Research Report
2001 – 2002
Academic Year
# TABLE OF CONTENTS

OUR MISSION ............................................................................................................................................. 2
ACADEMIC HIGHLIGHTS .......................................................................................................................... 2
DEVELOPMENT HIGHLIGHTS ................................................................................................................. 3
ALUMNI HIGHLIGHTS .............................................................................................................................. 4
PUBLICATIONS ........................................................................................................................................ 4
CO-OP PROGRAM ..................................................................................................................................... 4
OVERVIEW OF RESEARCH AREAS AND FACILITIES ............................................................................. 6
FACULTY SUMMARIES ............................................................................................................................ 10
AERODYNAMICS ...................................................................................................................................... 11
DYNAMICS & CONTROL .......................................................................................................................... 27
PROPULSION ........................................................................................................................................... 43
STRUCTURES & MATERIALS ..................................................................................................................... 51
ACTIVE RESEARCH PROJECTS .................................................................................................................. 73
RESEARCH AND OTHER SCHOLARLY ACTIVITIES ............................................................................... 74
GRADUATE THESES ............................................................................................................................... 80
COLLOQUIUM SERIES ............................................................................................................................ 85
HIGHLIGHTS AND AWARDS ................................................................................................................... 89
FACULTY HIGHLIGHTS ........................................................................................................................... 90
STUDENT HIGHLIGHTS .......................................................................................................................... 90
OUTREACH HIGHLIGHTS ........................................................................................................................ 93
CURRICULUM AND COURSE OFFERINGS ............................................................................................. 94
STAFF FOR THE 2001-2002 ACADEMIC YEAR ..................................................................................... 100
OUR MISSION

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

ACADEMIC HIGHLIGHTS

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

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

<table>
<thead>
<tr>
<th>Degrees Awarded School of Aeronautics &amp; Astronautics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
</tr>
<tr>
<td>B.S.</td>
</tr>
<tr>
<td>M.S.</td>
</tr>
<tr>
<td>Ph.D.</td>
</tr>
</tbody>
</table>

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

A “Satellite Design” course was offered as a capstone design experience in Spring 2002 by Professor Crossley. The course was sponsored by the Center for Satellite Engineering. The mission was to design a satellite that Purdue students could build and launch. Plans are afoot to continue this work to the build stage next year this involves both undergraduate and graduate students, and industrial/government sponsors.
Purdue University’s Program for Study Abroad Office currently offers more than 200 programs in over 40 countries around the world. The School of Aeronautics and Astronautics continues to develop relationships with international universities, and has student exchange agreements with: Bristol University, United Kingdom; Royal Melbourne Institute of Technology in Melbourne, Australia; University of New South Wales in Sydney, Australia; Ecole Superieure des Techniques Aeronautiques et de Construction Automobile (ESTACA) in Paris, France; and Osaka University in Japan.

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

The School of Aeronautics and Astronautics, through Purdue University’s Continuing Engineering Education (CEE) Program, offers graduate level courses in aerospace engineering. This opportunity to reach students through distance education, along with our history of quality education, we are confident that our School’s participation with CEE will be a benefit to all participants.

DEVELOPMENT HIGHLIGHTS

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

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

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

James D. Raisbeck (B.S.A.E. ’61, DEA ’79, OAE ’99) and his wife Sherry L. Raisbeck, donated $2,000,000 to Purdue University to establish “The Raisbeck Engineering Distinguished Professorship for Engineering and Technology Integration.” The School held a reception on October 25, 2001 to honor Dr. Alten F. Grandt as the
Raisbeck Distinguished Professor. Mr. Raisbeck started Raisbeck Engineering, and during his career developed the Supercritical Wing for the Sabreliner and the Mark II and Mark IV Systems for the Learjet 20 series. Raisbeck Engineering has developed and certified a number of aerodynamic improvements for business aircraft.

ALUMNI HIGHLIGHTS

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

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

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

PUBLICATIONS

Listings of books, journal articles, and other printed conference papers and reports published in calendar year 2001 are given in the “Faculty Summary” section of this report. Only documents that actually appeared in print during 2001 are listed. Note that 1 book, 1 patent, 33 journal articles or book chapters, and 148 conference papers or technical reports, were presented or published. In addition to the published technical reports listed, many other technical progress reports were submitted directly to project sponsors.

CO-OP PROGRAM

During the 2001-02 academic year, 65 students were enrolled in the Cooperative Engineering Program with the 24 companies listed on the following page. This popular program is limited only by the number of industry positions available. About 31 in 110 new applicants received appointments this year. Many other students gain industrial experience through internships.
# Co-Op Companies

## School of Aeronautics and Astronautics

**July 1, 2001-June 30, 2002**

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Number of A&amp;AE Co-op Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace Corporation</td>
<td>Los Angeles, CA</td>
<td>1</td>
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<tr>
<td>American Trans Air Engineering</td>
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</tr>
<tr>
<td>ATA Engineering Inc.</td>
<td>San Diego, CA</td>
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</tr>
<tr>
<td>Atlantic Research Corporation</td>
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<tr>
<td>Ball Aerospace &amp; Tech. Corp.</td>
<td>Boulder, CO</td>
<td>8</td>
</tr>
<tr>
<td>Boeing Satellite Systems</td>
<td>Los Angeles, CA</td>
<td>5</td>
</tr>
<tr>
<td>Delta Airlines</td>
<td>Atlanta, GA</td>
<td>0</td>
</tr>
<tr>
<td>General Electric Aircraft Engines</td>
<td>Cincinnati, OH</td>
<td>12</td>
</tr>
<tr>
<td>NASA-Ames Research Center</td>
<td>Moffett Field, CA</td>
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<tr>
<td>NASA-Dryden Flight Research Center</td>
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<tr>
<td>NASA-Glenn</td>
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<tr>
<td>NASA-Goddard</td>
<td>Greenbelt, MD</td>
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<tr>
<td>NASA-Johnson Space Center</td>
<td>Houston, TX</td>
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<tr>
<td>NASA-Kennedy Space Center</td>
<td>Kennedy Space Ctr., FL</td>
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<tr>
<td>NASA-Langley Research Center</td>
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<td>2</td>
</tr>
<tr>
<td>Naval Research Laboratory</td>
<td>Washington, DC</td>
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<tr>
<td>Raytheon E-Systems</td>
<td>Greenville, TX</td>
<td>0</td>
</tr>
<tr>
<td>Rockwell International Corporation</td>
<td>Cedar Rapids, IA</td>
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</tr>
<tr>
<td>Rolls-Royce</td>
<td>Indianapolis, IN</td>
<td>3</td>
</tr>
<tr>
<td>Structural Analysis Engineering</td>
<td>Cincinnati, OH</td>
<td>4</td>
</tr>
<tr>
<td>United Parcel Service (Air Group)</td>
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<tr>
<td>United Technologies Pratt &amp; Whitney</td>
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<td>0</td>
</tr>
<tr>
<td>United Technologies Pratt &amp; Whitney</td>
<td>East Hartford, CT</td>
<td>1</td>
</tr>
<tr>
<td>Wright-Patterson AFB</td>
<td>Dayton, OH</td>
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</table>
OVERVIEW OF RESEARCH AREAS AND FACILITIES

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

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

AERODYNAMICS

Aerodynamics research is directed toward a better understanding of the fundamental laws governing the flow of fluids. Research topics of recent interest include: numerical methods in aerodynamics; computational fluid mechanics; separated flow around wings and bodies at high angles of attack; aerodynamics of rotors and propellers; boundary layers, wakes and jets in V/STOL applications and aerodynamic noise; experimental measurements using laser systems; laminar-turbulent transition in high speed boundary layers.

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

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

Three small high-speed facilities are located in the Boeing Compressible-Flow Laboratory. The first is a 2-inch Mach-2.5 blowdown tunnel, and the second is a one-inch supersonic jet apparatus, designed for nozzle-flow studies. Both can be operated in pressure-vacuum mode and are used primarily for teaching. The jet apparatus also includes a heater and particle filter, to enable supersonic hot-wire calibrations. A 4-inch shock tube is also available.

Lastly, the Boeing Compressible-Flow Laboratory also includes two large Ludwieg tubes. The first has a 4-inch Mach-4 test section, and remains quiet to a length
Reynolds number of about 400,000. The second, which is nearing completion, will have a 9.5-inch Mach-6 quiet-flow test section. Instrumentation is specialized for study of laminar-turbulent instability and transition, and includes high-speed hot wires, fast-response pressure transducers, hot-film arrays and anemometers, a high-sensitivity laser-differential interferometer, a glow-discharge perturber, and a pulsed laser perturber.

DYNAMICS AND CONTROL

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

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

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

PROPELLION

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

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

The High Pressure Laboratory, also located at MZL is a major new facility shared with Mechanical Engineering. This facility has two 500 square foot test cells rated for propulsion testing up to 10,000 lbf thrust levels. The airbreathing propulsion cell has a cyclic pulse detonation rig capable of simultaneous firing of up to four tubes. A 5 million sample per second high speed data system and associated pressure instrumentation is available in addition to a more standard suite of pressure/temperature/thrust instrumentation. A high-pressure gas turbine combustor experiment is also housed in this cell. The rocket propulsion cell has capabilities to test liquid oxygen/hydrocarbon thrust units at thrust levels up to 5000 lbf and pressures up to 5000 psi. Experiments in both the airbreathing and rocket propulsion cells are controlled remotely with a state-of-the-art data acquisition and control panel.

The Energy Conversion Laboratory is housed at ASL, and is comprised of large four-function work areas. The Propellant Area is set up to synthesize and enrich/analyze Non-Toxic Hypergolic Miscible Fuels and Rocket Grade Hydrogen Peroxides, respectively. The Electrochemistry Area is designed to study the formation of hydrogen peroxide from water and electrical energy. The decomposition of hydrogen peroxide within a fuel cell is also studied in this laboratory. The Physical Energy Conversion Area was established to study thermoelectric and thermionic effects, as well as advanced ion thruster technologies. The Catalysis Area is used to synthesize and characterize heterogeneous and homogeneous substrates and additives for propulsion applications.

STRUCTURES AND MATERIALS

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

The McDonnell Douglas Composite Materials Laboratory contains equipment and facilities for general material testing and for fabrication of composite laminates. An autoclave specially designed for curing epoxy-matrix composites is available for laminate fabrication. A hot press is used for forming thermoplastic composites, and an EnTec filament winding machine is available for making cylindrical composite structures. A water jet cutting machine is used for specimen preparation. Four complete MTS material and fatigue testing machines (55 kip, 22 kip, 11 kip, and 1 kip capacity) and associated equipment are used to perform ultimate strength, stiffness, and fatigue tests on various composite materials. Nondestructive inspection equipment includes an x-ray machine and an ultrasonic C-scan system. Additional facilities for preparing laminated composites, impact testing, and creep testing are available.

The Fatigue and Fracture Laboratory is well-equipped to conduct structural integrity motivated research directed at evaluating the damage tolerant properties of
materials and components. Two computer-controlled electro-hydraulic test machines (11,000 and 22,000 lb. capacity) and associated equipment are used to measure fracture loads and to study fatigue crack formation and propagation in test specimens subjected to simulated aircraft or spacecraft load histories. Facilities are also available to artificially corrode specimens in connection with corrosion and/or corrosion/fatigue related research, and to perform nondestructive inspections by magnetic particle and dye penetrant methods.

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

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

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

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

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

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

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


M. H. Williams, Professor and Associate Head, Ph.D., Princeton, 1975, aerodynamics and computational fluid mechanics.
GREGORY A. BLAISDELL
1991
Associate Professor

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

Interests
Computational fluid mechanics
Transition and turbulence

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

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

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

Current research projects are described below. Many of these investigations are
being carried out using parallel processing computers. Parallel computing and advanced
numerical methods is another area of interest.
Development of Large Eddy Simulation Methodology and Application to a Turbulent Axial Vortex (Sponsored by Purdue Research Foundation; Graduate student: Brijesh Eshpuniyani; Computer resources: PUCC (IBM SP 2))

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

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

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

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

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

Conference Proceedings, Presentations, Invited Lectures, and Reports


STEVEN C. COLLCOTT
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

Conference Proceedings, Presentations, Invited Lectures and Reports


ANASTASIOS S. LYRINTZIS
1994
Professor

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

Interests
Computational Aeroacoustics
Aerodynamics for rotorcraft and jet flows

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

Research Areas

a. The Use of Integral Techniques in Computational Aeroacoustics

Dr. Lyrintzis has made significant contributions in the use of integral techniques Computational Aeroacoustics (CAA). CAA is concerned with the prediction of the aerodynamic sound source and the transmission of the generated sound starting from the time-dependent governing equations. The goal is to improve the state-of-the-art predictive techniques, so that aircraft and rotorcraft noise can be reduced. Dr. Lyrintzis has pioneered the use of integral techniques, (i.e. the Kirchhoff method and the porous Ffowcs Williams Hawkings [FWH] equation) for describing source propagation. The methods are attractive because they utilize surface integrals (over a source region) to determine far-field acoustics, as opposed to the memory intensive volume integrals found in traditional acoustic analogy methods.

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

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

Dr. Lyrintzis’ research demonstrates that a simple set of versatile portable Kirchhoff/Acoustic Analogy subroutines can be developed to analyze and reduce noise generation in a number of applications including fans, propellers, air-conditioning units etc.


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

Sponsored Research Summaries

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

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

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

**Publications**

**Conference Proceedings, Presentations, Invited Lectures, and Reports**


STEVEN P. SCHNEIDER  
1989  
Associate Professor  

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

Interests  
Experimental fluid mechanics  
High-speed laminar-turbulent transition  

Research Areas  
High-speed laminar-turbulent transition is critical for applications including hypersonic reconnaissance vehicles, thermal protection for re-entry vehicles, drag reduction on supersonic transports, and flow noise and heat transfer above IR windows on interceptor missiles. Unfortunately, nearly all existing high-speed experimental results are contaminated by facility noise, such as that radiating from the turbulent boundary layers normally present on the test-section walls of supersonic tunnels. Just as at low speeds, reliable experimental progress requires low-turbulence wind tunnels with noise levels comparable to those in flight.  

Sponsored Research Summaries  
NASA Langley has developed quiet supersonic tunnels over the last 25 years to address problems such as laminar-turbulent transition that are strongly affected by noise level. Detailed measurements of the mechanisms of transition are needed, under low noise conditions, in order to develop computational models that are grounded on the correct flow physics.  

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

A new 18-inch stainless-steel Ludwieg tube is now operational with a 9.5-inch quiet-flow Mach-6 test section. Quiet-flow operation to a length Reynolds number of 13 million is projected (AIAA Paper 98-0547), although quiet-flow has so far been achieved only at low Reynolds numbers. Modern digital and optical instrumentation will enable
efficient use of the 10-second run-time, and the short duration keeps operating costs low. The larger test section enables testing with larger models and thicker boundary layers.

**Publications**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


JOHN P. SULLIVAN
1975
Professor

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

Interests
Experimental aerodynamics
Laser instrumentation
Luminescent sensors for temperature and pressure measurements

Research Areas
Current research interest is in the area of experimental aerodynamics with
particular emphasis on comparison of experimental data with computational analysis. Current programs include:
1. High lift systems
2. Suction/blowing airfoils

In addition to the above programs, work also continues on developing laser
instrumentation (laser Doppler velocimeter, particle image velocimeter, laser sheet
concentration, etc.) and pressure and temperature paint for:
1. Wind tunnels - low speed to hypersonic
2. Gas turbine engines
3. Flight tests

Publications

Sakaue, H., and Sullivan, J. P., “Time Response of Anodized Aluminum Pressure-

Conference Proceedings, Presentations and Invited Lectures

MARC H. WILLIAMS
1981
Professor and Associate Head

Degrees
B. S., University of Pittsburgh, Aeronautical Engineering, Magna Cum Laude, 1969
M. A., Princeton University, Aerospace & Mechanical Sciences, 1971
Ph.D., Princeton University, Aerospace & Mechanical Sciences, 1975

Interests
Aerodynamics
Computational fluid Mechanics

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

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

Conference Proceedings, Presentations, Invited Lectures and Reports
Faculty Members

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

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

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

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

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

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

M. A. Rotea, Professor, Ph.D., Minnesota 1990, robust and nonlinear multivariable control, optimization, and system identification.
DOMINICK ANDRISANI
1980
Associate Professor

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

Interests
Estimation
Control
Dynamics
Flight Aircraft Flying Qualities

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

Conference Proceedings, Presentations, Invited Lectures and Reports
Aircraft and Tow Cable,” paper no. AIAA-2001-4254, AIAA Atmospheric Flight
Mechanics Conference, Montreal, Canada, Aug. 6-8, 2001.

the Motion Imagery Geopositioning Review and Workshop, Purdue Univ., W. Lafayette,
IN, July 24-25, 2001.

Andrisani, II, D., and Hoshizaki, T., “Aircraft Simulation Study Including Inertial
Navigation System (INS) Model with Errors,” presented at the Motion Imagery


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
Structures: Some Analytical Solutions,” International Journal of Solids and Structures,

Conference Proceedings, Presentations, Invited Lectures and Reports
Acikmese, A. B., and Corless, M., “Robust Constant Output Tracking for Uncertain/Nonlinear Systems with PI Controllers,” American Control Conference,

Acikmese, A. B., and Corless, M., “Robust Tracking and Disturbance Rejection for Uncertain/Nonlinear Systems with PI Controllers,” 39th Annual Conference on

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 $H^\infty$ 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

311-340.
JAMES L. GARRISON  
Assistant Professor  
2000

**Degrees**

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

**Interests**

Satellite navigation  
GPS  
Remote sensing

**Publications**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


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


Conference Proceedings, Presentations, Invited Lectures and Reports


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

Patents

Conference Proceedings, Presentations, Invited Lectures, and Reports
Autonomous Aerobraking for Near-Term Mars Exploration, paper no. AAS-01-388,
AAS/AIAA Astrodynamics Specialists Conference, Quebec City, Quebec, Canada, July

Orbiter Mission,” paper no. AAS-01-463, AAS/AIAA Astrodynamics Specialist
Conference, Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

Uranian Satellites, paper no. AAS-01-464, AAS/AIAA Astrodynamics Specialists
Conference, Quebec City, Quebec, Canada, July 30-Aug. 2, 2001.

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

to Design and Optimization of Low-Thrust Trajectories with Gravity-Assists,” paper no.
AAE-01-468, AAS/AIAA Astrodynamics Specialists Conference, Quebec City, Quebec,

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

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


MARIO A. ROTEA

1990
Professor

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

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

Awards and Major Appointments
NSF Young Investigator Award
Center for Satellite Engineering, Co-Director

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

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

**Modeling and Parameter Estimation of Autonomous Parachutes**

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

**Analysis and Design of Extremum Seeking Algorithms**

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

**Publications**


**Conference Proceedings, Presentations, Invited Lectures, and Reports**


Faculty & Staff Member

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

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

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

Scott Meyer, Senior Engineer, MSAE 1991, Purdue Univ.
WILLIAM E. ANDERSON  
2001  
Assistant Professor

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

Interests  
Combustor design  
Combustion stability  
Atomization  
Combined cycle propulsion

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

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

Non-Toxic Propellants – It is imperative to find safe replacements for highly toxic storable propellants. Before new propellant combinations can be used, reliable design databases must be developed. Experimental combustion data are being generated for hydrogen peroxide and dimethylethylamidoazide, two propellants that are significantly less toxic than storable propellants currently in use. The experiments include both realistic combustor conditions and geometries and measurements of propellant drop vaporization and chemical reaction in optically accessible chambers. Work is also

**Conference Proceedings, Presentations, Invited Lectures and Reports**


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**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


SCOTT MEYER
2001
Sr. Engineer

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

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

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

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

Mr. Meyer is a co-patent holder for a hybrid rocket engine ignition device.
JOHN J. RUSEK  
1998  
Adjunct Assistant Professor  

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

Interests  
Energy Conversion  
Chemical and Physical Propulsion  
Power Generation  

Awards and Major Appointments  
• Who’s Who in the World  
• Who’s Who in America  

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

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

Conference Proceedings, Presentations, Invited Lectures and Reports  


Faculty Members

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

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

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

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

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

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

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

Terrence A. Weisshaar, Professor, Ph.D., Stanford, 1971, aircraft structural mechanics, aeroelasticity, integrated design.
WILLIAM A. CROSSLEY
1995
Associate Professor

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

Interests
Optimization
Rotorcraft and aircraft design
Structure design

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

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

Genetic Algorithm Issues for Optimal Smart Actuator Placement. This research is investigating approaches for smart actuator placement to provide aircraft maneuverability without requiring hinged flaps or other control surfaces. The effort supports many of the goals of the Multidisciplinary Design Optimization focus efforts in NASA’s Aircraft
Morphing program. Computational studies are being conducted to allow comparison and selection of appropriate techniques for posing and solving an actuator placement problem. The work began with a geometrically simple wing model, but the approaches identified during this research have been applied to complete aircraft configurations. The problem statement and algorithm application are being used at NASA Langley by researchers working on the Aircraft Morphing Program. Research in this area has been cited twice as technical highlights for the NASA Langley Multidisciplinary Optimization Branch; once in 1998 and once in 1999.

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

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

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

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

Publications

Conference Proceedings, Presentations, Invited Lectures and Reports


JAMES F. DOYLE
1977
Professor

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

Interests
Structural dynamics
Experimental Mechanics
Inverse Problems
Wave propagation

Research Areas

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

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

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

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

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

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

FORCE IDENTIFICATION: from measurements made on the structure being
able to determine the impact of force history.
REMOTE SENSING: from analysis of the reflected and transmitted waves being able to locate flaws and estimate their size.

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

Whole Field Image Characterization
An alternative to strain gages and accelerometers in dynamic measurements is to use ultra-high speed photography coupled with such methods as photoelasticity; and moiré. The question being investigated is: Under what circumstances is a single (or a limited number) of photographs capable of completely characterizing the wave information? This touches on some fundamental aspects of transform theory coupled with measurement theory. The payoff is that photographs combined with digital imaging techniques offer unique possibilities for recording and post-processing the data. This is essentially an experimental problem because experimental data is always incomplete, so questions of quality of the data, the amount of data, etc. must be confronted, as well as the following aspects: (1) High-Speed photography and photoelasticity (2) Digital imaging techniques (3) @-D Fast Fourier Transforms.
THOMAS N. FARRIS  
1986  
Professor and Head

Degrees
B. S., Rice University, Cum Laude, Mechanical Engineering, 1982  
M. S., Northwestern University, Theoretical and Applied Mechanics, 1984  
Ph.D., Northwestern University, Theoretical and Applied Mechanics, 1986

Interests
Tribology  
Manufacturing processes  
Fatigue and fracture

Awards and Major Appointments

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**


**Books**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


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

Degrees
B. S., University of Illinois at Urbana-Champaign, General Engineering, 1968
M. S., University of Illinois at Urbana-Champaign, Theoretical and Applied Mechanics, 1969
Ph.D., University of Illinois at Urbana-Champaign, Theoretical and Applied Mechanics, 1971

Interests
Damage-tolerant structures and materials
Fatigue and fracture
Aging aircraft
Nondestructive inspection

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

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

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

Fundamental crack growth research is directed at predicting crack formation by fretting, corrosion, or cyclic loading, and as well as characterization of fatigue crack growth under complex variable amplitude and/or elevated temperature load histories.
Stress intensity factor analyses are aimed at obtaining solutions to evaluate complex two- and three-dimensional crack configurations common to aerospace structures (e.g. cracked fastener holes, dovetail joints, etc.).

**Conference Proceedings, Presentations, Invited Lectures and Reports**


PETER K. IMBRIE
Freshman Engineering
Assistant Professor

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

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

Research Areas
Current research interests include, educational research, solid mechanics, experimental mechanics, nonlinear materials characterization, microstructural evaluation of materials, and experiment and instrument design. He has been involved with various research projects sponsored by NSF, NASA, and AFOSR, ranging from education related issues to traditional research topics in the areas of elevated temperature constitutive modeling of monolithic super alloys and environmental effects on titanium based metal matrix composites.
HYONNY KIM
2001
Assistant Professor

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

Interests
Composites
Impact
Stability
Adhesive Joining

Research Areas
Adhesive Joining

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

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

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

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

Publications

Conference Proceedings, Presentations, Invited Lectures and Reports


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**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


TERRENCE A. WEISSHAAR
1980
Professor

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

Interests
Aircraft structural mechanics
Aeroelasticity
Integrated Design

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

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

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

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

**Publications**


**Conference Proceedings, Presentations, Invited Lectures and Reports**


RESEARCH AND OTHER SCHOLARLY ACTIVITIES

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage of Total</th>
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<tbody>
<tr>
<td>Department of Defense</td>
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<td>NASA</td>
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<td>National Science Foundation</td>
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<td>Industry</td>
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<td>Indiana 21st Century R &amp; D</td>
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<td>Other</td>
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<td>NASA</td>
<td>Improved Preliminary Design Analysis Process for High-Pressure Rocket Combustion</td>
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<td>NASA</td>
<td>Development of a Partial Design Database for Advanced Hydrogen Peroxide Engines</td>
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<td>Orbital Sciences</td>
<td>Upper Stage Flight Experiment (USFE) Injector Calibration and HTP Flow-test</td>
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<td>NASA</td>
<td>Field Test Methods for Hydrogen Peroxide Stability Margin</td>
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<td>Design, Fabrication, and Testing of a Rocket Based Combined Cycle Flight Experiment</td>
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<td>Indiana Space Grant Consortium Program Grant</td>
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<td>Rockwell Collins</td>
<td>Portable Data Acquisition and Control System</td>
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<td>Airborne Motion Imagery Modeling Study</td>
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<td>Rolls-Royce</td>
<td>Dynamics of Engine Oil Sumps and Drains</td>
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<td>NASA</td>
<td>Zero-Gravity Validation of Surface-Tension Propellant for Rocket-Grade Hydrogen Peroxide</td>
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<td>Laser-Perturbation Design</td>
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<td>Rolls-Royce</td>
<td>Purdue Sump-Flow Research</td>
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<tr>
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<td>University of Illinois</td>
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<td>NSF Matching</td>
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<td>Applied Optimiz.</td>
<td>Genetic Algorithm Approaches for Unknown Target Signature Separation</td>
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<td>NASA</td>
<td>Design Methods and Optimization for Morphing Aircraft</td>
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<td>Mide Tech. Corp.</td>
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<td>NASA</td>
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<td>NASA</td>
<td>Investigation of the Fundamental Properties of Forward Scattered GPS Signals for Oceanographic Remote Sensing</td>
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<td>Model Improvement and Validation for GPS Code Tracking in High Earth Orbits (HEO)</td>
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<td>ALCOA</td>
<td>Durability of Aircraft Joints</td>
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<td>NASA</td>
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<td>Science Applications International</td>
<td>Trajectory Control through Thrust Vector Rotation</td>
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<td>Applications of Dynamical Systems Theory, Control Methods and Optimization Strategies to Trajectory Design &amp; Mission Analysis Involving Formation Flying at Libration Points for GSFC Missions</td>
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<td>Univ. of Calif. Santa Barbara/FAA</td>
<td>Damage Tolerance Design of Bonded Composite Structures</td>
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<td>Buckling Stability of Disbonded Composite Structures</td>
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<td>Trajectory Analysis and Design in Support of Planetary and Interplanetary Missions</td>
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<td>Low-Thrust Gravity-Assist Trajectory Design</td>
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<td>Cyclical Visits to Mars Via Astronaut Hotels</td>
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<td>21st Century Research and Technology Fund</td>
<td>Development of Low Jet Noise Aircraft Engines</td>
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<td>Advanced Nontoxic Propellant Propulsion</td>
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<td>Pratt &amp; Whitney</td>
<td>Advanced Hydrogen Peroxide Catalyst Testing</td>
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<td>Analysis and Design of Multivariable Extremum Seeking Algorithms</td>
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<td>Sandia National Labs</td>
<td>Aerothermodynamic Predictions for Hypersonic Reentry Vehicles</td>
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<td>NASA</td>
<td>Cold-Wire Measurements in the Body-Flap Cavity of an X-38 Model</td>
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<td>NASA</td>
<td>Mechanisms of Boundary-Layer Transition on Reusable Launch Vehicles</td>
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<td>Sandia National Labs</td>
<td>Effect of Roughness on Boundary-Layer Transition for Re-entry Vehicles: Quiet Tunnel Experiments</td>
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<td>AFOSR</td>
<td>Mechanisms of Hypersonic Boundary-Layer Transition on a Generic Scramjet Forebody</td>
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<td>AFOSR</td>
<td>Active Control of Secondary Flow in Engine Inlets</td>
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<td>Raisbeck Engineering</td>
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<td>A. T. C. Incorporated</td>
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<td>A Laser Scanning PSP-TSP System for Propulsion Applications</td>
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<td>Physical Acoustics Corporation</td>
<td>Composite Armor Material Characterization</td>
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<td>ARO</td>
<td>Lightweight Layered Materials/Structures for Damage Tolerant Armor</td>
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<tr>
<td></td>
<td>(Co-PI's: Doyle, Espinosa, Bolton, Trumble)</td>
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<td>ONR</td>
<td>Dynamic Constitutive and Failure Modeling of Composite Materials and Structures</td>
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<tr>
<td>NSF</td>
<td>Fracture and Fatigue of Piezoceramics Under Combined Mechanical and Electrical Loading</td>
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<td>Tuskegee Univ./NSF</td>
<td>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</td>
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<td>Development of Composites Reinforced with Short Wavy Fibers</td>
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<td>Mixed Mode Fracture of Tubular Steel Structures</td>
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<td>Modeling and Lowering Residual Stresses in Bonded Composite Patch Repairs of Metallic Aircraft Structures</td>
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<td>Modeling of Nano Materials</td>
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<td>Analytical Study of Adaptive Control Surfaces for Drag Reduction for Sensorcraft Class</td>
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<td>Perez-Ruberte, Eddie T. N. Farris</td>
<td>“Elasto-Plastic Finite Element Analysis of Contacts with Applications to Fretting Fatigue”</td>
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<td>Shimo, Masayoshi S. D. Heister</td>
<td>“Modeling of Oil Film Behavior on a Seal Runner and a Sump Wall”</td>
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<td>Skoch, Craig R. S. P. Schneider</td>
<td>“Final Assembly and Initial Testing of the Purdue Mach-6 Quiet-Flow Ludwieg Tube”</td>
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<td>Bulathsinghala, Ivor J. S. D. Heister</td>
<td>“Trajectory Control Through Thrust Vector Rotation”</td>
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### MASTER’S THESES

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<td>Kowalkowski, Matthew</td>
<td>“Trajectory Control for Agile Landmines”</td>
<td>M.S.</td>
<td>May 2002</td>
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<td>Kenneth</td>
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<td>Krautheim, Michael S.</td>
<td>“Downstream Measurements of a High Reynolds Number Horseshoe Vortex”</td>
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### DOCTORAL THESES

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<tr>
<td>Chen, Yun</td>
<td>“Analysis of Indentation Cracking in Brittle Solids”</td>
<td>Ph.D.</td>
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<td>T. N. Farris</td>
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<td>W. A. Crossley</td>
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<td>Hu, Huiwen</td>
<td>“Modeling Physical Aging in Polymeric Composites”</td>
<td>Ph.D.</td>
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<td>C. T. Sun</td>
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<td>Jin, Long</td>
<td>“Simulation of Quenching and Tempering of Steels”</td>
<td>Ph.D.</td>
<td>August 2001</td>
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<td>T. N. Farris</td>
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<td>M. H. Williams</td>
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<td>Maley, Scott</td>
<td>“Particulate Enhanced Damping of Sandwich Structures”</td>
<td>Ph.D.</td>
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<td>Tsai, Jia-Lin</td>
<td>“Dynamic Microbuckling Model for Compressive Strength of Polymeric Composites”</td>
<td>Ph.D.</td>
<td>August 2001</td>
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<td>D’Amato, Fernando J.</td>
<td>“Efficient Algorithms for the Maximization of Linear Fractional Transformations”</td>
<td>Ph.D.</td>
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<td>M. A. Rotea</td>
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<td>Ekici, Kivanc</td>
<td>“Parallel Computing Techniques for Rotorcraft Aerodynamics”</td>
<td>Ph.D.</td>
<td>December 2001</td>
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<td>A. S. Lyrintzis</td>
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<td>Golden, Patrick John</td>
<td>“High Cycle Fatigue of Fretting Induced Cracks”</td>
<td>Ph.D.</td>
<td>December 2001</td>
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<td>A. F. Grandt</td>
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<td>Pakalapati, Rejeev T.</td>
<td>“Fretting Contact of Dissimilar Isotropic/Anisotropic Materials”</td>
<td>Ph.D.</td>
<td>December 2001</td>
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<td>T. N. Farris</td>
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<td>Xu, Changhai</td>
<td>“Simulation of Orifice Internal Flows Including Cavitation and Turbulence”</td>
<td>Ph.D.</td>
<td>December 2001</td>
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<td>S. H. Collicott</td>
<td>Experiments”</td>
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School of Aeronautics and Astronautics 2001-2002 Research Report 84
# Colloquium Series – Fall 2001

<table>
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<tr>
<th>DATE/TIME</th>
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<th>SPEAKER</th>
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<tbody>
<tr>
<td>September 24, 2001  7:00 p.m.</td>
<td>Air Force Basic Research Directions and Opportunities</td>
<td>Colonel Steven G. Reznick, Commander &amp; Deputy Dir. AFOSR</td>
</tr>
<tr>
<td>October 4, 2001  1:30 p.m.</td>
<td>Mars Analog Research in the High Canadian Arctic</td>
<td>Jaret Matthews, Purdue A&amp;AE, Undergraduate Collaborator on the NASA Haughton-Mars Project, &amp; Crewmember of the Mars Arctic Research Station</td>
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<tr>
<td>October 25, 2001  3:30 p.m.</td>
<td>Hypersonic Testing with Rocket Sleds</td>
<td>Birk Billingsley, Test Mgr. Hypersonic Upgrade Program U.S.A.F.</td>
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<tr>
<td>November 1, 2001  1:30 p.m.</td>
<td>Pratt &amp; Whitney Gas Turbine Engine Instrumentation Overview</td>
<td>Dr. Robert Johnston, Pratt &amp; Whitney Technology Mgr. for the Measurement Ctr.</td>
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<tr>
<td>November 15, 2001  4:00 p.m.</td>
<td>Air Transportation System Security</td>
<td>John B. Hayhurst, Sr. Vice President The Boeing Co. President, Air Traffic Mgmt.</td>
</tr>
<tr>
<td>November 29, 2001  4:00 p.m.</td>
<td>Propulsion Technology for Next Generation Reusable Launch Vehicles and Satellites</td>
<td>R. Joseph Cassady, Sr. Mgr. Of Business Dev. for the Eastern Region U.S. General Dynamics Space Propulsion Systems</td>
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<tr>
<td>**November 30, 2001  4:00 p.m.</td>
<td>Free Shear Flows of Polymers and Comments on Turbulent Drag Reduction</td>
<td>Professor G. M. Homsy, Mech. &amp; Environ. Engrg. Univ. of California Santa Barbara</td>
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</tbody>
</table>
December 11, 2001  1:30 p.m.  Grissom 170

The Use of RANS/CFD in the Prediction of Jet Noise  

Phillip J. Morris  
Boeing/A.D. Welliver Prof. of Aerospace Engrg.  
Penn State Univ.

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

**Jointly sponsored by the School of Aeronautics & Astronautics and the Mechanical Engineering Dept.; Midwest Mechanics Seminar
# Colloquium Series – Spring 2002

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

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

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

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

Other highlights include:

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

STUDENT HIGHLIGHTS

There are four student organizations with a relationship with the School. They are the Aeronautics and Astronautics Engineering Student Advisory Council (AAESAC); American Institute of Aeronautics and Astronautics (AIAA); Students for the Exploration and Development of Space (SEDS); and Sigma Gamma Tau (SGT). AIAA, SGT, and SEDS conducted the 6th annual Fall Space Day. Additionally, SEDS hosted their annual Open Forum Discussion entitled “Whose Bucks for Buck Rogers.” SGT hosted “Professor Pizzas,” an opportunity for students to interact one-on-one with an AAE professors and visiting dignitaries. Several student groups continue to perform well in national design competitions.
Student Awards

Congratulations to the following students who have earned top honors

**Summer 2001**

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

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

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

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

**Fall 2001**

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

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

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

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

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

Indiana Space Grant Consortium Winners

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

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

CSMES Scholarship

Congratulations to See-Chen Lee, James Pinyerd, Brent Robbins and Kevin Wade who were awarded NSF CSMES scholarships.
Congratulations to Chris Peters, who won first place in the IronCAD student design competition for AY 2000-2001 based on the solid modeling he did for the Silarius 490 project. And to Jeff Rodrian, who took an honorable mention for the 2001 SURFCAM parts contest for the work on the Hyperion composite radio controlled aircraft.

2002 Clare Boothe Luce Fellowship – Belinda Marchand

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

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

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

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

2002 - Outstanding Senior Award – Luca Bertucelli

2002 - Outstanding Graduate Student Award - Jason Helms

2002 Hsu Lo Fellowship – Hai-Yang Qian


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

Congratulations to:

Olivia Djibo on the Special John Logan Memorial Award
Darryl Johnson on the merit award from Daimler-Chrysler, and the Sophomore Class Award Conrad Golbov on the merit award from Lockheed Martin
Presentation of Awards at the 2002 Society of Women Engineers Brunch

Congratulations to:

Jayleen Guttromson for being named the Outstanding Sophomore, Boeing Company
Heather Pawley on a merit award from the Boeing Company
Gina Pieri on a merit award from the Boeing Company
Robin Pinson on a merit award from Alcoa Foundation
Elizabeth Newsome on a merit award from Lockheed Martin
Melanie Silosky on a merit award from United Technologies

OUTREACH HIGHLIGHTS

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

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

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

July 2001 to June 2002
## CURRICULUM AND COURSE OFFERINGS

Course enrollments and summarized class enrollment statistics are listed below:

### Course Enrollments
**School of Aeronautics and Astronautics**

**2001-2002 Academic Year**

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<td>Garrison</td>
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<td>Corless</td>
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<td>Imbrie</td>
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<td>Sullivan</td>
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<td>Fluid Mechanics</td>
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# Aerospace Engineering Requires a Multidisciplinary Curriculum

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

## Aerodynamics
<table>
<thead>
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<th>Required Undergraduate</th>
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<tr>
<td>333-Fluid Mechanics &amp; Lab.</td>
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<td>334-Aerodynamics and Lab</td>
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## Dynamics and Control
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<td>421-Flight Dynamics or</td>
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<td>440-Spacecraft Att. Dynamics</td>
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## Propulsion
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## Structures and Materials
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<td>352-Structural Analysis &amp; Lab</td>
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## Undergraduate Electives
- 412-Intro to CFD
- 414-Compressible Aero
- 416-Viscous Flows

## Undergraduate Capstone Design
- 450 Spacecraft Design or 451 Aircraft Design

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

## Undergraduate/Graduate Electives
- 511-Intro. to Fluid Mech.
- 512-Computational Aero
- 514-Intermediate Aero
- 515-Rotorcraft Aerodynamics
- 518-Low Gravity Fluid Mech.
- 519-Satellite Aerodynamics
- 520-Experimental Aero.
- 613-Viscous Flow Theory
- 615-Aerocoustics
- 626-Turbulence
- 507-Basic Mechanics
- 531-Flight Mechanics
- 532-Orbit Mechanics
- 564-Systems Anal. and Control
- 565-Guidance and Control
- 567-Intro to Stochastic Proc.
- 574-Digital Flight Control Sys.
- 590G-Satellite Nav and Pos
- 632-Adv Orbital Dynamics
- 660-Operator Methods
- 666-Nonlinear Dynamics
- 696-Multivariate Control
- 536-Adv Energy Conversion
- 537-Hypersonic Propulsion
- 538-Air Breathing Propulsion
- 539-Adv. Rocket Propulsion
- 630-Stability of Free Surfaces
- 637-Future Prop Concepts
- 546-Struct. Dyn and Stability
- 547-Experimental Stress Anal.
- 550-MDO
- 551-Design Th and Methods
- 552-NDE of Struct and Mat.
- 553-Elasticity in Aero. Eng
- 554-Fatigue in Struct. and Mat.
- 555-Mech. of Composite Mat.
- 556-Aeroelasticity
- 558-Finite Element Methods
- 559-Mech. of Friction & Wear
- 646-Elastic Wave Propagation
- 654-Fracture Mechanics
- 655-Adv Topics in Composites
### Summarized Class Enrollment Statistics for the 2001-2002 Academic Year

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<th>Semester</th>
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<th>100, 200, 300, 400, Levels</th>
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<th>600 Level</th>
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<td>8</td>
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*(does not include AAE 490, 590, 698 and 699)*
STAFF FOR THE 2001-2002 ACADEMIC YEAR

Administrative Assistants
  L. Flack, T. Moore

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

Clerical
  P. Kerkhove, S. Wise

Director of Communications and Development
  T. Bobillo

Communications Administrator
  A. Broughton

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