CAV Review '05

CENTER FOR ACOUSTICS AND VIBRATION

CAV Workshop
May 10 – 11, 2006

This year's workshop will be held at the Penn Stater Conference Center and will focus on the new research initiatives within the Center.

The program for this year will feature a mix of presenters – our own technical group leaders, our corporate sponsors and our international liaisons. Our graduate students and their advisors associated with the particular CAV technical groups will be available for questions on their research projects. With such a good mix of people, it will be a unique opportunity for all of us to broaden our perspectives on the emerging technologies within and beyond our particular disciplines.

At last year's workshop attendees were able to tour the Penn State Nanolab. Since this activity was so well received we will again tour laboratories associated with the Materials Research Institute.

While formal presentations are organized to allow for the exchange of technical information there will be opportunities for informal discussions at a picnic Wednesday evening.

Engineered Adaptive Structures V

The Center for Acoustics and Vibration is sponsoring the Engineered Adaptive Structures V (EAS V) Conference in Maiori, Amalfi, Italy, June 18 -23, 2006. The conference will be held at the Hotel Reginna Palace which overlooks the picturesque sea coast.

The Conference's organizing committee is comprised of Antonio Concilio, CIRA, Italy; Thilo Bein, Fraunhofer Institute for Structural Durability & System Reliability LBF, Germany; Michael Brennan, ISVR, United Kingdom; and Stansilaw Pietrzko of EMPA, Switzerland. This group has retained the same format for the event as the past four with morning sessions and afternoons for colleagues to participate in informal discussion. There will also be plenty of time for attendees and their guests to take in all the sights of the surrounding area.

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Penn State Research Team Develops OctArm Soft Robot Manipulator

OctArm mounted on a Foster-Miller Talon Robot

Recent interest in expanding the capabilities of robot manipulators has led to significant research in continuum manipulators. The idea behind these robots is to replace the serial chain of rigid links in conventional manipulators with smooth, continuous, and flexible links. Unlike traditional rigid-linked robots, continuum robot manipulators can conform to their surroundings, navigate through unstructured environments, and grasp objects using whole arm manipulation. Soft continuum manipulators can be designed with a large number of actuators to provide hyper-redundant operation that enables dexterous movement and manipulation with robust performance. This improved functionality leads to many applications in industrial, space, and defense robotics.

Previous continuum robots used cable-tendon and pressurized tube actuatorswith limited performance. Cable-tendons must be tensioned or the cables become snarled or fall off drive pulleys, limiting the robot speed. Pneumatic bellows have low shear stiffness, limiting load capacity. Thus, there exists a need for a highly dexterous, fast, and strong soft robot manipulators.

Dr. Christopher Rahn, Professor of Mechanical Engineering at Penn State along with his students Dustin Dienno and Mike Pritts, and assisted by Dr. Michael Grissom developed the OctArm manipulator uisng air muscle actuators. These actuators are constructed by covering latex tubing with a double helical weave, plastic mesh sheath to provide the large strength to weight ratio and strain required for soft robot manipulators.

OctArm is divided into three sections. Each section is capable of two axis bending and extension which allows nine degrees of freedom. The manipulators are actuated with pressurized air (Maximum pressure = 120 psi) pressure control valves and polyurethane connective tubing.

The air muscle actuators are optimized to provide the desired wrap angles and workspace. The distal section of each OctArm is designed to have a minimum wrap diameter of 10 cm. The length of each section is chosen so that the manipulator can provide a range of 360 degrees wrap angles to accommodate a wide range of objects sizes. To provide the desired dexterity, OctArm is constructed with high strain extensor actuators extend up to 80%.

To provide two-axis bending and extension, three control channels are used. selected. Six actuators are used in sections one and two and three actuators are used in section three. The six sections have two actuators for each control channel and results in actuators located at a larger radius, corresponding to higher stiffness and load capacity. Secondary layers of mesh sleeving are used to group individual actua

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OctArm Manipulator (cont.)

tors in control channels. Three closely-spaced actuators provide high curvature for the distal sections. The third, visible, mesh layer or fabric skin is designed to protect the manipulator from abrasion and wear.

For the field tests, OctArm was mounted to the second link of a Foster-Miller TALON platform. The control valves and two air tanks provided nine channels of controlled pneumatic pressure. Clemson University provided the control electonics and operation interface for these tests. The OctArm /Talon system underwent extensive field trials in the spring of 2005 at the Southwest Research Institute (SwRI) in San Antonio, Texas.

Initial tasks included stacking and unstacking traffic cones. The ability of the system to grasp objects such as spheres and cylinders over a wide range of scales was recorded. The system was also operated in water. The OctArm was submerged in water, while attempting to grasp various payloads and to maintain grasps under turbulent flow. The system was also operated in rubble piles. The trials described demonstrate that OctArm continuum robots are a feasible and attractive alternative to conventional robot manipulators in unstructured environments, and also that there is room for improvement.

To further test the robot in real-world conditions, Dr. Rahn and his post-doc, Mike Grissom, took the Talon to the Radio Park Elementary School for demonstrations in three classrooms. First, the robot was teleoperated by Dr. Grissom while Dr. Rahn introduced the students to the vehicle and the electrical, mechanical, and computer engineering required to build it. The robot "responded" to audio commands (it has a microphone). Eventually, the fifth graders guessed that the robot was teleoperated after it answered some tough true/false questions. The third graders (and some of the teachers) initially thought it was just an extremely intelligent robot. The kindergarteners treated it like a pet dog – Robbie the Robot. The students were extremely excited about the visit and even wrote thank-you letters. Many said "I want to be an engineer!"

Robots in Education Program: Radio Park Elementary, State College, Pa, January 2005.

EAS V to be held in Italy (cont.)

As before EAS V will focus on the emerging technologies based on the concept that structures can be engineered to adapt to changing environments. This adaptability is achieved by integrating sensing and actuating devices within the structure together with some form of intelligence for control purposes. While the adaptability is common in the biological world, e.g., changes in the skin color of a chameleon to match its environment, adaptability in engineered structures is still very much an emerging technology. Applications similar to this are due to advances in four major technologies that are continuing to develop rapidly in Asia, Europe, and the USA. These include: development of modern, man-made transduction materials that both sense and actuate, e.g., piezo-ceramics, magnetostrictives, and shape memory alloys; modem digital control and decision theory; and miniaturization of electronic components used with sensors/actuators/controllers techniques for fabricating structures of composite materials with embedded sensors/actuators/controllers

More information on this conference can be found at www.cira.it/easv_conf or by emailing Karen Thal (kjt3@psu.edu).

Corporate Membership in the Center

Corporate membership in the Center for Acoustics and Vibration offers opportunities for collaborative technology development and transfer through the interactions of people from academia, industry, and government. Membership also entitles a representative to participate in the Center's annual Technology Transfer Workshop held every spring at Penn State, participation in a corporate recruiting program, and a consultation visit with Penn State researchers.

If you are interested in becoming a corporate member of the Center for Acoustics and Vibration and would like more information please contact Dr. Gary H, Koopmann, Director of the CAV at 814-865-2761 or by email at ghk1@psu.edu

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CIRA (Italy) – Antonio Concillio

CAV Members Receive Awards and Honors

*Christopher Rahn***,** PSES Outstanding Research Award
Eric Mockensturm, PSES Outstanding Advising Award
Gerald Lauchle, named a member of the National Academy of Engineering Steering Committee for Noise Control
Gary Koopmann, Humboldt Award for Senior U.S. Scientists
Bernhard Tittmann, Third place winner in the 5th Annual ASM-EDFAS Photo Contest
Michael Pedrick, named to the Chancellors List of Who's Who Among American Graduate Students
Anthony Atchley, elected president of ASA

Atchley Named President of ASA

Dr. Anthony Atchley, chair of the Acoustics Program at Penn State University has been named as president of the Acoustical Society of America. His one-year term will begin May 2006.

Atchley has been the chair of the Acoustics Program as well as a faculty member at Penn State since 1997. His research interests include finite amplitude acoustics, physical acoustics, sonoluminescience, and thermoacoustic heat transfer.

Prior to coming to Penn State, Dr. Atchley was a professor and chair of the Department of Physics at the Naval Postgraduate School. Atchley received his BS from the University of the South, his M.S. from the New Mexico Institute, and his Ph.D. from the University of Mississippi

Scholars Visit the CAV

During this past year, the CAV Quiet Product Design Group was pleased to host Dr. Katsuju Akamatsu, an expert in machinery acoustics, recently retired from the Mitsubishi Corporation in Japan. Dr. Akamatsu put his analytical skills to work in helping our group resolve some singularity problems that appeared in our spatial digitization models. Incidentally, Drs. Akamatsu and Koopmann were colleagues at the ISVR in Southampton in early 1970's.

The CAV was also pleased to have Dr. (Doug) Chih-Chun Cheng join the Quiet Products Design Group. Dr. Cheng is a Professor of Mechanical Engineering, National Chung Cheng University, Taiwan. While at the CAV, 'Doug' gave seminars, worked on laboratory projects with our graduate students and in general, contributed to the esprit de corps of the groups. We were grateful for his visit.

Koopmann receives Humboldt Award

Koopmann receiving award from Professor Dr. Wolfgang Fruhwald, President of the Alexander von Humboldt Foundation

Gary Koopmann, distinguished professor of mechanical engineering and Director of the Center for Acoustics and Vibration (CAV), has received the Humboldt Award for Senior U.S. Scientists from the Alexander von Humboldt Foundation in Bonn, Germany, in honor of his achievements in the disciplines of vibrations, acoustics and noise control. The Humboldt Awards are a lifelong tribute to the academic accomplishments of the awardees.

Award winners are invited to carry out research projects of their own choice at German research institutes. Koopmann will pursue his research project at the DLR, Germany's Aerospace Research Center and Space Agency, in collaboration with his colleague of 25 years, Dr. Wolfgang Neise, Director of the DLR's Institute for Turbulence Research. They will apply the emerging technology of smart materials to turbomachinery designs that could lead to a new and improved quieter generation of fans, compressors and jet engines. Their research effort is based on regeneration and active control mechanisms that emerged from cooperative efforts between scientists and engineers at Penn State's Center for Acoustics and Vibration and the DLR. During his six-month stay, Koopmann and his graduate student, Lee Gorny, will conduct experiments on DLR's world class turbomachinery facility to demonstrate the application of smart materials-based, noise control technology.

Koopmann has lectured extensively in Europe and Asia. In 2000, he was chosen as the inaugural recipient of Tokyo Institute of Technology's Chair of International Cooperation. In 1999, he was invited to give the prestigious Rayleigh Lecture at the International American Society of Mechanical Engineering Conference and Exposition and in 2000 was selected as the E.J. Richards Lecturer at the University of Southampton, U.K. As a Professional Engineer, Koopmann has been active on the editorial boards of the Journal of Sound and Vibration, Journal of Applied Acoustics, and the Applied Mechanics Review. He holds the rank of fellow in the Acoustical Society of America and the American Society of Mechanical Engineers. Koopmann earned his bachelor's degree at the University of Nebraska and his master's degree and doctoral degree from the Catholic University of America. Prior to coming to Penn State, Koopmann served as a research scientist at the US Naval Research Laboratory, the Institute of Sound and Vibration Research (University of Southampton, United Kingdom), and was director of the University of Houston's Laboratory for Sound and Vibration Research for eleven years. In 1988, Koopmann joined the mechanical engineering faculty at Penn State. In 1991, he became the founding director of Penn State's CAV—a center that has grown to encompass eight university departments and units with 40 affiliated faculty and over 100 graduate students.

Throughout his career, Koopmann has received numerous University and national awards and honors. Koopmann was recognized with the Per Bruel Gold Medal from ASME International for his research accomplishments in noise control and acoustics. He was awarded the University's special academic title of distinguished professor of mechanical engineering and was the recipient of the Penn State Engineering Society's Premier Research Award. His national honors include the Deutscher Akademischer Ausauschdienst Scholarship in and the US Naval Research Laboratory's Research Publication Award and Outstanding Achievement Award.

Gerald Lauchle Completes Successful Year as INCE/USA President

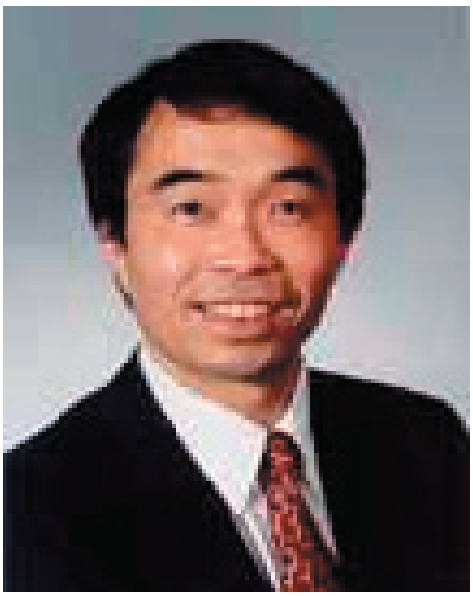
Dr. Gerald C. Lauchle has completed his year as President of INCE/USA. During his presidency Lauchle reports that the Institute continues to have many on-going noise control activities and initiatives. There is good stability within the organization; student membership has grown slightly; Noise Control Engineering Journal (NCEJ) is seeing an increase in papers; INCE/USA members are becoming more active in USA noise policy issues; and there were two very successful noise conferences held in 2005. INTER-NOISE 2005 took place in Rio de Janeiro during August, and NOISE-CON 2005 was concurrent with the 150th Meeting of the Acoustical Society of America (ASA) held in Minneapolis, MN during October. There were nearly 200 papers presented and published in the NOISE-CON Proceedings. The strong collaboration with ASA is very evident in that many of these papers came from special noise sessions jointly organized by the ASA Technical Committees on Noise, Architectural Acoustics, and Structural Acoustics. The remaining sessions were organized by the INCE/USA Technical Activities Board.

Lauchle also announces that the Board of Directors of INCE/USA has accepted the offer from the Australian Acoustical Society to hold Active 2006 at the University of Adelaide in September; INCE/USA will co-host with INCE/Japan INTER-NOISE 2006 in Honolulu in December; and NOISE-CON 2007 will be in Reno, NV in early fall with Penn Staters Steve Hambric and Steve Conlon serving as General and Technical Chairs, respectively.

A member survey and detailed analysis of the Board Certification and re-certification processes was recently completed. Various improvements and upgrades are being implemented because of this effort. There is a move within INCE/USA to have Board Certification be made equivalent to an Engineering State License in the discipline of noise control engineering. Basically, the INCE/USA Board Certification Exam will have to be accepted as equivalent to the Professional Engineering Exam. David Swanson of Penn State has been appointed Chair of an ad hoc committee to investigate and bring this action to closure.

The technology and policies of noise control engineering in the USA is the subject of a study being conducted by the National Academy of Engineering (NAE). Lauchle recognizes and thanks founding INCE/USA members George Maling, Bill Lang, and Leo Beranek for their continuous effort – since 1972 – in bringing the issues of noise and noise policy to the attention of the Academy and others in the Federal government. Through their direction of a Steering Committee (chaired by George Maling) consisting of practicing noise control specialists, the NAE held a very successful workshop in September 2005. Many INCE/USA members gave keynote addresses at this workshop, in addition to participating in working groups to define appropriate courses of action in the areas of noise control engineering cost-benefit analysis, demand, and education; new technologies; improved occupational noise controls and community noise metrics; public awareness; and government coordination and assistance. The study is expected to continue for at least two more years. The goals are to summarize the current state-of-the-art of noise control engineering, to recommend policies and practices for government agencies, and to develop an expanded research and education agenda.

Wang Named Editor of ASME Journal of Vibrations and Acoustics



Dr. Kon-Well Wang, Editor of JVA

Dr. Kon-Well Wang, Diefenderfer Chaired Professor in Mechanical Engineering, has been named Editor of ASME (American Society of Mechanical Engineers) Transactions, Journal of Vibration and Acoustics (JVA). Dr. Wang received his Ph.D. degree from the University of California at Berkeley. Following three years as a senior research engineer at the General Motors Research Labs, he joined Penn State in 1988. Dr. Wang is currently Director of the Structural Dynamics and Controls Research Laboratory, Associate Director of the Rotorcraft Center of Excellence, and Leader of the CAV Structural Vibration and Acoustics Group. Professor Wang's major technical interests are in structural dynamics, vibration controls, and adaptive structural systems. He has published over 200 technical articles and is the holder of several patents in these areas. Professor Wang is a Fellow of the ASME. He has chaired the ASME Technical Committee on Vibration and Sound and the Damping and Isolation Conference of the SPIE Smart Structures and Materials Symposium. He is also currently an Associate Editor for the Journal of Intelligent Material Systems and Structures and has been an Editorial Board member of the Journal of Vibration and Control. The purpose of the ASME JVA is to serve as a vehicle for the communication of original research results of permanent interest in the areas of vibration and acoustics. Examples of topic areas covered include: vibration of continuous and lumped parameter systems; linear and non-linear vibrations; random vibration; modal analysis; mechanical signatures; structural dynamics and control; vibration suppression; vibration isolation; passive and active damping; machinery dynamics; rotor dynamics and vibration; acoustic emission; noise control; machinery noise; structural acoustics; fluid-structure interaction; aeroelasticity; and flow induced noise and vibration. It is published bi-monthly by ASME. Dr. Wang's editorship started on January 1, 2005, with Ms. Karen J. Thal as the Journal Assistant.

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Acoustics Characterization of Materials

Bernhard R. Tittmann, Group Leader
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The mission of the Acoustical Characterization of Materials Group is to develop a new understanding of how various types of waves, i.e., ultrasonic x-ray, thermal, optical, electromagnetic, acoustic, etc. interact with advanced materials; to translate this understanding into techniques for monitoring and controlling industrial processes; and to apply these techniques to the development of materials processes.

Dr. Tittmann's group is now under contract from Bechtel Bettis and Bechtel Power Plant Machinery to develop sensors and devices. Also, the group has a Master's student from from the University of Erlangen, Germany, Dominik Pellkofer.

New members to the group include Professor Albert E. Segall. Dr. Segall is specializing in friction and wear. He is a faculty member of the Department of Engineering Science and Mechanics. New students to the group include Matthew Kropf, Michael Pedrick, and Manton Guers. These are all Ph.D. candidates.

Graduating this year are Xiaowei Wang with a M.S. in Engineering Sciences and Mechanics. Christopher Fontana, Elizabeth Blickley, Mark Bohenick all are IGU students and are graduating with B.S. in Engineering Science. Cliff Searfoss graduated with a B.S. in Engineering Science.

Current M. S. students are Dan Zilinskis, David Parks, and Ryan Pfaff.

Active Structures

George Lesieutre, Group Leader
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Professor George Lesieutre and his students are pursuing a number of projects in vibration control and active structures. The Air Force Office of Scientific Research (AFOSR) is sponsoring a new effort in reconfigurable aircraft structures. The National Rotorcraft Technology Center (NRTC) is supporting three projects. The first aims to develop layered fluid-elastic isolation mounts to reduce interior noise; the second, to develop blade-embedded vibration absorbers to stabilize areomechanical instabilities without the use of root lag dampers; and the third, to actively deploy tiny trailing-edge devices to improve rotor performance. The Department of Energy and KCF Technologies support a project in self-powered piezoelectric energy harvesting.

Title: Reconfigurable Aircraft Structures
Sponsor: AFOSR
Summary: Develop and demonstrate concepts for reconfiguring flight vehicle structures: primary structure, skin, and actuation. These must be capable of carrying realistic loads and not be substantially heavier than structures that perform similar functions today. The initial focus is on frame structures with compliant joints, actuated using active tendons. New design methodologies are being developed to optimize truss members, tendons and actuators within a wing structure.
Collaborator: Dr. Mary Frecker (ME)
Student: Jamie Browne, M.S. expected December 2006 ("Scaling of Weight and Actuation for a 2-D Cellular Morphing Wing")

Title: Layered Fluid-Elastic Isolation to Reduce Rotorcraft Interior Noise
Sponsor: Army / NASA National Rotorcraft Technology Center
Summary: Develop layered isolators to reduce noise transmission from a helicopter gearbox to the fuselage. Focus on the frequency range from 500 to 2000 Hz. The basic passive layered mount consists of three elastomer-metal cells, analogous to a multi-stage isolator. The frequency at which isolation begins to be effective can be lowered through the use of integral fluidic motion amplifiers, yielding a passive device that meets performance goals within design constraints. Performance can be further improved though the use of an active piezoelectric element that acts to reduce the transmission of strong tonal components of the input disturbance.
Collaborator: Dr. Edward Smith
Student: Conor Marr, M.S. expected May 2007
Post-Doc: Dr. Joseph Szefi

Title: Miniature Trailing Edge Effectors (MiTEs) for Rotorcraft Applications
Sponsor: Army / NASA National Rotorcraft Technology Center
Summary: Address the use of MITEs for stall alleviation, flight control, and vibration reduction. Consider steady and unsteady aerodynamics, wind-tunnel experiments and CFD analysis, actuation, rotor performance.
Collaborator: Dr. Mark Maughmer, Dr. Gary Koopmann (ME)
Student: Michael Thiel, M.S. expected August 2006

Title: Blade-Embedded Inertial Dampers
Sponsor: Army / NASA National Rotorcraft Technology Center
Summary: Assess feasibility of blade-embedded vibration absorbers to stabilize aeromechanical instabilities without the use of root lag dampers. The device has high static stiffness to preclude an internal instability, while integral fluidic motion amplifiers reduce the dynamic stiffness to permit tuning of the internal resonance to the range of interest.
Collaborator: Dr. Edward Smith
Post-Doc: Dr. Joseph Szefi

Title: Self-Powered Energy Harvesting System for Wireless Health Monitoring
Sponsor: DOE / KCF Technologies
Summary: Develop self-powered energy harvesting system for wireless health monitoring of machinery, buildings, and tires. Novel configurations of piezoelectric elements along with special-purpose circuitry provide significant improvement over the state-or-the-art in energy harvesting.
Collaborators: Dr. Heath Hofmann (EE)
Student: Jeff Kauffman, M.S. expected May 2007

Dr. Mary Frecker and her students in the Engineering Design & Optimization Group (EDOG) are pursuing a number of active structures projects. NIH is supporting the development of new electroactive polymer materials along with modeling of their nonlinear mechanical and electromechanical behavior. These models are used in the design and optimization of devices such as blood pumps and innovative surgical instruments (students: Nakhiah Goulbourne and Eunice Yang). AFOSR sponsors research into the optimal design of morphing aircraft structures (student: Terrence Johnson). The National Rotorcraft Technology Center has supported the design an actively-conformable rotor airfoil that can change its shape (thickness and camber) as it traverses around the azimuth (student: Andrew Nissly, with Dr. Gandhi). AFOSR is supporting research into optimal design of tendon-actuated morphing aircraft structures (students: Smita Bharti, Deepak Ramrakhyani, with Dr. Lesieutre). Incision Tech, Inc. is supporting research on design of multifunctional instruments for microsurgery (students: Milton Aguirre and Shamus Cronin).

Title: Design of Multifunctional Surgical Instruments
Summary: The goal of this project is to optimally design multifunctional instruments which can be used to perform more than one task, thus reducing instrument exchange time. Target instruments are on the order of 1.0 mm in diameter. Prototype instruments are currently being fabricated and evaluated.
Sponsor: Incision Tech, Inc.
Collaborator: Dr. Randy Haluck (Dept. of Surgery)

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Student: Milton Aguirre, M.S. expected May 2007
Title: Optimal Design of Morphing Aircraft Structures
Summary: The project involves optimal design of tendon-actuated compliant cellular truss structures for morphing aircraft. New design methodologies are being developed to optimize truss members, tendons and actuators within the wing structure. Shape changes in span and cross-section of wings are being considered.
Sponsor: Air Force Office of Scientific Research
Collaborator: Dr. George Lesieutre
Student: Smita Bharti, Ph.D. expected December 2006

Title: Design of Microsurgical Instruments for Flexible Endoscopy
Summary: The goal of this project is to design and manufacture new surgical instruments for flexible endoscopy. Target instruments are on the order of 1-3 mm in diameter. New nanofabrication methods and materials are being explored.
Sponsor: Materials Research Institute
Collaborators: Dr. Jim Adair (Materials Science), Dr. Abraham Mathew (Dept. of Gastroenterology)
Student: Shamus Cronin, M.S. expected August 2007

Title: Electroelastic Modeling of Dielectric Elastomer Membrane Actuators
Summary: Methods for modeling the nonlinear mechanical and electromechanical behavior of dielectric elastomer materials have been developed. It is envisioned that a dielectric elastomer membrane may be used as both a blood sac and motive element in a blood pumps, similar to the natural heart.
Sponsor: NIH Bioengineering Research Partnership
Collaborators: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering)
Student: Nakhiah Goulbourne, Ph.D. August 2005

Title: Optimization of Diamond Cell Mechanisms for Morphing Aircraft Structures
Summary: Mechanisms for large wing area changes are the focus of this project. Optimization methods are being developed for actuator placement, including nonlinear finite element analysis. This work is being done in collaboration with the Air Force Research Lab in Dayton, Ohio.
Sponsor: Air Force Office of Scientific Research
Collaborators: Dr. Doug Lindner and Dr. Zafer Gurdal (Virginia Tech)
Student: Terrence Johnson, M.S. May 2005; Ph.D. expected December 2007

Title: Design of a Conformable Rotor Airfoil
Summary: The goal of this project is to design an actively conformable rotor airfoil that can change its shape as it traverses around the azimuth for vibration control. Smart materials-based actuation is used to actively adapt to conditions for both the advancing tip and the retreating side in high speed flight. New topology optimization methods have been developed for piezoelctric actuation systems to handle the tradeoff between trailing edge deflection under actuation and stiffness under airloads. Build and test of a demonstration prototype has been completed.
Sponsor: NRTC/Penn State Rotorcraft Center
Collaborator: Dr. Farhan Ghandi
Student: Andrew Nissly, M.S. December 2005

Title: Morphing Aircraft Structures Using Tendon Actuated Compliant Cellular Truss
Summary: The project involves optimal design of tendon-actuated compliant cellular truss structures for morphing aircraft. New design methodologies are being developed to optimize truss members, tendons and actuators within the wing structure. Shape changes in span and cross-section of wings are being considered.
Sponsor: Air Force Office of Scientific Research
Collaborator: Dr. George Lesieutre
Student: Deepak Ramrakhyani, Ph.D. August 2005

Title: Design and Modeling of Electroactive Polymer Actuators
Summary: The current focus is on modeling and experimental verficication of the viscoelastic behavior of dielectric elastomer materials. A dielectric elastomer annulus has been modeled analytically and prototype actuators are currently being tested. It is envisioned that such an actuator may be used as a pumping device for drug delivery or other biomedical applications. Ongoing work includes modeling and optimization of other hollow actuators.
Sponsor: NIH Bioengineering Research Partnership
Collaborators: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering)
Student: Eunice Yang, Ph.D. expected August 2006

Current efforts in Dr. Chris Rahn's Mechatronics Research Laboratory are directed towards: biologically inspired robotic manipulators, reduced order models of fuel cells and batteries, smart tether sensors, fluidic flexible matrix composites, and harbor defense. DARPA is supporting the development of soft robot manipulators that have robust dexterity for follow-the-leader teleoperation and whole arm manipulation in collaboration with Dr. Qiming Zhang in the Materials Research Laboratory. DARPA is also funding research on flexible matrix composite actuators and plates that deform when filled with pressurized fluid in collaboration with Drs. Wang of MNE and Bakis of ESM. Drs. Koopmann and Rahn are collaborating on two projects for the Office of Naval Research. First, they are developing MEMS sensors and catenary algorithms that predict the shape of underwater tethers used for communication and power transmission for underwater vehicles. Second, they are developing underwater acoustic defense systems for Naval assets in harbors.

Title: NASTIC Structure Initiative
Sponsor: DARPA
Summary: Fluidic flexible matrix composite development for structural actuation.

Title: Soft Robot Manipulators
Sponsor: DARPA
Summary: Novel robotic manipulators that are biologically inspired by elephant trunks and squid tentacles.
Students: Mike Pritts (MS-2005) "Air Muscle Robotic Arm", Arun Srininvasan (MS-2005) "Modeling of EAP Actuators", Dustin Dienno (MS-2006), "Design of OctArm VI", Amir Lotfi (PhD - 2008) "Control of Flexible Structures", Deepak Trivedi (PhD - 2008) "Modeling of Soft Active Structures"

Title: Smart Tether
Sponsor: Office of Naval Research
Summary: Underwater sensing of cable shape.
Student: Dave Kraige,M.S. expected 2007

Title: Harbor Defense
Sponsor: Office of Naval Research
Summary: Underwater acoustic fence to protect ships in harbors.
Student: Andy Kankey,Ph.D. expected 2008

Flow Induced Noise Control

Dr. Dean Capone, Group Leader
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The mission of the Flow-Induced Noise Group of the Center for Acoustics and Vibration is the understanding and control of acoustic noise and structural vibration induced by fluid flow. A summary of the accomplishments of the members of the Flow-Induced Noise Technical Group is presented below.

Drs. Gary Koopmann and Mike Jonson are investigating the use of an underwater turbomachine for noise generation at low frequency.

An array of such turbomachines will direct infrasound to deter adversarial divers within harbors.

Mr. Geon-Seok Kim and Dr. Gerald Lauchle are proposing to work with Cummins Power Generation on quieting diesel generator sets in the 35 kW size range. These generators are acoustically noisy due to various engine cooling fan related mechanisms. Data provided by project sponsor Cummins Power Generation indicate that the fan noise dominates the engine noise over a rather substantial range of low frequencies. Because of the broadband nature of this noise and the fact that it predominantly occurs at low frequencies, leads to the hypothesis that it is caused by random flow fluctuations entering the fan. This type of noise is known as turbulence ingestion noise. The supplied noise data also show some tones in the spectra. These are very likely due to time-invariant inflow distortions. The proposed research will address experimentally and analytically the fan noise associated with the 35 kW generator sets. The acquired flow data, along with available computational results from Cummins, will be used to develop fan noise prediction methods that may be applied to the design of quieter fan products.

Drs. Tim Brungart, Dean Capone, Mr. Eric Myer and Mr. Robert Campbell completed an Office of Naval Research-sponsored, multi-year investigation of a technique to reduce the vibration and noise from hydrofoils experiencing unsteady hydrodynamic loads. Such loads are generated when hydrofoils interact with approach-flow disturbances and are concentrated in the vicinity of the leading edge. The hydrofoil was tested in a water tunnel facility with a wake generator placed upstream to produce the approach-flow disturbances.

Dr. Tim Brungart, Mr. Steve Young, and Mr. Greg Myer, in conjunction with Dr. Michael Howe of Boston University, are developing analytical models and conducting supporting water tunnel experiments to predict the noise radiated by the surface vibration of ventilated supercavities. Ventilated supercavities are used to envelop undersea vehicles and reduce their skin friction by an order of magnitude compared to conventional undersea vehicles in order to achieve speeds far in excess of conventional undersea vehicles. Dr. Howe is developing the analytical model of the noise in terms of the spatial and temporal characteristics of the cavity surface vibrations and the Penn State personnel are measuring the radiated noise with hydrophones and the supercavity surface vibrations with a two component laser Doppler vibrometer. The Penn State researchers were the first to report such ventilated supercavity surface vibration measurements. The Office of Naval Research supports their work.

Dr. Tim Brungart and Mr. Eric Myer continue to develop noise and flow control techniques for devices used to treat sleep apnea. Their work has resulted in fans, mufflers and vibration isolation mounts that generate less noise and attenuate far more noise and vibration, respectively, than previous designs. The effort is motivated by the need for the manufacturer to compete in the European marketplace where noise regulations are more stringent than in the United States. Respironics, Inc. supports their work.

Drs. Tim Brungart, Nick Nicholas and Tim McDevitt are in the process of assessing the ability of commercial-off-the-shelf acoustic hailing devices to project intelligible speech and warning signals to distant targets in the presence of background noise. The Joint Non-Lethal Weapons Directorate supports their work.

Mr. Pete Lysak and Drs. Jim Dreyer, John Fahnline, Mike Jonson, and Dean Capone worked with DARPA on the prediction of aeroacoustic noise from micro-unmanned aerial vehicles (UAVs).

Dr. Y. Fan Hwang and Mr. William Bonness continue an experimental study of low wavenumber turbulent boundary layer wall pressure spectra on smooth and rough walls. They hope to address longstanding questions about the amount of energy in a turbulent boundary layer which couples well to marine structures. They also plan to develop a model for the relationship between surface roughness and this energy.

Mr. Lee Gorny and Drs. Gary Koopmann and Dean Capone are currently working on using quarter wavelength resonators to reduce blade tone noise generated by axial fan systems. Resonators are introduced into the region surrounding a given fan system, which behave as passive, flow-driven secondary sources. We are now in the process of implementing and investigating the effects of adaptively tunable resonators, which can be tuned through modification of both their opening impedance and tube length. These resonators are to be introduced into high-speed fan systems such that noise reduction will be achieved not only for plane wave propagations of blade tone noise but for higher order duct modes. This project involves a cooperative effort between the Pennsylvania State University's Center of Acoustics and Vibrations (CAV) Flow Induced Noise Group and the Deutsches Zentrum fur Luft-und Ramufahrt (DLR) in Berlin, Germany. Testing is set to commence in Berlin starting in early May.

Machinery Prognostics and Condition Monitoring

Dr. Karl M. Reichard, Group Leader
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The Machinery Prognostics and Condition Monitoring Technical Group is focused on methodologies and technologies for accurate and reliable assessment of equipment condition and predicting remaining useful life in machinery. One of the significant trends driving the development of new technology and applications in this area is a focus on autonomic logistics systems customers of the information from machinery health monitoring systems.

Mitch Lebold and Brian Murphy (ARL) completed the first phase of a project with local company RLW, Inc. (www.rlwinc.com) of State College, PA to implement condition monitoring on a low-pressure air compressor used on Navy ships. The RLW lead project, is sponsored by the Navy Supply Systems Command. In addition to monitoring the health of the machinery, the system also automatically generated parts orders and work requests via links into other Naval information systems.

Jeff Banks of the Applied Research Laboratory (ARL) has lead several efforts during the past year to develop and demonstrate advanced health information systems for Army trucks. One project developed and implemented a diagnostic system for the hydraulic load handling system (LHS) on a US Army HEMTT truck. ARL researchers developed Matlab® and Simulink® models of the hydraulic system that are being used to develop the advanced diagnostic algorithms and for model-based health monitoring. The project demonstrated the fusion of both low and high bandwidth sensor data for monitoring the health of the hydraulic system.

The system was demonstrated on an LHS HEMTT on loan to the Applied Research Laboratory from the Army. A key aspect of the system was the development of a graphical user interface which provides access to health and status information on the vehicle to drivers, maintainers, commanders or logisticians. The use of open standards such as OSA-CBM and MIMOSA for exchanging and archiving health related data and information insures capability with programs such as the Army's Common Logistics Operating Environment (CLOE) and the Future Combat Systems Common Operating Environment. Under separate efforts, the group is working directly on the development of open standards and software tools for their

application.

As an offshoot of the HEMTT hydraulic work, Brian Murphy has developed a technique for end-to-end diagnostic monitoring and fault detection for hydraulic braking systems. This will be demonstrated on both a medium tactical truck and a HMMWV.

Figure 1 - HEMTT health monitoring system user interface.

Jim Kozlowski and Chris Rogan lead an effort to demonstrate hardware and software for advanced diagnostics and prognostics for the batteries on the US Army HEMTT, the USMC Expeditionary Fighting Vehicle (EFV), and unmanned ground vehicles. Accurate detection and diagnosis of battery faults promises significant cost savings over the lifetime of these platforms since maintainers often replace all batteries when a single battery or pair of batteries is faulty because of a lack of ability to isolate the faults or failures while the batteries are installed in the vehicles. In unmanned systems, accurate knowledge of the health and status of power and electrical systems provides important operational information. The group completed a project last year with John Deere and Applied Perception that implemented battery health monitoring on a John Deere Gator ATV retrofitted for autonomous operation. This year they are beginning a project with iRobot to implement system health monitoring technology on an iRobot PackBot robot.

Figure 2 - iRobot PackBot robot.

Mitch Lebold and Marty Tretheway continue development and evaluation of techniques for shaft crack detecting and monitoring for the power industry under sponsorship from the Electric Power Research Institute. The team of ARL and University researchers also began to investigate the application of these techniques in steam turbine power systems.

There are a number of students working on machinery condition monitoring related projects. Jonathan Hasker and Josh Friel, recently completed their Master's theses in Mechanical Engineering, based on work in torsional vibration monitoring for shaft crack detection. Jonathan's thesis examined improvements to the torsional vibration measurement system to increase signal-to-noise ratio and improve the detectability of low-amplitude torsional vibration modes. Josh' thesis examined modal identification and statistical control techniques for torsional vibration monitoring.

Randy May, is investigating the use of structural intensity techniques to monitor structural health. Initial experimental results reported last year by Steve Conlon, Karl Reichard and Jeff Banks showed the detectability of cracks in a composite tube using structural intensity measurements. Randy expects to complete his M.S. in Acoustics in 2007.

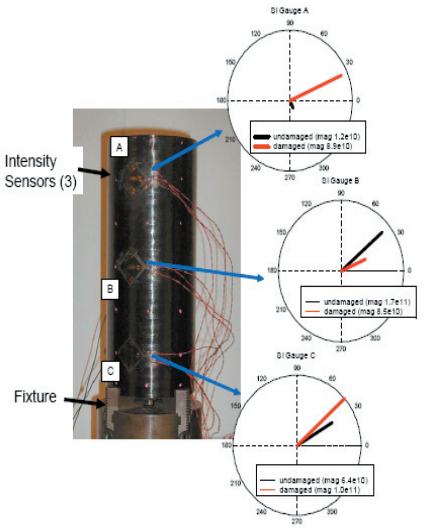

Figure 3 - Structural intensity experimental setup.

Harrison Gyurko has designed a test rig for investigating noise radiation mechanisms in journal bearings. The test rig is currently under construction and testing should begin this summer. Harrison expects to complete his Ph.D. in Acoustics in 2007.

Bryon Rattman is studying the application of information theoretic metrics and compression techniques to the detection of faults in mechanical and electrical systems. Bryon's initial results demonstrate sensitivity to increased damage in data collected on the ARL Machinery Diagnostic Test Bed. Bryon expects to complete his Master's Degree in Acoustics in the fall of 2006.

Propagation and Radiation

Dr. Victor Sparrow, Group Leader
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2005 was a good year for the propagation and radiation group. Much of the ongoing work is related to outdoor sound propagation and/or aircraft noise and is funded through the PARTNER Center of Excellence via grants from the Federal Aviation Administration and the National Aeronautics and Space Administration. The Penn State Graduate Program in Acoustics is a founding member of PARNTER (Partnership for AiR Transportation Noise and Emissions Reduction), led by MIT. (See http://web.mit.edu/ aeroastro/ www/ partner/ .) There are two major ongoing projects within PARTNER that are led by PSU faculty.

PARTNER Project 1 is a low-frequency noise study led by Kathleen Hodgdon of the Penn State Applied Research Laboratory and by Dr. Anthony Atchley of the Penn State Graduate Program in Acoustics. The goals of Project 1 are (a.) to further investigate the factors related to noise complaints in the vicinity of airports so as to facilitate understanding between airports and surrounding communities, and (b.) to increase the effectiveness of noise models and metrics used to predict the overall impact of low frequency aircraft noise on communities. Some of the studies conducted include an investigation of source noise, particularly thrust reverser, sideline on acceleration, and start of takeoff roll; an analysis of noise propagated to nearby homes; and an investigation of the vibration impact at nearby houses. This research used data taken by Penn State at Washington-Dulles International Airport (IAD) during October 2004 near runways and in and around two houses on airport property. Three M.S. theses in Acoustics have already resulted from Project 1.

PARTNER Project 8 is a sonic boom noise mitigation study, let by Dr. Victor W. Sparrow of the Graduate Program in Acoustics. In April 2005 Penn State received a 2-year, $630K grant from the FAA and NASA (a.) to determine the effect of atmospheric turbulence on new low-boom, sonic boom waveforms, and (b.) to assess the perceived loudness and annoyance of such sounds on people. Kathleen Hodgdon of ARL is focused on the loudness and annoyance studies, while Victor Sparrow is continuing his studies on the distortion effects of atmospheric turbulence. Preliminary results presented last July at ISNA17, described below, indicate that it is possible to develop "filter functions" to account for atmospheric turbulence. Such filter functions allow one to take a clean low-boom sonic boom waveform, obtained from a super-

sonic aircraft manufacturer, and to incorporate realistic atmospheric turbulence distortion effects for the purposes of subjective testing. If a clean waveform sounds acceptable, will the waveform still sound acceptable after passing through turbulence?

For additional information about any of the research in the PARTNER Center of Excellence at Penn State, please contact Anthony Atchley, Kathleen Hodgdon, or Victor Sparrow. The PARTNER projects will be a major focus of the CAV Propagation and Radiation Group activities during the next few years.

An additional activity in 2005 worth mentioning was The Penn State Graduate Program in Acoustics hosting the 17th International Symposium on Nonlinear Acoustics (ISNA17) during July 18-22, 2005 at the Penn Stater Conference Center. This is the premier conference on nonlinear acoustics, the study of high-amplitude sound. The meeting is held once every three years at different locations around the world, and there were approximately 180 participants at this Penn State-hosted event. There were nineteen technical sessions including a multi-session International Sonic Boom Forum hosted by Victor Sparrow of Penn State and Francois Coulouvrat of France. The meeting was financially supported by Penn State, the Acoustical Society of America (ASA), and the International Commission on Acoustics (ICA). The proceedings of the meeting are being published by the American Institute of Physics and will be available later in 2006.

Graduate Students:

Lauren Falco, Ph.D. expected 2006
Thesis: A Single-Point Indicator of Acoustic Nonlinearity
Sponsor: National Science Foundation and Office of Naval Research
Advisor: A. Atchley

Remy Gutierrez, M.S. 2005
Thesis: Low Frequency Commercial Aircraft Noise Characterization During Start of Takeoff Roll and Thrust Reverser
Sponsor: FAA
Advisors: A. Atchley and K. Hodgdon

Erin Horan, M.S. expected 2006
Thesis: Vibration And Rattle Community Impact Due To Low Frequency Aircraft Noise
Sponsor: FAA
Advisors: A. Atchley and K. Hodgdon

Lance Locey, Ph.D. expected 2007
Thesis: Propagation of Low-boom Sonic Booms Through Atmospheric Turbulence
Sponsor: FAA/NASA
Advisor: V. Sparrow

Alexandra Loubeau, Ph.D. expected 2006
Thesis: High-frequency Content of Blast Waves in the Hearing Range of Chiroptera
Sponsor: U.S. Army Corps of Engineers, ERDC-CERL
Advisor: V. Sparrow

Peter Shapiro, M.S. expected 2006
Thesis: Subjective Response To Low-Frequency Aircraft Noise
Sponsor: FAA
Advisors: A. Atchley and K. Hodgdon

Brian Tuttle, Ph.D. expected 2006
Thesis: Nonlinear Acoustic Streaming in Conical Thermoacoustic Devices
Sponsor: Office of Naval Research
Advisor: V. Sparrow

Mark Wochner, Ph.D. expected 2006
Thesis: Numerical Simulation of Multi-dimensional Acoustic Propagation in Air Including the Effects of Molecular Relaxation
Sponsor: Office of Naval Research
Advisor: A. Atchley

Quiet Product Design

Dr. Gary Koopmann, Group Leader
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Faculty Affiliates: Dr. Ashok Belegundu Dr. Weicheng Chen
Visitors: Dr. Katsuji Akamatsu, Tokyo, Japan Dr. Chih-Chun Cheng, National Chung Cheng University, Taiwan

Several projects are in progress that build on the computer programs developed by former Ph.D. students, Michael Grissom's program 'Optimal Acoustic Design' and John Fahnline's program POWER. During May 2005 following the CAV workshop, Professor Koopmann and former PSU student Dr. Jeremy Frank, (now President of KCF Technologies) gave a three-day, graduate level course to 12 design engineers. The Quiet Product Design group has started several new industry-supported projects that apply its quiet product design strategies to existing and new machines.

Starting in March 2006, Koopmann and his Ph.D. advisee, Lee Gorny took up residence at the DLR in Berlin Germany where together with its director, Prof. Dr. Wolfgang Neise, they are investigating the viability of using fluid-excited resonators to quasi-actively control the blade tones of a scaled, jet engine turbofan. Koopmann will be in Berlin until mid-August while Gorny will continue on the project until mid-December.

This past year, the STTR project sponsored by the DOE on energy harvesting using piezomaterials continued with KCF Technologies. Professors Heath Hoffmann (EE), George Lesieutre (Aero E) and Gary Koopmann worked on the project led by KCF Technologies president Dr. Jeremy Frank. The project has entered into a Phase II level toward developing a commercially available energy harvesting device that can be combined with wireless sensor applications

Theses Completed/Summer 2005 Graduations

Dr. Dongjai Lee successfully defended his Ph.D. thesis entitled "Optimal Design of Enclosures for Minimal Broadband Sound Radiation." and is now working as a research engineer for GE Power Systems in Greenville, South Carolina

Lee Gorney, MS
Thesis: Use of Fluid Excited Resonators to Control Blade tones of Axial Fans.
Summary: In this study, several tuned resonators are mounted on the shroud of an axial fan. The shroud is perforated near the tip of the fan blades to allow communication with each resonator that in turn generates a tone in antiphase to the blade tone.
Sponsor: Weiss Fellowship and E&F Fellowship, Applied Research Lab
Advisors: G. Koopmann, D. Capone

Andrew Kankey, MS
Thesis: Study of Inverse Methods to Characterize the Structural Acoustic Coupling of Submerged Structures.
Summary: In this study, the use of piezo actuators is investigated to examine reciprocity phenomenon in structural acoustic systems.
Sponsor: US Navy
Advisors: G. Koopmann, S. Hambric, and J. Fahnline

Randy Rozema, M.S.Engr. Spring 2006
Thesis: The design and development of a robotically controlled sound intensity scanning arm for mapping the sound intensity spectrum of small industrial machines.
Sponsor: Emerson Climate Technologies
Advisor: G. Koopmann

Research Projects in Progress

Title: Compressor Noise and Vibration Mitigation Using Acoustic Design Optimization Strategies
Sponsor: Copeland Corporation, Sidney, Ohio
PIs: G. Koopmann, M. Grissom, J. Frank (KCF Technologies0

Graduate Students:

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Brian Zellers, Ph.D. expected Summer 2006
Thesis: Topological Optimization of Radiating Surfaces.
Summary: In this study, a highly efficient acoustic superposition program is being developed that incorporates changes in a machine's geometry as an acoustic design variable
Sponsor: Office of Naval Research
Advisors: G. Koopmann and M. Jonson

Germain Huang, Ph.D. expected Fall 2006
Thesis: Approximate computational methods applied to acoustic superposition formulations to circumvent large matrix inversions.
Sponsor: The Graduate Program in Acoustics
Advisors: G. Koopmann and V. Sparrow

Lee Gorny, Ph.D. expected 2008
Thesis: The Use of Flow-excited Resonators for Quasi-active Control of Blade Tones and Their Harmonics.
Summary: In this investigation, a series of resonators are incorporated into the shroud of an axial fan in the plane of the rotating blades. The rotating blades excite the resonators that are actively configured to generated tones (and their harmonics) in the inlet and outlet side of the ducting that are in anti-phase to the blade tones and their harmonics.
Advisors: G. Koopmann and D. Capone

Rotorcraft Acoustics and Dynamics

Ed Smith, Group Leader
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The past year in CAV's Rotorcraft Acoustics and Dynamics Group was dominated by a massive effort to develop a proposal to renew the Rotorcraft Center of Excellence. More precisely, to transform and expand our Rotorcraft Center into a multi-university Vertical Lift Center of Excellence (VLRCOE). In response to a solicitation released in February 2006 by the US Army, our Penn State team joined forces with a set of outstanding faculty members at five other universities. Drexel University, Ohio State, Iowa State, RPI, and Howard University all contributed projects to our proposal. These partnerships will help us bring breakthrough ideas in nanotechnology, quiet gear dynamics, software engineering, computational fluid mechanics, and obstacle and collision avoidance systems to our integrated VLRCOE. We also teamed with on-campus faculty experts in areas such as ultrasonic NDE, intelligent controls, experimental fluid mechanics, armor materials, and erosion-resistant materials. We were excited to add Dr. Bob Bill to our team to anchor our propulsion thrust area and work closely with our young researchers. Penn State again provided substantial cost sharing (exceeds 40%), amounting to $ 6.6 M over five years. Several industrial partners (Lord Corporation and Purdy Corporation) pledged both cash and in-kind cost sharing. Furthermore, Penn State recently invested to more than double our VLRCOE Laboratory space. The newly-occupied 6000 sf lab features contiguous space for all graduate students and facilities, including a 125 HP instrumented rotor stand with icing chamber and a brand-new state-of-the-art manned flight simulation facility. We built on an excellent record of technology transfer via a wide network of industry and government partners. Our educational program includes a full complement of VSTOL and rotorcraft courses, industry-sponsored design projects, first-year seminars, short courses, and televised courses and seminars. Building directly on three decades of technical contributions to the VSTOL aeromechanics community, we have already initiated ongoing major programs, teamed with industry and DoD, focused on a wide range of challenging problems facing Ducted Rotor/Fancraft vehicles, as well as slowed rotor compound and gyroplanes. We are poised to transform our traditional Rotorcraft Center into a dynamic and diversified Vertical Lift Research Center.

Another major development was our new research grant awarded by the Office of Naval Research. In January 2006, ONR funded a program titled "Innovative Technologies for Enhanced Safety, Survivability, and Performance of Naval Rotorcraft." In this program, we are addressing topics such as variable-speed transmissions, crashworthy mounts, and active rotors for shipboard gust response. We are also heavily engaged with CRI, to transition our basic research technology, and to explore new initiatives in both propulsion technology (gearbox windage, optimal design of drive systems) and condition-based maintenance (advanced sensors). This new program represents a bold and historic step in US Navy investment into rotorcraft basic research. With US Army (the traditional leader in supporting university research in rotary-wing aircraft) funds stretched thin by operations across the globe, the Navy has crafted a technology vision involving academia, Navy labs and industrial partners. New Navy and Marine Corps rotorcraft such as the V-22, CH-53X, AH1-Z, UH-1Y and VH-71 Presidential Helicopter all present a new generation of technology challenges for Navy engineers (and Penn State faculty & students!). We are proud to be continuing the long tradition between the US Navy and Penn State. Stay tuned for exciting new technology developments in coming years.

Finally, our Rotorcraft Flight Dynamics and Simulation capabilities made a giant leap forward in facilities, thanks to a generous donation from Bell Helicopter Textron Inc. In summer 2005, Bell delivered an industrial strength flight simulation facility to University Park. This facility, actually constructed using one of the original XV-15 Tiltrotor aircraft, features realistic flight controls for pilot and co-pilot, fully functional instrument panels, and a complex system of control load motors to simulate flight control loads during maneuvers. The extraordinary facility was used heavily for two decades at Bell's simulation lab in Fort Worth, Texas. While a modern BA 609 simulator comes online at Bell, Professor Joe Horn and his students will breath new life into the venerable XV-15 facility, creating a centerpiece for our new Vertical Lift Center Laboratories.

By the time of the CAV Workshop, we should be informed of the status of our renewal proposal. We also look forward to NASA's renewed interest in basic rotorcraft aeronautics research. The coming year should see great things "taking flight" for the CAV Rotorcraft Acoustics and Dynamics Group.

Check out our Rotorcraft Center Webpage for additional details on our ongoing research programs. (http://www.psu.edu/dept/rcoe/).

Structural Vibration and Acoustics

Kon-Well Wang, Group Leader
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During the past year, the Structural Vibration and Acoustics Group has organized two group meetings with seminars presented by Dr. Norden Huang from NASA Goddard in Fall 2005 and by Dr. Michael Philen from Penn State in Spring 2006. Dr. Huang's talk was on the development of a new method, the Hilbert-Huang Transform, specifically to process nonstationary and nonlinear time series. Dr. Philen's presentation was on adaptive structural systems for vibration and shape controls. The seminars have attracted many audiences and have stimulated some very good discussions.

During the 2004 Spring Workshop, the Structural Vibration and Acoustics Group has highlighted a couple of research programs, these include projects in the Applied Research Lab (Dr. Steve Hambric) and the Structural Dynamics and Controls Lab (Professor Kon-Well Wang).

To highlight the research activities, several recent research projects and the graduate students/staff working on the projects are summarized below:

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Title: Vibration and Acoustic Radiation from Elliptic-Cylinrdical shells
Sponsor: NUWC/ONR
co-PI: Sabih I Hayek (PSU) & Jeff E. Boisvert (NUWC)

Title: High Frequency Vibration and Radiation of Long Spheroidal Shells
Sponsor: NUWC/ONR
Co-PI: S. I. Hayek (PSU) and Jeff E. Boisvert (NUWC)

Title: Acoustics of Shaftless Propulsors
Sponsor: DARPA
PI: S. Hambric

Title: Intensity-based Nearfield Acoustic Holography in Reverberant Water Environments
Sponsor: NAVSEA 073R
PI: S. Hambric
Student: Andrew Barnard (PhD candidate)

Title: Structural-acoustic behavior of a Large Unmanned Underwater Vehicle (LUUV)
Sponsor: ONR Code 334
PI: S. Hambric

Title: Measurements of distributed dynamic impedance of fluid film bearings
Sponsor: ARL E&F
PIs: S. Hambric and K. Reichard
Student: Harrison Gyurko (PhD candidate)

Title: An agent-based negotiation framework for the robust design of active-passive hybrid piezoelectric vibration control networks
Sponsor: National Science Foundation
PIs: K.W. Wang and John Yen
Students: Lijun Jiang (Ph.D) and Kaivan Kamali (Ph.D)

Title: Bio-inspired fibrillar network adaptive structure with ion transport actuation
Sponsor: DARPA
PI: K.W. Wang
Co PIs: C.D. Rahn, A.L. Zydney, C.E. Bakis, S.M. Assmann, and M.L. Jonson
Students: Mike Philen (Ph.D) and Ying Shan (Ph.D)
Postdoc Fellow: Mike Grissom

Title: Vibration confinement and disturbance rejection through electromechanical synthesis of piezoelectric networks
Sponsor: National Science Foundation
PI: K.W. Wang
Student: Tian-Yau Wu (Ph.D)

Title: High performance damping with carbon nanotube-polymer composites
Sponsor: US Army Research Office
PIs: K.W. Wang and Charles Bakis
Students: Ailin Liu (Ph.D.) and Ambuj Sharma (Ph.D.)

Title: Piezoelectric tailoring with enhances electromechanical coupling for concurrent vibration control of mistuned periodic structures
Sponsor: Air Force Office of Scientific Research
PI: K.W. Wang
Student: H. Bill Yu (Ph.D.)

Title: High authority piezoelectric actuator for rotor vibration control via mechanical resonance and electrical circuit synthesis
Sponsor: National Rotorcraft Technology Center
PIs: K. W. Wang and Ed Smith
Student: Jun-Sik Kim (Ph.D.)

Title: Helicopter driveline with flexible matrix composite shafting and active bearing controls
Sponsor: National Rotorcraft Technology Center
PIs: K. W. Wang, Charles Bakis and Ed Smith
Student: Bryan Mayrides (M.S.)

Title: Design, systems evaluation, and testing of flexible composite driveshafts
Sponsor: Center for Rotorcraft Innovation
PIs: Charles Bakis, Ed Smith, and K. W. Wang
Student: Ying Shan (Ph.D.)

Title: Piezoelectric material based friction component actuator and shift control valve in automatic transmissions
Sponsor: Ford Motor Company
PI: K. W. Wang
Student: Gi-Woo Kim (Ph.D.).

Title: SST-Multifunctional adaptive piezoelectric sensory system for structural damage detection
Sponsor: National Science Foundation
PIs: K.W. Wang and Heath Hofmann
Students: Lijun Jiang (Ph.D) and Matthew Whitehead (M.S.)

Title: High-precision adaptive control of large antenna surface
Sponsor: Jet Propulsion Lab
PI: K.W. Wang
Students: Matthew Patoom (M.S.), Jeff Hill (Ph.D.)

CAV Active in World University Network

Over the past several years, The University of Southampton's ISVR and Penn State's CAV and Graduate Program in Acoustics have been fostering collaboration on mutual research interests with exchanges of student and faculty. This past year, ISVR's Mirko Schaedlich was a visiting PhD. Scholar within the CAV. Mirko reports that he benefited immensely from this opportunity to present and discuss his work on shock response tests with both individual CAV researchers and their research groups. These sessions provided him with very valuable feedback, as the main advances at ISVR had been the development of some idealised theoretical models. In contrast, the group at CAV provided much experimental data which can now be used for comparison and inclusion in Mirko's PhD, thesis without the need to duplicate or replicate expensive, time consuming and quite difficult experiments. As a result of his visit, Mirko was able to refine and extend his existing models in conjunction with supervision by the academics in CAV. He returned to ISVR with different perspectives on his research which is, of course, is in the true spirit of inquiry. We are grateful that the WUN program gave us and Mirko this excellent opportunity.

To add momentum to this well-established link, PSU's CAV and Graduate Program in Acoustics and Southampton's ISVR are now in the process of preparing a proposal for the next exchange to involve both faculty and graduate students. Toward this end, Prof. G. Koopmann met with Profs. P. Nelson and S. Elliot in London on February 15, 2006.

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