to determine the influence of widespread fatigue damage on the residual strength and fatigue life of mechanically fastened joints and stiffened panels. Techniques for quantifying the effect of corrosion on structural integrity are also being investigated, along with assessment of changes in fatigue crack growth properties in structural materials that have experienced extended periods of service.

One current project involves determining the cyclic growth and coalescence of fretting induced cracks, and is part of a larger research program directed at predicting the onset of High Cycle Fatigue failures in turbine engine components. Another effort is focused on developing a fatigue specimen and test methodology to assess the cyclic performance of new aluminum alloys in aircraft joint configurations.

Other recent efforts examined the nucleation and early growth of fatigue cracks in various materials and structural configurations. In one project, high strength steel specimens were subjected to several constant and variable amplitude load histories to determine the initial growth, coalescence, and fracture of fatigue cracks that develop at notches in the specimens. Another related project evaluated the resistance to fatigue crack formation provided by new aluminum alloys, and involved subjecting large, multi-hole specimens to a given number of fatigue cycles. Those specimens were then sectioned and examined to determine the numbers and sizes of cracks that have developed at the many hole locations. A technique for monitoring the service loading of structural components by the use of pre-cracked coupons mounted to structural members has also been recently studied.

Publications

Wang, H. L., and Grandt, Jr., A. F., "Fatigue Analysis of Multiple Site Damage in Lap Joint Specimens," *Fatigue and Fracture Mechanics: 30th Volume ASTM STP 1360,* American Society for Testing and Materials, 2000, pp. 214-226.

Conference Proceedings, Presentations, Invited Lectures and Reports

Golden, P. J., and Grandt, Jr., A. F., "Characterization of Fretting Fatigue Induced Cracks in Ti-6A1-4V," *Proceedings of the 5th National Turbine Engine High Cycle Fatigue Conference,* Chandler, AZ, March 7-9, 2000.

Saunder, T. J., and Grandt, Jr., A. F., "The Effect of Edge Distance on Coldworking Fastener Holes," *Proceedings of the Fourth Joint DoD/FAA/NASA Conference on Aging Aircraft,* St. Louis, MO, May 15-18, 2000.

Grandt, Jr., A. F., and Scheuring, J. N., "Evaluating the Effect of Corrosion Damage on Subsequent Fatigue Life," AeroMat 2000, *11th Annual Advanced Aerospace Materials and Processes Conference and Exposition,* Bellevue, WA, June 26-29, 2000. (abstract only)

Scheuring, J. N., and Grandt, Jr., A. F., "Evaluating the Effect of Corrosion on Fatigue Life," *37th Annual Technical Meeting, Society of Engineering Science,* Columbia, SC, Oct. 25, 2000. (abstract only)

Grandt, Jr., A. F., "Analysis of Aging Aircraft Scenarios," *2000 USAF Aircraft Structural Integrity Program Conference,* San Antonio, TX, Dec. 4, 2000.

Grandt, Jr., A. F., "Models for Fracture Mechanics Research," 2000 *USAF Aircraft Structural Integrity Program Conference*, San Antonio, TX, Dec. 4, 2000.

Grandt, Jr., A. F., "Monitoring Aircraft Usage with Crack Growth Gages," *2000 USAF Aircraft Structural Integrity Program Conference*, San Antonio, TX, Dec. 4, 2000.

PETER K. IMBRIE
Freshman Engineering
Assistant Professor

Degrees

M.S., Texas A&M University, May 1985.
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.

Publications

Everett, L.J., Imbrie, P.K., and Morgan J., "Integrated Curricula: Purpose and Design," *Journal of Engineering Education*, May 2000.

Conference Proceedings, Presentations, Invited Lectures and Reports
Imbrie, P.K., "Exploring A New Engineering Education Paradigm," International Conference on The First-Year Experience, University of Reading, Reading, England, July 2000.

Imbrie, P.K., "Building Tomorrows Engineers Today," President's Council Back-to-Class presentations, Purdue University, West Lafayette, IN, October 2000.

Imbrie, P.K., "On Oxidation of Various 1-D and 2-D Geometries of Titanium and Ti-Based MMC's," The School of Aeronautics and Astronautics Colloquium Series, Purdue University, West Lafayette, IN, March 2000.

Imbrie, P.K., Budny, D., and Waller, A., "2000 American Society of Engineering Conference," St. Louis, MO, June 2000.

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

Hasebe, R. S., and Sun, C. T., "Performance of Sandwich Structures with Composite Reinforced Core," *Journal of Sandwich Structures and Materials,* Vol. 2, Jan. 2000, pp. 75-100.

Weng, T. L., and Sun, C. T., "A Study of Fracture Criteria for Ductile Materials," *Engineering Failure Analysis,* Vol. 7, 2000, pp. 101-125.

Yang, Z., Sun, C. T., and Wang, J., "Fracture Mode Separation for Delamination in Plate-like Composite Structures," *AIAA Journal,* Vol. 35, No. 5, May 2000, pp. 868-874.

Han, C., and Sun, C. T., "A Study of Pre-Stress Effect on Static and Dynamic Contact Failure in Brittle Materials," *International Journal of Impact Engineering,* Vol. 24, 2000, pp. 597-611.

Turaga, U.V.R.S., and Sun, C. T., "Failure Modes and Load Transfer in Sandwich T-Joints," *Journal of Sandwich Structures and Materials,* Vol. 2, No. 3, 2000, pp. 225-245.

Kwon, W., and Sun, C. T., "Characteristics of Three-Dimensional Stress Fields in Plates with a Through-the-Thickness Crack," *International Journal of Fracture,* Vol. 104, No. 3, 2000, pp. 291-315.

Book Chapters

Sun, C. T., "Chapter 1.21, Strength Analysis of Unidirectional Composites and Laminates," in Comprehensive Composite Materials, Editors: A. Kelly and C. Zweben, Elsevier Science, Ltd., Oxford, UK, 2000.

Conference Proceedings, Presentations, Invited Lectures and Reports

Sun, C. T., "The Proper Use of Fracture Mechanics in the Analysis of Composite Materials and Laminates," *ACCM-2000, 2nd Asian-Australian Conference,* Kyongju, Korea, Aug. 18-20, 2000.

Agrawal, P., and Sun, C. T., "Experimental Characterization and Elastic-Plastic Constitutive Modeling of Metal and Ceramic Matrix Composites in Elastic-Plastic Region," *Proceedings of American Society of Composites 15th Technical Conference,* College Station, TX, Sept. 25-27, 2000, pp. 621-630.

Tsai, J., and Sun, C. T., "Nonlinear Constitutive Model for High Strain Rate Response in Polymeric Composites," *Proceedings of American Society of Composites 15th Technical Conference,* College Station, TX, Sept. 25-27, 2000, pp. 421-430.

Hu, H., and Sun, C. T., "Moisture Effect on Physical Aging in Polymeric Composites," *Proceedings of American Society of Composites 15th Technical Conference,* College Station, TX, Sept. 25-27, 2000, pp. 548-557.

Zhu, C., and Sun, C. T., "Micromechanical Modeling of Fiber Composites under Off-Axis Loading," *Proceedings of American Society of Composites 15th Technical Conference,* College Station, TX, Sept. 25-27, 2000, pp. 143-152.

Tsai, J., and Sun, C. T., "Strain Rate Effect on Dynamic Compressive Failures in Off-Axis Glass-Epoxy Composites," *the 2000 IMECE,* Orlando, FL, Nov. 5-10, 2000.

Agrawal, P., and Sun, C. T., "Crack Growth in Metal-Ceramic Composites," *the 2000 IMECE,* Orlando, FL, Nov. 5-10, 2000.

Zeng, Q., and Sun, C. T., "Further Study on a Novel Design of Wavy Shaped Bonded Composite Joints," *the 2000 IMECE,* Orlando, FL, Nov. 5-10, 2000.

Sun, C. T., and Chang, I., "Singular Stress Field near Crack Tip in Piezoceramics under Electrical and Mechanical Loading," *Mesomechanics 2000, Proceedings of the 3rd International Conference for Mesomechanics,* Xi'an, China, June 13-16, 2000, pp. 819-826.

Zeng, Q., and Sun, C. T., "A New Bonded Composite Wavy Lap Joint," *Proceedings of the 41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference,* Atlanta, GA, Apr. 3-6, 2000.

Sun, C. T., and Cho, J., "Effect of Lowering Thermal Residual Stresses on Fatigue of Bonded Composite Patch Repairs," *Advancing with Composites 2000*, Milan, Italy, May 8-10, 2000, pp. 227-232.

Sun, C. T., and Cho, J, "Optimization of Bonding Cycles to Reduce Thermal Residual Stresses in Adhesively Bonded Composite Patch Repair," *Proceedings of the 2000 USAF Aircraft Structural Integrity Program Conference*, San Antonio, TX, Dec. 5-7, 2000.

Sun, C. T., and Turaga, U. V. R. S., "Compressive and Tensile Characteristics of Sandwich T-Joints," *Proceedings of the 5th International Conference on Sandwich Construction*, Zurich, Switzerland, Sept. 5-7, 2000.

Sun, C. T., "Wavy Lap Joint," Dept. of Aeronautics and Astronautics, seminar Univ. of Washington, Seattle, WA, May 22, 2000.

Sun, C. T., "Strain Rate Effect on Compressive Strength of Fiber Composites," seminar School of Mechanical Engineering, Georgia Tech., GA, Nov. 16, 2000.

Sun, C. T., "Strain Rate on Compressive Strength of Composites and Wavy Lap Joint," seminar Univ. of Calgary, Italy, May 12, 2000.

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.

Conference Proceedings, Presentations, Invited Lectures and Reports

Weisshaar, T. A., Duke, D. K., and Dobbins, A., "Active Aeroelastic Tailoring with Adaptive Continuous Control Surfaces," *41st AIAA/ASME/ASCE/AHS Structural Dynamics and Materials Conference,* AIAA paper #2000-1619, Atlanta, GA, April 3-6, 2000.

Danilin, A. I., and Weisshaar, T. A., "The Use of Optimality Criteria for Aircraft Conceptual Level Structural Design," *41st AIAA/ASME/ASCE/AHS Structural Dynamics and Materials Conference,* AIAA paper #2000-1328, Atlanta, GA, April 3-6, 2000.

Taylor, R. M., and Weisshaar, T. A., "Structural Information Technologies for Aircraft Design Process Improvement," *41st AIAA/ASME/ASCE/AHS Structural Dynamics and Materials Conference,* AIAA paper #2000-1375, Atlanta, GA, April 3-6, 2000.

Blair, M., Moorhouse, D., and Weisshaar, T. A., "System Design Innovation Using Multidisplinary Optimization and Simulation," *AIAA Multidisplinary Optimization and Design Conference,* AIAA Paper #2000-4705, Long Beach, CA, 2000.

Weisshaar, T. A., "Active Materials and Smart Structures: Their (New) Role in the Aerospace Force," *Aerosmart 2000 Conference,* College Station, TX, Sept. 2000.

ACTIVE RESEARCH PROJECTS
JULY 1, 2000 to JUNE 30, 2001

RESEARCH AND OTHER SCHOLARLY ACTIVITIES

In the areas of Aerodynamics, Dynamics and Controls, Propulsion, and Structures and Materials, $3.6 million in expenditures were realized between July 1, 2000 and June 30, 2001. These expenditures represent significant funding from industry, which shows they are developing a greater appreciation for the School's research. Faculty of the School are involved with several 21st Century Research and Technology Fund Projects highlighted by the establishment of the Propulsion and Power Center of Excellence.

The external expenditure research for the 2000-2001 year were attributed to the following sources.

SOURCE OF SPONSORED RESEARCH FOR 2000-2001	
Source	**Percentage of Total**
Department of Defense	47%
NASA	21%
National Science Foundation	4%
Industrial	15%
21st Century Expenditures	4%
Other	9%
Total	100.0%

SPONSORED RESEARCH PROJECTS
ACTIVE DURING THE PERIOD JULY 1, 2000 TO JUNE 30, 2001

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
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	10/01/00-09/30/01	$125,651	Co-PI: Andrisani (PI: Bethel)
NSF	Career: Experimental Investigation of the Internal Structures in Atomizing Orifice Flows	08/01/95-07/31/00	$341,678	Collicott
Rolls-Royce Allison	Purdue Sump-Flow Research	01/01/00-12/31/01	$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	08/15/00-01/01/01	$95,382	Collicott
Rolls-Royce Allison	Purdue Sump Flow Research	01/01/00-12/31/01	$189,032	Collicott (Co-P.I.: Heister)
NASA	Actuator Placement via Genetic Algorithm for Aircraft Morphing	01/01/00-12/31/00	$30,000	Crossley
Mide Tech. Corp.	Self Consuming Spacecraft	12/01/99-99/99/99	$2,000	Crossley
NASA	Topology Design of Rotor Blades for Aerodynamic and Structural Consideration	07/01/97-10/31/00	$66,000	Crossley
NASA	Genetic Algorithm Approaches for Actuator Placement	12/09/98-6/30/00	$20,581	Crossley
NASA	Improved Aircraft Conceptual Design Using A Genetic Algorithm Based Approach	07/01/98-06/30/01	$66,000	Crossley
NASA	NASA/FAA National General Aviation Design Competition Travel Award	07/14/01-08/31/01	$1,500	Crossley
NASA	Chobinatorial Multiobjective Optimization Using Genetic Algorithms	04/10/01-04/09/02	$30,003	Crossley
General Electric Corporate Res & Dev	Flow Solver Validation	01/08/01-12/31/01	$44,149	Crossley

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
Univ. Dayton Res. Inst.	Advanced High Cycle Fatigue Life Assurance Methodologies	04/01/99-03/31/02	$578,629	Farris (Co-P.I. Grandt)
NSF	A Proposal to Establish an Engineering Research Center for Collaborative Manufacturing	09/01/97 – 09/30/00	$519,900	Farris
General Electric Aircraft Engines	Amelioration of Fretting Fatigue of Titanium	08/16/00-12/31/01	$99,560	Farris
LSP Technologies	Fretting Fatigue Testing For LSP Technologies, INC.	11/01/00-12/31/00	$5,550	Farris
NSF	Use of Polishing Process Model as an Example for Manufacturing System Design	09/15/97-08/31/00	$162,768	Chandrasekar (Co-P.I. Farris, Compton)
NASA	Optimization of GPS Tracking Loops For Spacecraft Navigation in HEO/GEO Orbits	05/01/01-01/31/01	$20,000	Garrison
ALCOA	Durability of Aircraft Joints	06/01/99-12/31/01	$210,000	Grandt
Carrier Corp.	Cavitating Flow Simulations in Air Conditioner Applications	01/01/00-05/31/00	$25,000	Heister (Co-P.I. Collicott)
AFOSR	Modeling Dense Sprays in Liquid Rocket Engines	01/01/99-10/31/00	$247,175	Heister
NASA	Simulation and Visualization of Cavitating Venturi Flows	01/01/01-12/31/01	$50,000	Heister
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
Science Applications International Corporation	Trajectory Control through Thrust Vector Rotation	03/01/01-02/28/02	$55,000	Heister
NASA	Dynamic Systems Theory, Numerical Methods, Optimization Strategies and their Application to Trajectory Design and Mission Analysis Involving Lissajous and Halo Orbits	08/01/98-07/31/02	$299,347	Howell

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
NASA	Triana Mission: Contingency Analysis	02/09/01-06/30/01	$10,000	Howell
JPL/NASA	Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions	11/1/99-10/31/01	$295,895	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
NASA	On the Development of Supersonic Jet Noise Prediction Methodology	11/25/97-11/24/00	$104,186	Lyrintzis (Co-PI: Blaisdell)
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
NSF	National Science Foundation Young Investigator Award	10/01/93-03/01/01	$295,000	Rotea
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	7/12/00-7/11/01	$33,304	Rotea
United Tech. Res. Center	Robust Control Analysis and Synthesis	09/01/98-99/99/99	$37,500	Rotea
NASA/ISGC	Methods for Nonlinear Parameter Estimation	06/01/00-5/31/01	$5,000	Rotea
TRW	Advanced Catalyst for HTP	02/10/00-05/28/00	$50,210	Rusek
KB Sciences	Non-Toxic Hypergolic Miscible Bipropellant Studies	5/9/00-5/8/02	$130,000	Rusek (Co-PI: Heister)
Lockheed-Martin	Advanced Non-Toxic Propellants	11/15/99-12/21/00	$30,990	Rusek
Trask Trust Fund	Hydrogen Peroxide Fuel Cell	06/01/00-05/31/01	$84,384	Rusek
Technology Development Association	Development of a Propellant Hypertester	1/1/00-6/30/00	$3,000	Rusek
AFOSR	Mechanisms of Hypersonic Boundary-Layer Transition on a Generic Scramjet Forebody	11/15/99-11/14/01	$254,697	Schneider (Co-P.I.: H. Reed ASU)

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
Sandia National Labs	Aerothermodynamic Predictions for Hypersonic Reentry Vehicles	08/27/99-05/31/03	$230,000	Schneider
NASA	Mechanism of Boundary-Layer Transition on Reusable Launch Vehicles: X-33 Experiments	1/1/01-1/31/02	$50,000	Schneider
AFOSR	Completion of the 9.5-inch Mach-6 Ludwieg Tube: Enabling Low-Cost Hypersonic Quiet-Flow Experiments	06/01/99-11/30/00	$170,000	Schneider (Co.PI's: Collicott & 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	Laser Spot Heating System for Transition Detection in Cryogenic Wind Tunnels	7/1/98-6/30/00	$99,738	Sullivan
NASA	A Laser Scanning PSP-TSP System for Propulsion Applications	7/1/01-6/30/02	$49,242	Sullivan
Raytheon	Pressure and Temperature Paint Systems for Flight Testing	7/1/98-6/60/01	$133,000	Sullivan
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	09/01/96-8/31/01	$3,135,500	Sun (Co-PI's: Doyle, Espinosa, Bolton, Trumble)
ONR	Dynamic Constitutive and Failure Modeling of Composite Materials and Structures	02/01/96-1/12/02	$671,981	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	09/01/97-11/30/01	$180,000	Sun
AFOSR	Characterizing and Modeling Physical Aging in Polymeric Composites	12/0197-03/31/01	$283,911	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	9/1/96-12/31/03	$80,000	Sun

SPONSOR	PROJECT TITLE	PROJECT PERIOD	AWARD AMOUNT	P. I.
Air Force Res. Lab	Improved Methodology for Advanced Aircraft Design	9/29/00-9/28/03	$192,999	Weisshaar
Anteon Corporations	Aero-Morphing Aircraft Concepts	2/1/01-8/30/01	$48,998	Weisshaar

GRADUATE THESES
JULY 2000- JUNE 2001

MASTER'S THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree** **Date Granted**
Frolik, Steven A. *J. J. Rusek*	"Development of Hypergolic Liquid Fuels for use with Hydrogen Peroxide"	M. S. August 2000
Long, Matthew R. *J. J. Rusek*	"Characterization of Substrate Geometries for the Catalytic Decomposition of Hydrogen Peroxide"	M. S. August 2000
McInnes, Allan I. S. *K. C. Howell*	"Solar Sail Trajectories in the Circular Restricted Three-Body Problem"	M. S. August 2000
Ong, David *S. H. Collicott*	"Investigation of Cavitation in Circular and Slot Orifices with a Step"	M. S. August 2000
Cho, Sung Man *J. F. Doyle*	"Reconstructing Dynamic Events from Time-Limited Spatially Distributed Data"	M .S. December 2000
Cook, Andrea *W. A. Crossley*	"Genetic Algorithm Approaches to Optimizing the Location and Number of Smart Actuators on an Aircraft Wing"	M. S. December 2000
Haradanahalli, Murthy *T. N. Farris*	"Modeling of Fretting Fatigue in Blade/Disk Contacts and Life Prediction"	M. S. December 2000
Heaton, Andrew Floyd *J. M. Longuski*	"A Systematic Method for Gravity-Assist Mission Design"	M. S. December 2000
Marchand, Belinda G. *K. C. Howell*	"Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems"	M. S. December 2000
Rufer, Shann J. *S. P. Schneider*	"Development of Burst-Diaphragm and Hot-Wire Apparatus for use in the Mach-6 Quiet-Flow Ludwieg Tube"	M. S. December 2000
Henderson, Joseph A. T. A. Weisshaar	"Formal Design Space Evaluation and Optimization for Innovative Aeroelastic Concepts"	M. S. May 2001
Matlik, John *T. N. Farris*	"Motivation, Design, and Calibration of a High Frequency Fretting Fatigue Load Frame"	M. S. May 2001

DOCTORAL THESES

Student/ ***Major Professor***	**Thesis Title**	**Degree** **Date Granted**
Barden, Brian T. *K. C. Howell*	"Application of Dynamical Systems Theory in Mission Design and Conceptual Development for Libration Point Missions"	Ph.D. August 2000
Koutsavdis, Evangelos *A. S. Lyrintzis*	"On the Development of a Jet Noise Prediction Methodology"	Ph.D. August 2000
Kwon, Soonwook *C. T. Sun*	"Characteristics of Three-Dimensional Stress Fields of Cracked Plates under General Loading"	Ph.D. August 2000
Pham, Tuan L. *S. D. Heister*	"A Computational Tool for Spray Modeling using Lagrangian Droplet Tracking in a Homogeneous Flow Model"	Ph.D. August 2000
Ganapathy, Harish *T. N. Farris*	"Coupled Thermoelastic Analysis of Fretting Contacts"	Ph.D. December 2000
Han, Chenghua *C. T. Sun*	"Dynamic Response and Failure in Layered Structures and Composites"	Ph.D. December 2000
Li, Zhiyong *H. T. Yang and S. Chandrasekar*	"Analysis of Micro- and Nano – Indentation	Ph.D. December 2000
Pancake, Trent A. *M. Corless*	"Analysis and Control of Uncertain/Nonlinear Systems in the Presence of Bounded Disturbance"	Ph.D. December 2000
Taylor, Robert M. *T. A. Weisshaar*	"Aerospace Structural Design Process Improvement using Systematic Evolutionary Structural Modeling"	Ph.D. December 2000
Yang, Zhengwen *C. T. Sun*	"Fracture Mode Separation for Delamination and Interlaminar Fracture for Composites"	Ph.D. December 2000
Zavattieri, Pablo D. *H. D. Espinosa*	"Computational Modeling for Bridging Size Scales in the Failure of Solids"	Ph.D. December 2000

Adams, Douglas *C. T. Sun*	"Effects of Lateral Confinement of the Static and Dynamic Strength of Brittle Materials"	Ph.D. May 2001
Agrawal, Parul *C. T. Sun*	"Micromechanical and Fracture Characteristics of Metal-Ceramic Composites"	Ph.D. May 2001
Guzman, Jose *K. C. Howell*	"Spacecraft Trajectory Design in the Context of a Coherent Restricted Four-Body Problem,"	Ph.D. May 2001
Petropoulos, Anastasios *J. M. Longuski*	"A Shape-Based Approach to Automated, Low-Thrust. Gravity-Assist Trajectory Design"	Ph.D. May 2001
Smith, Crawford Frederick III *W. Crossley*	"Response Surface Methods for Optimization"	Ph.D. May 2001
Zeng, Qinggang *C. T. Sun*	"A Study on Composite Adhesive Lap Joint"	Ph.D. May 2001

COLLOQUIUM SERIES
2000-2001

Colloquium Series – Fall 2000

DATE/TIME	TOPIC	SPEAKER
September 7, 2000 4:00 p.m. GRIS 170	Satellite Thermal Propulsion Systems Activities in the Commercial Space Business	**Mr. Jack Divers** Lockheed Martin Space Systems Co.
September 20, 2000 4:30 p.m. GRIS 280	The Beal Aerospace BA-2C Heavy-Lift Commercial Liquid Rocket Program	**Mark E. Henry** Propulsion Director and Deputy Program Manager Beal Aerospace Technologies
September 28, 2000 4:30 p.m. GRIS 170	Real-Time Analysis System for Gas Turbine Ground Test Acoustic Measurements	**Robert T. Johnston** Pratt & Whitney
October 20, 2000 4:30 p.m. GRIS 170	Gas Dynamics and Thermodynamics of Pulsed Detonation Engines	**Razi Nalim** IUPUI
October 26, 2000** 3:00 p.m. Fowler Hall	Kennedy Space Center: Constructing a Future	**Roy Bridges** Director of Kennedy Space Center & Former Astronaut
October 27, 2000	Aerodynamic Study of Two Business Jets with External Aft Fuselage Lockers	**James Raisbeck** Raisbeck Engineering
November 30, 2000 4:00 p.m. GRIS 170	NASA's Morphing Project – Aggressively Developing and Integrating Smart and Biometric Technologies to Enable Revolutionary Advances in Air and Space Vehicles	**Anna Rivas McGowen** NASA Langley Research Center

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

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

Colloquium Series - Spring 2001

DATE/TIME	TOPIC	SPEAKER
January 18, 2001 4:00 p.m. GRIS 166	Background for Aging Aircraft Structural Research	**Dr. John W. Lincoln** Technical Advisor, Aeronautical Systems Ctr. WPAFB, OH.
February 15, 2001 4:00 p.m. GRIS 166	Propulsion Integration: A Key Technology for Future Aircraft	**Marvin Gridley** WPAFB, OH
February 22, 2001 4:00 p.m. GRIS 166	Next Generation Guidance & Control: Where are we Going?	**Andrew J. Staugler** C. S. Draper Laboratory Cambridge, MA
March 1, 2001 4:00 p.m. GRIS 166	Numerical Simulation of Plasma Aerodynamics Experiments	**Graham Candler** Univ. of Minnesota
March 29, 2001 4:00 p.m. GRIS 166	A Design Reference Mission for the Human Exploration of Mars	**David Kaplan** NASA Johnson Space Center
*March 30, 2001 4:00 p.m. GRIS 160	Crack Growth Predictions Based on Cohesive Zone Models	**Viggo Tvergaard** Professor, Dr. Techn. Tech. Univ. of Denmark
*April 6, 2001 4:00 p.m. GRIS 160	A Review of the Mechanical Properties of Metallic Foams and Lattice-materials	**Norman A. Fleck** Prof. of Mech. of Materials Cambridge University
April 12, 2001 4:00 p.m. GRIS 166	Recent Advances in Air Force Rocket Propulsion Technologies	**Mike Huggins** Air Force Rocket Lab. Edwards AFB

April 26, 2001 4:00 p.m. GRIS 166	Studies of the Optimum Performance of Tapered Vortex Flaps	**Kenichi Rinoie** Dept. of Aeronautics & Astronautics Univ. of Tokyo
*April 27, 2001 4:00 p.m. Stewart Center 313	Mechanics, Mixing, and Patterns in the Ocean Surface Layer	**Sidney Leibovich** Professor, Cornell Univ.

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

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

FACULTY HIGHLIGHTS

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

Highlights include:

- Professor Alten F. Grandt, Jr. was the 5th recipient of The John W. Lincoln Award that was established in 1996 by the aircraft structural integrity community to recognize a distinguished career expert who has made significant contributions toward advancements in flight vehicle structural integrity and safety. Professor Grandt was also named the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration.
- Professor James Longuski was named the recipient of the W. A. Gustafson Teaching Award and the Elmer F. Bruhn Teaching Award.
- Professor Stephen Heister was named a recipient of the 2001 Bruhn Best Teaching Award.
- Professor James Doyle was named Fellow of the Society of Experimental Mechanics and published his 3rd book entitled *Nonlinear Analysis of Thin-Walled Structures* with Springer.
- Professor Arthur Frazho spent the fall on sabbatical at Vrije Universiteit.
- Professor Tasos Lyrintzis spent the fall on sabbatical at Rolls-Royce.
- Professor Thomas Farris was general Chair of the 42nd AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Materials Conference
- Professor Kathleen Howell has been named fellow of the American Astronautical Society
- Professor Kathleen Howell and graduate student Belinda Marchand have been recognized by AIAA for the Best Paper Award sponsored by the Astrodynamics Technical Committee for their paper entitled "Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems"
- Professor Mario Rotea was awarded the best paper presentation award at the American Control Conference for the paper entitled "LFTB: An Optimized Algorithm to bound worst-case frequency response functions," session TP6, Washington, DC.
- Professor Steven Schneider was elected as Associate Fellow, AIAA
- Professor William A. Crossley was promoted to Associate Professor.
- Professor James L. Garrison was awarded along with Stephen J. Katzberg of NASA Langley, an "Exceptional Space Act Award" by NASA Headquarters for the patent entitled "Method and System for Generating Images of an Object."
- Faculty were invited for several keynote and plenary presentations detailed in their respective research descriptions.

Professor John Rusek resigned his position with the School to establish Swift Enterprises, Ltd. In the Purdue Research Park, W. Lafayette, Indiana. Drs. Hyonny Kim and William Anderson begin assistant professorships this fall.

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 5th 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 AAE professors and visiting dignitaries.

A team of AAE students, Keith Hout, Michale Koenigs, Craig Malmloff, Chris Peters, Brian Pfeiffer, Jeff Rodrian, and Tyson Strutzenburg took the 2nd place prize of $2,000 in the National General Aviation Design Competition. NASA, the FAA, and the US AFRL sponsor this prestigious award. In addition, the team won $3,000 for the Best Use of Air Force Developed Technology Award—these Purdue Students are focused on the bottom line. This is one example of students taking advantage of the enhanced Design/Build/Test capabilities in the School.

OUTREACH HIGHLIGHTS

In its fifth year, Fall Space Day '01 was a rousing success with more than 250 third through eighth graders, and 50 plus teachers and chaperones. Astronaut Janice Voss 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 Indiana Space Grant Consortium (ISGC), now in its 10th year, has 13 affiliates. IUPUI and the Lafayette Imagination Station are the newest members. The affiliates of ISGC reflect community, education, government, and industry involvement in the space program.

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

CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

Course Enrollments
School of Aeronautics and Astronautics
2000-2001 Academic Year

A&AE Course	Most Recent Title	Cr.	Fall 2000		Spring 2001	
			Enroll-ment	Instructor	Enroll-ment	Instructor
190	Intr. to Aerosp. Engrg.	2	130	Andrisani		
203-1	Aeromechanics I	3	65	Howell	60	Garrison
203-2	Aeromechanics I	3	59	Garrison		
204	Aeromechanics II	3	38	Crossley	85	Doyle
204L	Aeromechanics II Lab.	1	40	Doyle	90	Doyle
251	Intro. Aerosp. Design	3	42	Sullivan	92	Crossley
333	Fluid Mechanics	3	58	Blaisdell	28	Lyrintzis
333L	Fluid Mechanics Lab.	1	57	Collicott	26	Collicott
334	Aerodynamics	3	22	Collicott	46	Blaisdell
334L	Aerodynamics Lab.	1	16	Collicott	35	Collicott
340	Dynamics & Vibration	3	40	Longuski	39	Howell
352	Structural Anal. I	3	40	Weisshaar	32	Grandt
352L	Struct. Anal. I Lab.	1	11	Doyle	12	Doyle
364	Control System Analy.	3			43	Rotea
364L	Control Systems Lab.	1			33	Rotea
372	Jet Propl. Power Plt.	3			51	Yoon
412	Intro. Comp. Fluid Dyn.	3	32	Williams		
415	Aerodynamic Design	3	15	Sullivan		
416	Viscous Flows	3			12	Schneider
421	Stability & Control	3	18	Corless	27	Andrisani
421L	Flt. Dyn. Control Lab.	1	31	Rotea		
439	Rocket Propulsion	3	51	Heister		
440	Spacecr. Attitude Dyn.	3			19	Howell
450	Spacecraft Design	3			21	Longuski
451	Design I (Aircraft Design Spr. 01 Sem)	3 3	6 13	Schneider (div. 1) Andrisani (div. 2)	16	Weisshaar
453	Matr. Meth. Aerosp. Struc.	3			10	Doyle
454	Design Aerosp. Struct.	3	15	Grandt		

A&AE Course	Most Recent Title	Cr.	Fall 2000		Spring 2001	
			Enroll-ment	Instructor	Enroll-ment	Instructor
464	Control Sys. Anal.	3	32	Rotea		
490	Spec Prob in Aero Engr			Staff		Staff
490A	Flight Testing	3			8	Andrisani
490E	Intro. Satellite Sys.	3			30	Heister/Rotea
490G	Zero Grav. Flt. Exper.	3			9	Collicott
490T	Design Build Test	3			10	Sullivan
507	Principles of Dynam.	3	27	Longuski		
511	Intro. Fluid Mech.	3	30	Blaisdell		
514	Intermediate Aerodyn.	3			14	Lyrintzis
519	Satellite Aero & Entry	3			9	Schneider
520	Experimental Aerodyn.	3			21	Sullivan
532	Orbit Mechanics	3	30	Howell		
538	Airbreathing Prop.	3	21	Lawless (ME)		
539	Adv. Rocket Prop.	3			26	Heister
546	Aero Struct Dyn Stab.	3	2	Doyle		
547	Exper. Stress. Analy.	3			11	Doyle
553	Elasticity Aerosp. I	3	24	Doyle		
554	Fatigue Struct. & Matrl.	3	20	Grandt		
555	Mechanics Comp. Matl.	3			17	Sun
556	Aeroelasticity	3			15	Weisshaar
558	Finite Element Meth. in Aerospace Structures	3	31	Farris		
559	Mech. Frict. & Wear	3			12	Farris
564	System Anal. & Synth.	3	16	Corless		
567	Intro. Appl. Stoch. Proc	3			9	Frazho
590C	Prop. Syst. Design	3			25	Heister/Rusek
590G,Q	Multidis. Des. Optim.	3	18,14	Crossley		
590K	Adv. Energy Convers.	3	20	Rusek		

A&AE Course	Most Recent Title	Cr.	Fall 2000		Spring 2001	
			Enroll-ment	Instructor	Enroll-ment	Instructor
590T	Design Build Test	3			4	Sullivan
615	Aeroacoustics	3		Mongeau		
626	Turb. & Turb. Modeling	3			11	Blaisdell
630	Stability of Free Surf.	3	11	Heister		
654	Fracture Mechanics	3			21	Sun
655	Adv. Topics Convers.	3	15	Sun		
666	Nonlin. Dyn. Syst. Cont.	3			21	Corless
698	M.S. Thesis Research	--		Staff		Staff
699	Ph.D. Thesis Research	--		Staff		Staff
MA265	Linear Algebra	3			36	Corless
MA266	Ord. Diff. Equations	3			35	Williams
MA266	Ord. Diff. Equations	3			41	Adams
HONR 199I	Low-Gravity Experiments	3			6	Collicott

190-Introduction to Aerospace Engineering

Math Chemistry Physics Communications Economics Liberal Arts
Thermodynamics Electrical Circuits Computer Skills/Programming

251-Introduction to Aerospace Design			
Aerodynamics	*Dynamics and Control*	*Propulsion*	*Structures and Materials*
Required Undergraduate			
333-Fluid Mechanics & Lab. 334-Aerodynamics and Lab	203-Aeromech.I(statics/dyn) 340-Dynamics and Vibrations 364-Control System Analysis & Lab 421-Flight Dynamics or 440-Spacecraft Attitude Dynamics	372-Jet Propulsion or 439-Rocket Propulsion	204-Aeromech. II (Str of Mat.) & Lab 352-Structural Analysis & Lab
Undergraduate Electives			
412-Intro to CFD 414-Compressible Aero 416-Viscous Flows 490G-Low Gravity Exp.	361-Intro to Random Variables 421-Flight Dynamics or 440-Spacecraft Attitude Dynamics 474-Exp. Flight Mechs.	372-Jet Propulsion or 439-Rocket Propulsion 490E-Intro. to Satellite Engrg.	453-Matrix Methods in Structure
Design Electives			
415-Aerodynamic Design	490r-Control Systems Design	590c- Propulsion Design	454 Design of Aerospace Structure

Capstone Design (451-Aircraft or 450-Spacecraft)			
Undergraduate/ Graduate Electives			
511-Intro. to Fluid Mech. 512-Computational Aero 513-Transonic Aero. 514-Intermediate Aerodynamics 515-Rotorcraft Aerodynamics 517-Unsteady Aerodynamics 518-Low Gravity Fluid Mech. 519-Satellite Aerodyn. & Planet. Entry 520-Experimental Aerodynamics	507-Principles of Dynamics 508-Optimization in Aero. Eng. 531-Flight Mechanics 532-Orbit Mechanics 540-Spacecraft Attitude Dynamics 564-Systems Anal. and Control 565-Guid. & Contrl. Aerosp. Veh. 567-Intro to Stochastic Proc. 574-Digital Flight Control Sys.	536-Advanced Energy Conversion 538-Air Breathing Propulsion 539-Adv. Rocket Propulsion 590e-Astro. Nav. & Guidance	546-Aero. Structural Dyn. & Stability 547-Experimental Stress Anal. 550-Multidisciplinary Design. Opt. 552-Nondestructive Eval. of Str.&Matrl. 553-Elasticity in Aero. Eng 554-Fatigue in Struct. and Mat. 555-Mech. of Composite Mat. 556-Aeroelasticity 558-Finite Element Meth. Aero. Struct. 559-Mech. of Friction & Wear 590f-Design Theory and Methods
Graduate Electives		603 -Theoretical Methods	
611-Principles of Fluid Mech. 613-Viscous Flow Theory 615-Aeroacoustics 626-Turbulence & Turbulence Model.	607-Var.Prin. of Mechanics 632-Advanced Orbital Dynamics 660-Operator Methods on Crtl. Sup. 664-Uncertain Dyn. Systems 666-Nonlinear Dyn, Systems, Control 684-Design of Dyn. Systems 690r-Multi-Feedback Control	630-Stability of Free Surfaces 690a-Future Prop. Conc.	646-Elastic Wave Propagation 652-Theory of Plates & Shells 654-Fracture Mech 655-Composite Matrls. & Struct. .
Cooperative Education Courses			
241-Industrial Practice I 242-Industrial Practice II	341-Industrial Practice III 342-Industrial Practice IV 390-Professional Internship	442-Industrial Practice V 443-Industrial Practice Seminar	642-Graduate Professional Practice

Summarized Class Enrollment Statistics for the 2000-2001 Academic Year

Semester	Statistic	Three-Credit Courses				One-Credit Laboratory Courses
		100, 200, 300, 400, Levels	500 Levels	600 Level	All Levels	
Fall of 2000	No. of classes offered	15	11	3	29	5
	Total Enrollment	825	253	26	1104	249
	Average number of students per class	55	23	9	38	50
Spring of 2001	No. of classes offered	23	13	3	39	5
	Total enrollment	787	184	53	1024	290
	Average number of students per class	34	14	18	26	58

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

STAFF FOR THE 2000-01 ACADEMIC YEAR

Administrative Assistants

L. Flack, T. Moore

Business Office

D. Horton, L. Dispennett, J. Jackson, J. Rosch

Clerical

L. Crain, P. Kerkhove, D. Schafer, S. Wise

Director of Communications and Development

T. Bobillo

Fall Space Day Coordinator

A. Broughton

Professional/Technical

D. Bower, M. Chadwell, I. Ellis, G. Hahn, S. Meyer, D. Reagan, E. Weaver, R. Snodgrass, J. Younts