CAV Review '04

CENTER FOR ACOUSTICS AND VIBRATION

CAV Workshop
May 16 – 17, 2005

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

The program 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.

While formal presentations are organized to allow for the exchange of technical information there will be opportunities for informal discussions at a picnic at Shaver's Creek.

Engineered Adaptive Structures IV

The Center for Acoustics and Vibration hosted the "Engineered Adaptive Structures IV" in Banff, Canada, July 19–23, 2004. The conference was held at the Banff Conference Center.

EAS IV focuses 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.

The format for the conference was similar to the previous three. The participants had ample time to attend sessions and hold informal discussions. They also had the opportunities to explore the Canadian Rockies and visit many of the natural sites in the Banff National Park.

Donations to CAV Library Enhances Research Resources

During this past year the Center for Acoustics and Vibration (CAV) was very fortunate to receive two outstanding contributions to the CAV Library.

The first donation, from Dr. Eric Ungar consists of his private textbook and papers collection. We appreciate his years of assembling such a unique collection and making it available to our faculty, staff and graduate students. It represents an invaluable resource on the expansive subject of damping and to inherit a personal library from such an accomplished expert as Eric is our good fortune indeed.

The second gift, from Nahum Goldmann is his very extensive collection of Russian Acoustic Textbooks. For Mr. Goldmann to make the collection available to the acoustics community at large is an invaluable new resource of acoustic publications by Russian scientists. Many of the texts were previously unavailable in the West's libraries and thus we are aware of the historical significance of this generous donation. After the books have been cataloged within Penn State's library, we will publish the list for distribution within the acoustic's community.

Dr. Eric Ungar

Dr. Ungar is well known to our Penn State community. Over several decades, he organized and presented his highly popular short course on damping at Penn State. Colleagues from Penn State were invited to contribute in the presentations and over the years, the short course grew to be a very enjoyable event with good comraderie.

Dr. Ungar graduated from Washington University in 1951 after serving four years on active duty in the United States Army. While pursuing his doctoral studies in plasticity at New York University, he was an instructor in the Mechanical Engineering department. Upon receiving his Eng. ScD. Degree in 1957, he was promoted to assistant professor.

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Mr. Nahum Goldmann

Nahum Goldmann graduated with M.Eng. from Leningrad Electrotechnical University (LETI), Department of Electroacoustics in 1972. In 1976, he conducted postgraduate studies on development of standards and electroacoustic measurements at the Leningrad Advanced Institute for Standards and Metrology (VISM). In 1972-77, he was engaged at doctoral studies in acoustic metrology under the supervision of the Department of Electroacoustics, Leningrad Institute of Cinematographic Engineering (LIKI). Although the scientific part of the project had been completed, a defense of the thesis was not held due to Nahum's departure from the Soviet Union.
In the USSR and later in Italy and Canada Nahum was employed as an applied researcher,

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Ungar continued

In 1958 Dr. Ungar began an outstanding career with Bolt, Beranck and Newman, Inc. (BBN) of Cambridge, Massachusetts. The expertise that he developed in the general area of structural vibrations area and, in particular damping, is well known throughout the acoustics and noise control community. Retiring from BBN in 1996 with the title of Chief Consulting Engineer he then became the Chief Engineering Scientist for Acentech Inc. where he continues his consulting activities.

Dr. Ungar is a Fellow of the Acoustical Society of America and served as its president in 1992-93. He is a Life Fellow of ASME, having served as Chairman of its Design Engineering Division in 1978-79. He has published over 200 technical papers and chapters in handbooks and monographs. Among his awards is the 1993 Trent-Crede Medal of Acoustical Society of America and the 1994 ASME's Per Bruel Gold Meal for Noise Control and Acoustics. His spare time is devoted to enjoying the company of his grandchildren, practicing karate, and studying biblical texts and interpretations.

Goldmann continued

acoustic consultant and lecturer at a number of leading universities, academic institutes, government organizations and private firms. He was also a reviewer of foreign language publications for the "Referativnyj Zhurnal-Physics" at the All-Union Institute for Scientific and Technical Information (VINITI) of the Soviet Academy of Sciences. Nahum published a reference manual on how to make effective use of the Soviet information dissemination system for acoustic research.

Mr. Goldmann joined Bell-Northern Research (BNR, currently Nortel) in Ottawa Canada in 1983, where for 10 years he served as the Head of Acoustics Lab. At BNR he directed and was actively engaged in R&D of premium audio quality telecommunication products and computerized acoustic measurement systems. Mr. Goldmann published several books and over 15 articles on the subjects of acoustics, information retrieval, ecommerce and Internet security. He also holds Nortel patents on electroacoustic design in a dozen of countries. He is a member of the Professional Engineers of Ontario (PEO), ISO/IEC TC 29 Electroacoustics, and a past member of several scientific and technical societies (ASA, AES, CAA and ITU).

In 1993 Mr. Goldmann left BNR and, despite his love of acoustics, took quite literally a slogan placed on the Lab's wall by the members of technical staff: "Acoustics is not a suitable occupation for reasonable people to make a living". Luckily, after recalling that acousticians are well prepared for any and all professional activities, Goldmann joined ARRAY Development as VP, R&D, later the Executive VP and is currently Company's President. ARRAY Development (http://www.ARRAYdev.com/) specializes in conceptualizing, development and marketing of advanced Extranet-based B2B, G2G and G2B ecommerce and procurement services and software.

Mr. Goldmann is considered a pioneer in the area of conceptualizing Extranet Business Communities and developing business vision, transactional costing, security environment and functional specifications for such communities. He has been Professor at the School of Management at University of Ottawa and University of Toronto School of Management, lecturing on Internet Marketing and Venturing; a visiting lecturer at a number of leading universities and a keynote presenter at numerous Internet Commerce and Governance conferences in the US, UK, Canada and around the globe.

Mr. Goldmann is happily married and his daughter is currently a graduate student in Boston. His hobbies are languages, literature and art.

Corporate Membership

Corporate membership in the CAV 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 CAV's annual Technology Transfer Workshop, 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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Designing Quiet Structures Short Course May 18 – 20, 2005

The CAV will be offering Designing Quiet Structures, May 18 – 20, 2005. This short course introduces designers to noise prediction tools that aid in developing quiet products. Noisiness has become a deciding factor for consumers and a competitive factor in the world market. American industries must continuously improve their designs to quiet machines and appliances.

Designing Quiet Structures addresses that need. A popular short course, which has been offered at the Tokyo Institute of Technology, Finland's Helsinki University of Technology, the University of Naples in Italy, and the EMPA in Switzerland, it is also offered as a graduate-level course at Penn State.

This high level short course offers a broadly applicable methodology for the acoustic design of structures. This unique design method integrates structural dynamics, acoustics and optimization to create the possibility to factor sound into the early stages of product development.

Designing Quiet Structures offers a series of modular lectures, each supplemented with examples of experiments (numerical or physical) that demonstrate the design method. Demonstrations include quieting transmission panels, chillers, propellers and cylindrical containers.

Participants come away with a unified method for optimally designing a structure to "best fit" a specified set of acoustic characteristics, e.g., sound spectrum or radiated power.

CAV Members Receive Awards and Honors

Vigor Yang, PSES Premier Research Award
Timothy Simpson, PSES Premier Teaching Award
Mary Frecker, PSES Outstanding Research Award
Steve Young, Graduate Program in Acoustics Simowitz Citation
Dennis McLaughlin, AIAA Fellow
Anthony Atchley, elected President of the ASA
Gerald Lauchle, elected 2005 President of the Institute of Noise Control Engineering in USA
Sabih Hayek, Trent-Crede Silver Medal in Structural Acoustics, ASA
Gary Koopmann, was hosted by the Tokyo Institute of Technology during August 2004 as their Chair of International Cooperation
Kon-Well Wang, has recently been named Editor of ASME Transactions, Journal of Vibration and Acoustics

George Lesieutre Named Department Head

George A. Lesieutre, professor of aerospace engineering and associate director of the Center for Acoustics and Vibrations, was named the new head of the Department of Aerospace Engineering. Dr. Lesieutre began his new role on July 1, 2004.

Dr. Lesieutre's areas of research include dynamics of aerospace vehicles and structures, structural dynamics, vibration and noise control, controlled structures, damage modeling and health monitoring. His onging research includes projects sponsored by various agencies such as AFOSR, Army/NASA, and DARPA. He also has projects sponsored by companies such as KCF Technologies and Lockheed Martin.

Lesieutre is a member of the American Institute of Aeronautics and Astronautics, (AIAA), American Society for Composites (ASC), American Helicopter Society (AHS), and Society of Engineering Sciences (SES). He is an associate fellow of the AIAA. George has also received the Penn State Engineering Society Outstanding Research Award and various best paper awards for AIAA, ASME, and AHS.

Before coming to Penn State George held positions with Argonne National Laboratory, General Motors' Allison Gas Turbines Division, Rockwell International and SPARTA Inc. He received a bachelor of science in aeronautics and astronautics from the Massachusetts Institute of Technology in 1981, and his master of science in engineering and doctoral degree in aerospace engineering from the University of California, Los Angeles, in 1987 and 1989, respectively.

Visitors to CAV

Dr. Katsuji Akamatsu has been accepted as a visiting researcher to the Center for Acoustics and Vibration. Dr. Akamatsu received his Ph.D in mechanical engineering from the University of Kyoto in 2001. He worked at Mitsubishi Heavy Industries as a research engineer after his graduation from the University of Kyoto in aeronautical engineering. During his tenure, he received his M.Sc from ISVR, the University of Southampton. He was responsible for noise control projects in the field of power plant, transportation, fluid machinery, construction machinery, air conditioner, etc. at Takasago and Yokohama Technical Institute of MHI. He was a member of the Board of Directors of the Institute of Noise Control Engineering of Japan (INCE/JAPAN) from 1988 to 2003 and served as a vice president of the Institute from 2002 to 2004. He will be working with Professor Gary Koopmann on Designing Quiet Structures.

CAV Sponsors Summer Internships

The CAV Laboratory hosted two students under the ONR Summer Internship Program sponsored by the "Center of Excellence for Research and Education in Submarine Engineering." The students worked closely with research personnel in the Noise Control lab and ARL for ten weeks. Julie Venarchick a Penn State aerospace engineering student worked on the project titled "Effect of Curvature on the Structural Excitation and Transmission of Sound Through an Advanced Material Panel." Gary Koopmann was her advisor. Michael Stabley, Penn State mechanical engineering student, worked with Koompann and Dean Capone on "Adaptive Ring Resonators for Noise Control in Turbomachinery."

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 materials manufacturing processes; and to apply these techniques to the development of materials processes

Dr. Tittmann's group is now under contract from Bechtel Bettis to develop sensors for NASA's Promethius Project. This is the exploration of Jupiter and its moons. Also, the group has a visiting scholar from Germany, Sarah Gindner from the University of Konstanz.

New members to the group includes 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 Kroph and Michael Pedrick. Both are Ph.D. candidates.

Graduating this year are Kara Oliver with a M.S. and Xiauwei Wang also with a M.S. in Engineering Sciences and Mechanics. Brian Piccione is a Schreyer's Honor student graduating with a B.S. in Engineering Science and Laura Stimely with a B.S. in Engineering Science.

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
Student: Deepak Ramrakhyani Ph.D. expected: May 2005 ("Tendon Actuated Compliant Cellular Truss")

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: François LeHen, M.S. completed: December, 2004
Post-Doc: Dr. Joseph Szefi (Ph.D. August 2003)

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
Students: Michael Kinzel (aerodynamics), M.S. completed August 2004 and Michael Thiel (actuation), M.S. expected May 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
Student: Jason Petrie, M.S. completed August 2004
Post-Doc: Dr. Joseph Szefi (Ph.D. August 2003)

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

Title: Design Analysis of the Nonlinear Behavior of Particle Impact Dampers
Summary: Establish design parameters for particle dampers that result in high damping, damping that is insensitive to modest changes in the operating conditions.
Student: Sanjiv Ramachandran, M.S. completed August 2004

Title: A hybrid active/passive clamping piezoelectric actuator
Sponsor: Lockheed / DARPA
Summary: Develop a light, high power actuator for application to a morphing UAV. A hybrid active/passive clamping piezoelectric actuator is the focus. This research effort involved actuator modeling, fabricating prototype actuators, and experimental testing.
Collaborator: Dr. Gary Koopmann (PI)
Student: Jacob Loverich, Ph.D. completed August, 2004

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 coupled with aeroelasticty models (student: Terrence Johnson). The National Rotorcraft Technology Center is supporting 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 (student: Smita Bharti, with Dr. Lesieutre). The Life Sciences Greenhouse of Central PA has supported research on design of multifunctional instruments for ophthalmic surgery (student: Katie Powell).

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 Spring 2006

Title: Design and Modeling of an Innovative Electroactive Polymer Blood Pump
Summary: The current focus is on modeling the nonlinear mechanical and electromechanical behavior of dielectric elastomer materials. A dielectric elastomer membrane may be used as both a blood sac and motive element in a blood pumps, similar to the natural heart. Future work includes optimization of the membrane for variable compliance.
Sponsor: NIH Bioengineering Research Partnership
Collaborators: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering)
Student: Nakhiah Goulbourne, Ph.D. expected Summer 2005

Title: Optimal Design of Compliant Mechanisms with Multiple Actuators
Summary: The focus of this project is on optimally designing smart material actuators and compliant mechanism coupling structures simultaneously. A Genetic Algorithm has been developed to optimally place and size piezoelectric actuators while simultaneously optimizing the topology of the passive compliant mechanism. Target applications include morphing aircraft structures.
Sponsor: Air Force Office of Scientific Research
Collaborators: Dr. Doug Lindner and Dr. Zafer Gurdal (Virginia Tech)
Student: Terrence Johnson, M.S. Spring 2005: Ph.D. expected Spring 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 are being developed for piezoelctric actuation systems to handle the tradeoff between trailing edge deflection under actuation and stiffness under airloads. Ongoing work includes build and test of a demonstration

prototype.
Sponsor: NRTC/Penn State Rotorcraft Center
Collaborator: Dr. Farhan Ghandi
Student: Andrew Nissly, M.S. expected Summer 2005; Ph.D. expected Summer 2007

Title: Design of Multifunctional Mechanisms for Ophthalmic Surgery
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 and reducing the risk of retinal tears in ophthalmic procedures. Target instruments are on the order of 0.5 mm in diameter and require microfabrication. Prototype instruments are currently being fabricated and evaluated.
Sponsor: Life Sciences Greenhouse of Central PA
Collaborator: Dr. Randy Haluck (Dept. of Surgery), Dr. Kim Neely (Dept. of Ophthalmology), Alcon Manufacturing Ltd.
Student: Katie Powell, M.S. Completed Spring 2005

Title: Design and Modeling of Electroactive Polymer Actuators
Summary: The current focus is on modeling the nonlinear mechanical and electromechanical 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. Future 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 May 2006

Current efforts in Dr. Chris Rahn's Mechatronics Research Laboratory are directed towards: contact sensors for marine environments, biologically inspired robotic manipulators, and MEMS actuators. The Navy is supporting work on the development of mechanical imagers for shape measurement in the surf-zone for mine detection. 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 the Department of Electrical Engineering, micron sized actuators are being modeled, fabricated, and tested for MEMS applications.

Title: 3D Contact Sensing for Mine Detection in Surfzone Environments
Sponsor: Office of Naval Research
Description: The Navy is supporting the development of whisker contact sensors to be mounted on underwater crawlers for mine detection.
Students: Tyler Clements (MS - 2004) "Design and Implementation of a 3D Whisker Sensor", Haiyu Zhao (PhD - 2005) "Modeling and Control of Distributed Structural Elements"

Title: Soft Robot Manipulators
Sponsor: DARPA
Description: DARPA is supporting the development of 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"

Title: MEMS Actuators Contract
Sponsor: National Science Foundation
Description: Development of microactuators for MEMS applications.
Student: Jongpil Cheong (PhD - 2005) "Modeling and Fabrication of MEMS Actuators"

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.

In July 2004, Dr. Timothy A. Brungart delivered the third plenary lecture entitled Fan Noise at NOISE-CON 04, the 2004 National Conference on Noise Control Engineering held in Baltimore, Maryland. The lecture discussed the myriad applications of fans, fan types, fan noise characteristics, noise sources and methods of noise prediction and reduction. In his concluding remarks, he challenged the Institute of Noise Control Engineering to become more involved in noise control education, particularly fan noise, due to the wide gap between the state of the art of fan and air conditioning system design and the application of this knowledge.

In November 2004, Mr. Steven D. Young and Drs. Brungart and G. C. Lauchle presented a paper at the ASME International Mechanical Engineering Congress and RD&D Expo in Anaheim, California that theoretically and experimentally examined the effect of a downstream ventilated gas cavity on the spectrum of turbulent boundary layer wall pressure fluctuations. Experiments were found to be in agreement with the theory that the wall pressure fluctuations oscillate with increasing amplitude as the cavity is approached.

Drs. Brungart and Dean E. Capone continue to experimentally and computationally evaluate methods for reducing the turbulence ingestion noise for turbomachinery. In-water testing of the concept was conducted in 2004.

Dr. Y. Fan Hwang in conjunction with Mr. William K. Bonness, Dr. Stephen A. Hambric and Mr. Peter D. Lysak are evaluating the utility of various semi-empirical models for predicting frequency spectra of turbulent boundary layer wall pressure fluctuations and their ability to accommodate diverse flow conditions. The models are, in turn, used for predicting flow-induced vibrations on marine structures. The Office of Naval Research supports their work.

Dr. Y. Fan Hwang and Mr. William K. Bonness are also in the midst of 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. Student funding from NAVSEA 073R supports their work.

Dr. Brungart and Mr. Steven D. Young continue to study the noise associated with ventilated cavities formed over high-speed supercavitating undersea vehicles. Their work has focused on quantifying the spatial and temporal characteristics of the cavity interface vibrations with a laser Doppler vibrometer, the first measurements of their kind ever reported. The Office of Naval Research supports their work.

In August of 2004, Dr. Eric G. Paterson, Mr. John E. Poremba, Dr. Leonard J. Peltier, and Dr. Stephen A. Hambric presented their work on "A Physics-Based Simulation Methodology for Predicting Hydrofoil Singing," at the 25th Symposium on Naval Hydrodynamics St. John's, Newfoundland and Labrador, Canada. The work focused on a physics-based simulation methodology for predicting hydrofoil singing. Two model problems, each of which focuses on specific aspects of the methodology, namely fully-coupled fluid dynamics and structural acoustics, and hybrid RANS/LES simulation for practical propulsor geometry, have been studied.

For the former, a singing symmetrically-beveled cantilevered strut was studied to establish

the feasibility of coupling unsteady CFD and structural-acoustics simulations. The uncoupled shedding frequency was shown to agree well with experiment, and linear response of the strut was shown to be large, but only at a very specific speed which corresponds exactly to coincidence of shedding and modal natural frequencies. Fully-coupled simulations, on the other hand, showed a much broader and larger response indicating lock-in of near-resonant conditions. Impact of resonance on the flow field was shown to be significant with large increase in oscillatory pressure over the strut, re-organization of the vortex street, and generation of traveling-waves in the boundary layer due to unsteady changes in angle of attack.

DES for a propulsor stator blade was undertaken to study the unsteady flow field generated by trailing-edge vortex shedding. Results were shown to be similar to previous DES work, however, this case illustrates the effect of angle of attack and camber which were not present in earlier work. Spectra of both the unsteady forces and trailing-edge pressure show 3 distinct peaks corresponding to the vortex-shedding frequency and two super harmonics, the latter of which is directly related to unsteady drag. All 3 peaks are potentially close to the resonant response of the circumferential harmonic of the stator row 1st-bending mode, and thus motivates future work in coupling the DES and structural acoustics for this problem.

Machinery Prognostics and Condition Monitoring

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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.

Jeff Banks of the Applied Research Laboratory (ARL) has lead an effort during the past year to develop and implement advanced diagnostic techniques for the hydraulic subsystem on the load handling system (LHS) version of the US Army's HEMMT truck. Jeff Banks and Brian Murphy have 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 system is being demonstrated on an LHS HEMMT on loan to the Applied Research Laboratory from the Army. ARL is also working with local companies RLW, Inc. and DRS Laurel Technologies on the project.

Jim Kozlowski and Chris Rogan lead an effort to demonstrate hardware and software for advanced diagnostics and prognostics for the batteries on the HEMTT and for batteries on the USMC Expeditionary Fighting Vehicle (EFV). The HEMMT has 4 batteries and the EFV has 8 batteries. 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.

Mitch Lebold and Brian Murphy (ARL) are working with local company RLW, Inc. (www.rlwinc.com) to implement condition monitoring on a low-pressure air compressor on Navy ships. The project, on which RLW is the prime contractor, is sponsored by the Navy Supply Systems Command will demonstrate the application of machinery health monitoring in future sense and respond logistic systems.

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. Last summer they tested the techniques at a power plant in France. Mitch also completed project in support of a Department of Energy International Nuclear Engineering Research Initiative lead by Sandia National Laboratory to monitor the health of check valves. The project demonstrated the successful detection and classification of scratches and foreign objects on the valve face using measurements from accelerometers mounted on the exterior of the valve.

Mitch Lebold and Jeff Banks are leading an effort to detect degradation of an aircraft carrier propulsion system. This effort is focused on detecting blade failure in the Low-Pressure and High Pressure steam turbines and recognizing teeth degradation of the large reduction gearbox.

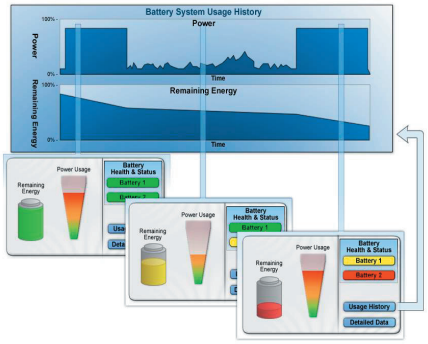
Jeff Banks also lead a team of ARL engineers in the development of a user interface for displaying helicopter health information. The project, supported by the US Army Aviation Engineering Directorate, developed an interactive, web-based interface for mission planners, program managers, and maintainers to access data and information from helicopters equipped with the VMEP HUMS system.

Amulya Garga lead a team of undergraduate students in the development of an embedded controller system for condition monitoring in small unmanned rotorcraft. The project demonstrates the capabilities and limitations of using small, affordable, low-cost microcontrollers in these applications. Amulya also worked with faculty members Dave Hall and Ken Jacobs and graduate student Cory Smith on the use of particle filters as an alternative to the Kalman filter for feature tracking and prediction in health monitoring systems. Particle filters have been demonstrated to work better than Kalman filters in systems with non-Gaussian noise or nonlinear dynamic models.

Eli Hughes, a graduate student in the Graduate Program in Acoustics conducted research to develop techniques for monitoring the health of piezoelectric transducers. The technique used electrical impedance spectroscopy – similar to the technique used in the battery health monitoring project - to detect changes in the material properties of the piezoelectric elements.

Karl Reichard and Ed Crow teamed with Applied Perception, Inc. and John Deere on a project funded by the National Center for Defense Robotics to demonstrate the integration of health monitoring information in unmanned ground vehicles. The project demonstrated the utility of battery health information in the operation, maintenance, and mission planning for unmanned ground robots.

TECHNICAL RESEARCH GROUP HIGHLIGHTS



Last fall, PSU researchers submitted 6 proposals in response to an extramural call for proposals by NASA to support its new vision for space exploration. A PSU team lead by Karl Reichard was awarded a contract to develop architectures and techniques for intelligent self-situational awareness for exploration systems. Intelligent self-situational awareness integrates autonomous control and system health monitoring to improve system safety, increase operational effectiveness, enable higher levels of autonomy and reduce operational and support costs.

Propagation and Radiation

Dr. Victor Sparrow, Group Leader
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The propagation and radiation group has completed another successful year in developing new understanding of how sound is generated and propagated in realistic environments, in translating this understanding into techniques for making decisions about the use and control of sound, in making inferences about sources and the environment, and in applying this understanding to the design of devices and systems. The most active projects are those related to outdoor sound propagation.

In April 2005 the Penn State Graduate Program in Acoustics received a 2-year, $630K grant from the Federal Aviation Administration and the National Aeronautics and Space Administration to study sonic boom mitigation. Dr. Victor Sparrow is Principal Investigator for this work, along with Co-PIs Prof. Anthony Atchley, head of the Graduate Program in Acoustics, and Kathleen Hodgdon of the Penn State Applied Research Laboratory. This effort is part of Penn State's successful participation in the FAA/NASA/Transport Canada Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence led by MIT. Prof. Anthony Atchley is the Penn State Principal Investigator for this Center, and Kathleen Hodgdon is the project lead or Co-PI on several other projects in the Center.

What is the motivation behind this new sonic boom research? As demand for long range business travel increases and technologies for efficient supersonic flight mature, a market for small supersonic civil aircraft appears to be forming. Results of recent studies indicate that such aircraft are feasible. However, a major remaining impediment to the operation of such aircraft is the cruise noise signature. Sonic boom noise issues are different from most other aspects of aircraft noise in that the potential annoyance occurs along the flight path rather than near airports.

Aircraft manufacturers would like to develop supersonic aircraft; however, maximum utility will require supersonic flight over land, and this is currently prohibited by law. The law was formulated and promulgated at a time before the purposeful shaping of the sonic boom waveform was conceived. The aim of the work is to determine if sufficient new data exists to warrant a reevaluation of the FAA's regulation prohibiting supersonic flight over land.

Recent research on shaped sonic booms has indicated low boom designs are possible and result in significantly less objectionable signatures than classic booms of the '60's-'80's. Several recent studies have investigated designs with initial overpressures of no more than 0.3 lb/ft2, in contrast to Concorde's typical 2 lb/ft2 N-wave signature --- a dramatic reduction in noise levels. Due to this technological progress and resulting potential commercial and military application for the United States, supersonic aircraft operation and sonic boom signatures will be investigated for low boom designs. This research is aimed at the development of new regulations to permit unrestricted operation of supersonic aircraft over both land and water in the United States and worldwide. Hence, studies will be initiated on the noise impacts of supersonic flight, now for the specific case of shaped boom aircraft designs.

For additional information about the sonic boom mitigation research, please contact Dr. Sparrow. This will be a major focus of the CAV Propagation and Radiation Group activities during the next few years.

Some other selected ongoing projects include:

Title: Nonlinear Propagation of Jet Noise
Sponsor: Strategic Environmental Research and Development Program and Wyle Laboratories
Summary: Develop computer algorithms to accurately predict the nonlinear propagation of jet noise from supersonic jets of interest to the DoD.
Student: Kent L. Gee
Collaborators: Dr. Victor Sparrow, Dr. Dennis McLaughlin, Dr. Philip Morris

Title: Modeling and Assessment of Near Field Blast Noise
Sponsor: US Army Engineer Research and Development Center – CERL
Summary: Determine the high frequency content surrounding blast events to provide input to biologists on whether the hearing of bats can be harmed by Army training.
Student: Alexandra Loubeau
Collaborators: Dr. Victor Sparrow

Title: Optimized Hyperthermia Treatment of Prostate Cancer Using a Novel Intracavity Ultrasound Array
Sponsor: US Army Medical Research and materiel Command
Summary: Develop improved array, electronics, and insonification methodology to improve the treatment of cancer of the prostate using ultrasound heating.
Student: Osama Al-Bataineh
Collaborators: Dr. Nadine Smith, Dr. Robert Keolian, Dr. Tom Gabrielson

Quiet Product Design

Dr. Gary Koopmann, Group Leader
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Faculty Affiliates: Dr. Ashok Belegundu Dr. Weicheng Chen
Visitors: Dr. E. Nishida, Tokyo, Japan and Professor Yang Xiang, Yuhan University, China

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 2004 Professor Koopmann and former PSU student Dr. Jeremy Frank, (now President of KCF Technologies) gave a week long graduate level course to 12 design engineers representing various European industries. The course was organized by Dr. Stanislaw Pietrzko of EMPA in Zurich, Switzerland. Dr. Pietrzko also presented lectures on modal analysis and provided excellent laboratory and computer facilities for the course participants. The Quiet Product Design group has started several new industry-supported projects that apply its quiet product design strategies to existing and new machines.

This past year, a project on energy harvesting using piezomaterials was initiated with KCF Technologies under a Phase 1 STTR sponsored by the DOE. Professors Heath Hoffmann

(EE), George Lesieutre (Aero E) and Gary Koopmann worked on the project with KCF Technologies president Dr. Frank. A Phase II proposal has been submitted that would combine energy harvesting with wireless sensor applications

In March 2005, Dr. Dongjai Lee successfully defended his Ph.D. thesis entitled "Optimal Design of Enclosures for Minimal Broadband Sound Radiation." Dr. Lee is continuing with the CAV for the summer to work on industrial projects related to his thesis work.

Projects in Progress
Title: Compressor Noise and Vibration Mitigation Using Acoustic Design Optimization Strategies
Sponsor: Copeland Corporation, Sidney, Ohio
PIs: E. Nishida, G. Koopmann, W. Chen, and D.J. Lee

Graduate Students:
Brian Zellers, Ph.D. expected Spring 2006
Thesis Topic: Topological Optimization of Radiating Surfaces. 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

Lee Gorney, MS expected Summer 2005
Thesis Topic: Use of Fluid Excited Resonators to Control Blade Tones of Axial Fans. 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

Andrew Kankey, MS expected Summer 2005
Thesis Topic: Study of Inverse Methods to Characterize the Structural Acoustic Coupling of Submerged Structures. 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, Ph.D. expected 2007
Thesis Topic: 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

Germain Huang, Ph.D. expected 2006
Thesis Topic: 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

Rotorcraft Acoustics and Dynamics

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The past year in CAV's Rotorcraft Acoustics and Dynamics Group was marked by a combination of technical research breakthroughs, and continued development of new experimental and computational facilities to be used for ongoing research work and class instruction.

The Rotorcraft Center continues to be a model of multidisciplinary and collegial interactions, involving 17 faculty members, approximately 30 graduate students, and 6 undergraduate research assistants from Aerospace, Mechanical, Engineering Science and Mechanics, and the Applied Research Laboratory. Led by a major DARPA grant on CFD Technologies for Quiet Helicopter Design (Brentner, Gandhi, et al) annual research volume was over the $3M mark – representing a healthy leverage of the $600K core award from NRTC. Research projects sponsored by the Army Research Office (equipment upgrades, vibration control), Piasecki Aircraft (compound helicopters), Bell Helicopters (Fluidlastic and elastomeric dampers), Boeing Helicopters and Sikorksy Aircraft (senior design projects), NASA (active control of drivelines, optimal design of low-weight rotor systems), Lord Corporation (embedded blade lag dampers, high frequency gearbox isolation mounts), NSF (rotor wake simulation), and NREL (acoustical simulation of wind turbine blades) were all active this past year. Check out our Rotorcraft Center Webpage for additional details on our ongoing research programs. (http://www.psu.edu/dept/rcoe/).

Major steps towards the development of our new model scale rotor test facility were realized this past year. Led by Profs. Camci and Smith, our Boeing-donated test stand now has a refurbished drive system, and large size low temperature chamber for rotor icing tests. Wok is continuing on control systems and a fully instrumented rotor head. Our new driveline dynamics testbed is up and working as well. This unique facility features a modular flexible driveline, active magnetic bearings, metallic or flexible matrix composite driveshafts, as well as host of instrumentation control hardware. Our new rotorcraft flight simulation research facility is also nearing completion and our capabilities for rotorcraft UAV flight research continue to grow.

Our team is busily preparing for a proposal aimed at renewal of the Rotorcraft Center for another five years. We will be pursuing many new and exciting technologies so stay tuned for even more research activity in the coming years.

Structural Vibration and Acoustics

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During the past year, the Structural Vibration and Acoustics Group has organized two group meetings with seminars presented by Professor William Clark from University of Pittsburgh in Fall 2004 and by Dr. Hans DeSmidt from Penn State in Spring 2005. Dr. Clark's talk was on vibration damping with state-switching piezoelectric circuits. Dr. DeSmidt's presentation was on active magnetic bearing control of highly flexible driveshafts with misalignment and load torque. 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 Modal Analysis Lab (Professor Martin Trethewey) 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:

Title: Wave dispersion study in cylindrical shells using symbolic math tools
Sponsor: NAVSEA
PI: Yun- Fan Hwang
Student: Joanne Rampersad (MS)

Title: The Mechanics of Web Handling
Sponsor: National Science Foundation
PI: E.M. Mockensturm
Students: Raghavan Balaji (Ph.D.) and Jianping Guo (Ph.D)

Title: Using Surface Interactions and Continuum Models to Develop New Modes of Nano-Device Operation
Sponsor: National Science Foundation
PIs: E.M. Mockensturm and Vince Crespi
Students: Arach Mahdavi (Ph.D.) and Cristiano Nisoli (Ph.D.)

Title: Design and Modeling of an Innovative

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Electroactive Polymer Blood Pump
Sponsor: NIH Bioengineering Research Partnership
PIs: E.M. Mockensturm, M. Frecker, Q. Zhang, and A. Snyder
Student: Nakhiah Goulbourne

Title: Design and Modeling of Electroactive Polymer Actuators
Sponsor: NIH Bioengineering Research Partnership
PIs: E.M. Mockensturm, M. Frecker, Q. Zhang, and A. Snyder

Title: Single Crystal Piezoelectric Actuators for Rotorcraft
Sponsor: SBIR
PI: Joseph Szafi
Co-PI: E.M. Mockensturm, K.W. Wang, and E.C. Smith

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 Fellows: Prakhar Prakash and Mike Grissom

Title: Control of large, lightweight, high-precision space reflectors
Sponsor: Jet Propulsion Lab
PI: K.W. Wang
Student: Matthew Patoom (M.S.)
Postdoc Fellow: Hans DeSmidt

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: Development of robust hydraulic pressure regulator system for vehicle automatic transmission
Sponsor: Ford Motor Company
PI: K. W. Wang
Student: Gi-Woo Kim (Ph.D.).
Postdoc Fellow: Ming Cao (now Research Engineer at UTRC).

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.)

MARK YOUR CALENDARS

Engineered Adaptive Structures V will be held in June 2006 in Italy. Antonio Concilio from CIRA in Italy, Mike Brennan from ISVR in United Kingdom, Stanislaw Pietrzko from EMPA in Switzerland, and Thilo Bien, from the Technical University Darmstadt in Germany will be organizing the conference.

If anyone would like more information about the upcoming conference please contact Karen Thal at kjt3@psu.edu.

Senior design project - a sound intensity scanner

CAV INFORMATION

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