CAV Review '07

CENTER FOR ACOUSTICS VIBRATION

CAV Workshop May 8—9, 2008

The Center for Acoustics and Vibration's annual workshop will be held at the Penn Stater Conference Center once again and will focus on new research initiatives within the Center.

As in the past the program will be a mixture of the Center's technical group leaders, international liaisons from ISVR in England, DLR in Germany, and CIRA in Italy and a couple of the corporate sponsors of the Center. The graduate students and their advisors will be available for questions concerning their research. There will be a tour of the Penn State Rotorcraft Center on Thursday afternoon.

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

Forward Flight Upgrade to Aerospace Engineering's Jet Noise Facility

Professor Dennis McLaughlin and doctoral student in aerospace engineering, Ching-Wen Kuo adjust instrumentation in the new forward flight jet noise facility at Penn State.

Penn State University's high speed jet noise facility is undergoing a major upgrade which will allow researchers to simulate the forward flight of the aircraft and measure the way it affects the jet's sound generation and propagation mechanism.

The simulated forward flight addition will provide a velocity 230ft/s (Mach 0.2) through an area of around 1 square foot. That leads to a volume flow rate of about 14000 CFM. Obtaining a 230ft/s flow requires a pressure drop of inches of water. There is already a low speed fan installed for ventilation purpose, but it is far from providing the necessary conditions. Purchase of a high speed low noise fan has been made and the fan has just been installed in the facility. The power supply and controller for the fan has been provided from EMS in Pennsylvania. That company has the expertise required, has already been working with our department on other projects and visited our installations in order to give a better estimate the costs. The ducting from the fan to the anechoic chamber has

Continued on page 2

Engineered Adaptive Structures VI

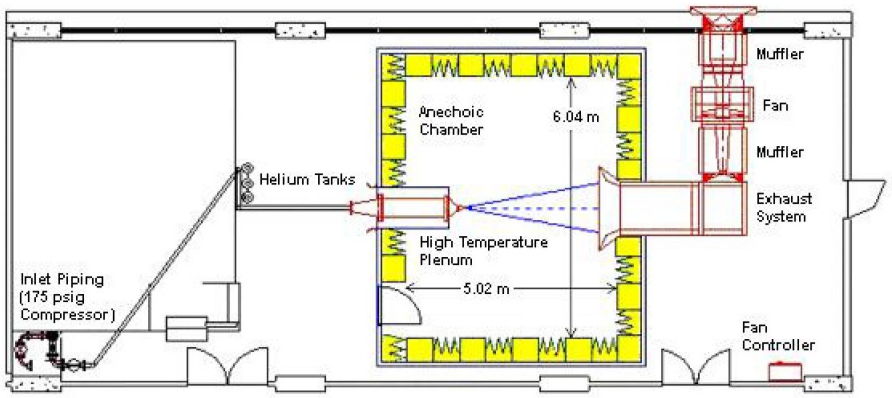
The Engineered Adaptive Structures Conference will be held in Big Sky, Montana, July 20—25, 2008. The conference will be held at the Big Sky Resort and Conference Center.

This is the sixth conference for the engineered adaptive structure research area with focus on the adaptation of structures to the changing environment. The format for the conference will be the same as previous years with morning

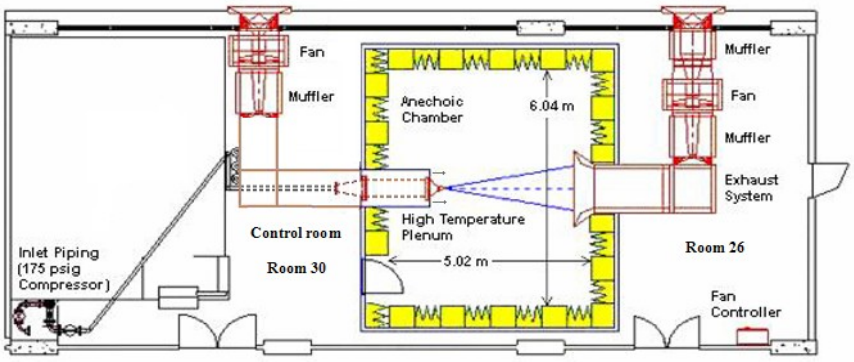
Continued on page 2

also been designed, purchased and mostly installed. It is acoustically treated inside in order to decrease influence of the noise produced by the fan on the measurements made downstream. The frame supporting the fan has been fabricated in the department and is also mostly installed The nozzle at the outlet of the duct will need to be custom made, as well as the inlet of the fan. Acoustical Solution will provide wrapping in order to acoustically treat the whole installation and protect the operator of the facility from excessive noise.

It is anticipated that the facility will be ready for "shake down" tests by late summer and research quality experiments will commence in the fall.



Above is the facility before the modifications. Below is the facility after the modifications.



EAS VI 2008

(cont.)

sessions and the afternoons for informal discussions.

The Big Sky area offers an opportunity for the participants families to accompany them to the conference. Nearby Yellowstone National Park offers a whole range of excursions from tour guided sightseeing to individual hiking trips. There will be an organized tour through Yellowstone on Wednesday, July 23rd. There are also many more activities in the Big Sky area for everyone to enjoy.

If you would like to attend this conference or receive more information concerning it please contact Karen Thal at kjt3@psue.du.

CAV Members Receive Honors and Awards

Gary Koopmann, George Lesieutre, Steve Hambric, and Michael Yang—2006 Martin Hirschorn IAC Prize, Institute of Noise Control Engineering of the USA, INC.
Conor Marr—Northeast Region Lichten Award from the American Helicopter Society
Kon-Well Wang— ASME N.O. Myklestad Award
Timothy Simpson—Penn State Engineering Society Premier Research Award
Christopher Rahn—ASME Fellow
Sava Yavuzkurt—ASME Fekllow

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 annula Technology Transfer Workshop held every spring at Penn State, participation in a corporate recruiting program, and a consultation visit with Penn State researcher.

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

Corporate Members and Representatives

Bettis Atomic Power Lab– Eric Shunk

Copeland Corporation—Macinissa Mezache

Electric Boat –Albert Kirwan

Fisher Controls—Al Fagerlund

Lockheed Martin/KAPL—Steve Dunn

Sincoceramics—Jingru Zhang

Trane Corporation—Gregory Meeuwsen

United Launch Alliance—Ed Heyd

United Technologies Research Center—Rebecca Bryant

Westinghouse Electric Company—Larry Corr

International Liaisons and Representative

ISVR (U.K) - Steve Elliot

DLR (Germany) - Wolfgang Neise

CIRA (Italy) - Antonio Contilio

CAV Review '07

CAV Welcomes New Corporate Sponsors

Westinghouse Electric

The Center for Acoustics and Vibration is pleased to announce that Westinghouse Electric Company of Monroeville, PA has joined the Center as a corporate sponsor. The representative for the company is Larwence Corr, Ph.D. Some of you may recognize Dr. Corr's name as being a past representative of another of our sponsors.

Westinghouse Electric Company offers a wide range of nuclear plant products and services to utilities throughout the world, including fuel, spent fuel management, service and maintenance, instrumentation and control, and advanced nuclear plant designs.

Nearly 50 percent of the nuclear power plants in operation worldwide, and nearly 60 percent in the United States, are based on Westinghouse technology. Worldwide, the more than 9,000 employees of Westinghouse Electric Company continue to pioneer value-added engineering and services creating success for our customers in their increasingly demanding markets.

The selection of Westinghouse to supply four AP1000™ nuclear power plants in China is the most recent in a series of positive announcements. The AP1000 has also been identified as the technology of choice for no less than 12 new projected plants in the United States.

United Launch Alliance

The Center for Acoustics and Vibration is pleased to announce that United Launch Alliance of Littleton, CO has joined the Center as a corporate sponsor. Edward Heyd will be the companies representative.

ULA brings together two of the launch industry's most experienced and successful teams—the Lockheed Martin Atlas and Boeing Delta teams—that have supported America's presence in space for almost 50 years. Atlas and Delta expendable launch vehicles have carried more than 850 combined payloads to space ranging from weather, telecommunications and national security satellites that protect and improve life on Earth, to deep space and interplanetary exploration missions that further our knowledge of the universe.

Under ULA, Delta and Atlas rockets will provide safe, cost-efficient, readily available and reliable access to space of U.S. government missions, continuing the tradition of supporting strategic U.S. space initiatives with advanced, robust launch solutions.

Wang Named to New Position

This past December it was announced that Kon-Well Wang, Diefenderfer Chaired Professor in Mechanical Engineering was named as the Department Chair and Stephen P. Timoshenko Professor in Mechanical Engineering at the University of Michigan. Dr. Wang will begin his tenure on June 1, 2008.

Dr. Wang began his career as a senior research engineer at the General Motors Research Labs after receiving his Ph.D. from the University of California at Berkeley in 1985. He then came to Penn State in 1988 where he soon began a very successful research career. Wang is the Director of the Structural Dynamics and Controls Lab, Associate Director of the Rotorcraft Center of Excellence and the Group Leader of the Structural Vibration and Acoustics Group for the Center for Acoustics and Vibration. This position he has held since 1993.

While at Penn State Dr. Wang has greatly contributed to the research of multi-field coupling and tailoring of adaptive structural systems for vibration control and monitoring. Due to his research he has been able to publish over 200 technical papers and holds several patents. He has been named as an American Society of Mechanical Engineers Fellow (ASME), has received the Penn State Society of Engineers the Outstanding and Premier Research Awards and also their Outstanding Teaching Award. Wang recently received the ASME N. O. Myklestad Award. Dr. Wang has been invited to give lectures and keynote speeches at international conferences and institutions both here in the United State and abroad.

Dr. Wang has been or is currently advisor or co-advisor to students who have either received their PH.D. and/or their M.S. degrees. Many of his students have come for their M.S. and have stayed on to receive their Ph.D. Some of these students have gone on to become a member of the academia community while others have excelled in industrial research areas. Dr. Wang has also supervised many post doctoral positions associated with his research.

Even though Dr. Wang has also been very active in supporting his teaching and research work at Penn State he has held many other titles in the Profession such as chair and member of many organizing committees for international and national conferences. Wang has also served on many University, College and Department committees such as Penn State Faculty Scholar Section Panel, Promotion and Tenure Committee, and had recently chaired the Department Head Search Committee. At this time Dr. Wang is the Editor of the ASME Journal of Vibration and Acoustics.

While Dr. Wang leaves very large shoes to fill in many different areas at Penn State we wish him well with his future responsibilities at the University of Michigan.

CAV Review '07

The CAV Assists Homeland Defense

The CAV has joined the efforts of the Office of Naval Research to defend U.S. harbors from swimmers with malicious intent. PhD Candidate Andrew Kankey is working with Dr. Gary Koopmann and Dr. Chris Rahn from the ME Dept. and Dr. Dave Bradley and Dr. Kyle Becker from the Acoustics Dept. to develop a method for focusing low frequency, high amplitude acoustic energy on a prescribed swimmer location as a nonlethal deterrent. The method uses an array of underwater sources phased such that the sound waves arrive at the swimmer location with the maximum of constructive interference. The required phases are calculated prior to implementation by characterizing the harbor into sectors using multiple hydrophones. Each sector will have a unique set of phases allowing the sources to focus energy on a swimmer within that sector. LabVIEW has been used to develop a touchscreen user interface to implement the phasing method and for "firing" the acoustic deterrent. An acoustic finite element code is being developed in Matlab to model the harbor and thus predict the low frequency acoustic field. The FEM code will also allow for the optimization of source placement and phases. The experimental part of the method was tested last spring with marked success at Coddington Cove, Newport, RI. The FEM code is currently eing used to explore the effects of phasing on the re acoustic field in the harbor. The project will conclude at the final demonstration in Newport this June followed by a report to ONR over the summer

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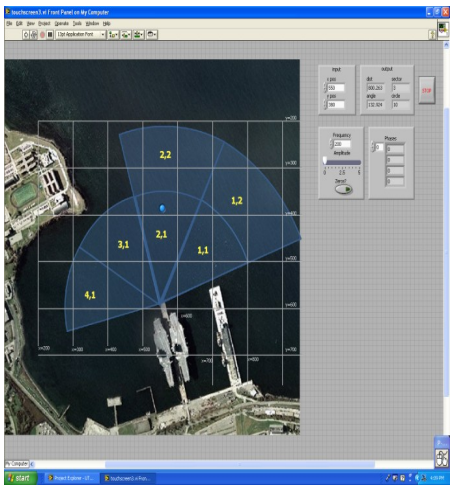
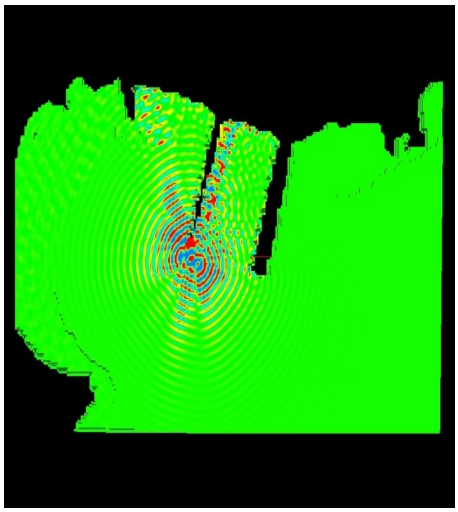


LabVIEW screenshot for calibrating sectors of harbor and "firing" sources.



FEM results for three 50 Hz sources in phase in Coddington Cove, view from bottom.

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Acoustics Characterization of Materials

Bernhard R. Tittmann, Group Leader
brt4@psu.edu

The mission of the Acoustics 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.

Doctoral student Jikai Du gave at lecture at the technical group luncheon in the spring entitled "Toward the Acoustic Evaluation of Low Modulus Thin Film Structures."

Active Structures

George Lesieutre, Group Leader
g-lesieutre@psu.edu

Professor George Lesieutre and his students are pursuing a number of projects in vibration control and active structures. Working with Prof. Frecker's group, they just completed a research project in "morphing" aircraft structures for the Air Force Office of Scientific Research (AFOSR). The National Rotorcraft Technology Center (NRTC) supports a project powered piezoelectric energy harvesting. A new project in piezoelectric damping of integrally-bladed rotors is about to begin.

Title: Morphing 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. Recent focus is on compliant structures actuated using active tendons. New design methodologies have been developed to optimize truss members, tendons and actuators within a wing

structure. Recent results provide insight into the scaling of morphing performance and structural weight fraction with vehicle size.
Collaborator: Dr. Mary Frecker (ME)
Student: Jamie Browne
M.S. completed: August 2007 ("Scaling of Weight and Actuation for a 2-D Cellular Morphing Wing")

Title: Miniature Trailing Edge Effectors (MiTEs) for Rotorcraft Applications
Sponsor: Army / NASA National Rotorcraft Technology Center
Summary: Address the use of MITEs for tall 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. Farhan Gandhi
Student: Michael Thiel
Ph.D. expected: December 2010

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. Low-order modeling provides rapid sizing and optimization of new devices.
Collaborators: Dr. Heath Hofmann (EE)
Student: Jeff Kauffman **M.S. completed:** December 2007 **Ph.D. expected** May 2010.

Title: Dynamic Modeling of Lag Dampers
Sponsor: Bell Helicopters
Summary: Develop models of various lag dampers to capture dependence of dynamic behavior on amplitude, frequency, and temperature. Integrate into comprehensive rotorcraft analysis codes.
Collaborator: Dr. Edward Smith
Student: Conor Marr
M.S. completed: August, 2007
Ph.D. expected May 2010

Current efforts in Dr. Chris Rahn's Mechatronics Research Laboratory are directed towards: biologically inspired robotic manipulators, smart tether sensors, fluidic flexible matrix composites, and harbor defemse/ 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 change stiffness by orders of magnitude when filled with pressurized fluid in collaboration with Drs. KW 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. Finally, Dr. Rahn has a seed grant from the AFOSR to study piezoelectric actuators for nano air vehicles.

The Flow-Induced Noise Control

Dean E. Capone, Group Leader
dec5@psu.edu

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.

Dr. Michael Krane is leading an investigation of the physics of human speech sound production. The study uses physical and numerical models of air motion in the vocal system, in which flow-induced vibration of the vocal folds and turbulent jets produce the sounds we use to communicate. The work, being done in collaboration with Dr. Timothy Wei of the Rensselaer Polytechnic Institute, Dr. Siddartha Khosla of the University of Cincinnati Medical School, and Dr. Joel Peltier of PSU ARL, is funded by the National Institutes of Health.

Mr. William Bonness and Dr. Dean Capone continue an experimental study of low wavenumber turbulent boundary layer wall pressure spectra in a cylindrical pipe. The work will address long-standing questions about the amount of energy in a turbulent boundary layer which couples well to marine structures. They also plan to investigate the role of fluctuating wall shear stress on structural excitation. Additionally Dr. Capone and Mr. Bonness are investigating the transmission of turbulent boundary layer unsteady shear through elastomeric coatings in water.

Drs. Gary Koopmann and Mike Jonson are investigating the use of an underwater turbomachine for noise generation at low frequency. Such a source will be used to direct infrasound to deter adversarial divers within harbors.

Dr. Stephen Hambric continues to consult for the NRC on flow-induced vibration and fatigue failure problems in U.S. commercial nuclear power plants.

Dr. Tim Brungart and Mr. Steve Young 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.

Machinery Prognostics and Condition Monitoring

Dr. Karl M. Reichard, Group Leader
Kmr5@psu.edu

The Machinery Prognostics and Condition Monitoring technical group is focused on methodologies and technologies for accurate and reliable assess-

ment of equipment condition and predicting remaining useful life in machinery. Below are short descriptions of several recently completed or current pro-

C-130 Structural Health Monitoring

The Applied Research Laboratory is leading a team of researchers exploring the development and deployment of structural health monitoring techniques for aging aircraft. The group is investigating the use of acoustic emissions and the use of frequency response tracking to detect cracking in US Air Force C-130 rainbow fittings.

The C-130 upper and lower rainbow fittings provide the structural connection support between the aircraft center wing box and the outer wing as shown in Figure 1. The primary cause of the cracking is from common fatigue that occurs almost exclusively on the in-board rainbow fittings. The secondary cause of cracking is from stress corrosion that occurs mainly on the in-board and occasionally on the out-board rainbow fittings. The cracking occurs predominantly in the counter bore region of the fittings as shown in Figure 2

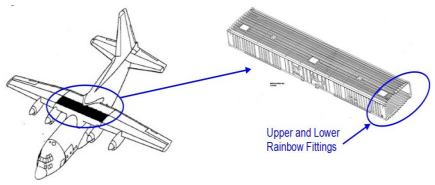


Figure 1 C-130 Center Wing Box and Rainbow Fitting

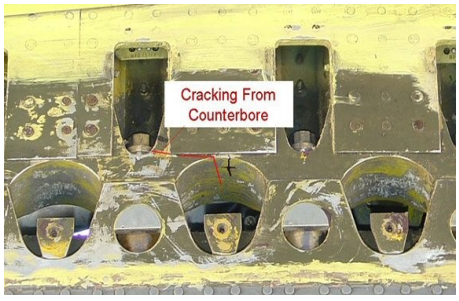


Figure 2 C-130 Upper and Lower Rainbow Fittings

After a preliminary cursory evaluation of several technologies including ultrasound and natural frequency assessment, the primary technology that was chosen to provide crack detection and fault isolation is Acoustic Emission (AE). AE is a non-destructive evaluation technique that is used for surface and inner structure crack detection and localization. This technology involves monitoring for the emission of high frequency vibration (> 100,000 Hz) as an existing structural defect (crack) is stressed from the static loading of the system. An analogous low frequency example of this technique is when a tree branch is strained from a hung weight; the branch emits an audible cracking sound.

Based on the testing conducted at the component level in the laboratory and at the aircraft level in a field environment, the acoustic emission technology has demonstrated that it can provide a less labor intensive and possible higher probability of detection capability than eddy current technology. The AE technology has the potential to be further developed and applied as an ISHM capability that would provide a regular assessment of rainbow fitting integrity and crack propagation.

Robot Health Monitoring

Several ongoing projects are examining the application of health monitoring techniques to unmanned and robotic systems. In one project, ARL is working with iRobot, manufacturer of the Packbot Explosive Ordinance Disposal robot shown in Figure 3, to investigate ways to build health monitoring into robotic platforms and robot operator control units. ARL is also working with several members of the Penn State Mechanical and Industrial Engineering faculty to integrate health monitoring and autonomous control in robotic platforms, and to develop techniques for incorporating health monitoring into robot family design concepts.

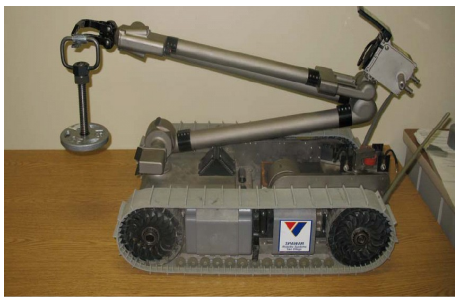


Figure 3 iRobot Packbot robot

As part of this project, ARL conducted a failure modes and effects analysis for the robot, reviewed field repair and parts order records, and interviewed robot system operators and maintainers to determine the most top degraders of robot performance and availability. This degrader analysis was used to guide the development of health monitoring solutions for the robot. Working with iRobot, ARL demonstrated health monitoring for the robot batteries and the robot manipulator arm.

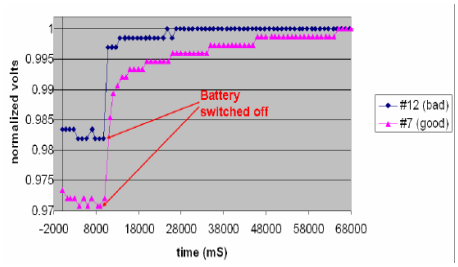


Figure 4 Voltage recovery measurements for "good" and "bad" batteries.

One of the key to successful operation of unmanned systems is providing the correct information on system health to the remote operator. Failure modes associated with the robot arm are usually caused by the operator overstressing the arm motors by lifting objects which are too heavy or lifting objects with the arm extended too far (putting excess torque on the arm and motors). Figure 5 shows an example user display of health information.

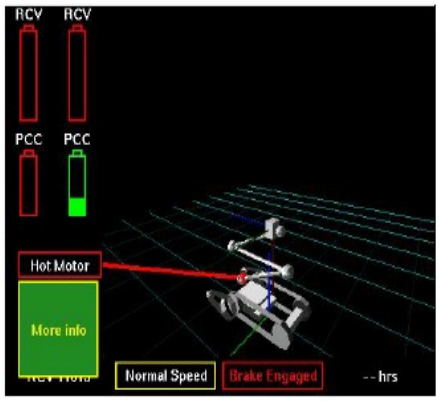


Figure 5 Operator interface showing battery and arm health information.

The robotics related research programs executed by the Applied Research Lab and the Penn State College of Engineering have demonstrated the implementation and benefit of health monitoring on unmanned systems. The project with iRobot on the Packbot EOD robot demonstrated health monitoring applications using existing sensors and signals available in the existing robot control system. Future projects will add sensors to implement health monitoring for additional degraders and provide health monitoring information to onboard autonomous control systems as well as the operator.

Student projects

Harrison Gyurko (Ph.D., Acoustics) – Design and development of a test bed for collecting vibration data from journal bearings. Data from the test bed will be used to validate numerical models of journal bearing noise mechanisms and to collect data for bearing health management algorithms.

Greg Bower (Ph.D., EE) – Development of a prognostic health management system for silicon carbide semiconductors. The project involves developing models for SiC semiconductor failure modes, the collection of failure data, and the development and implementation of prognostic health monitoring algorithms based on the application of symbolic dynamics.

Scott Laurin (MS, Acoustics) – Prognostic health of electromagnetic actuators. The project will implement impedance spectroscopy to measure the health of the components in electromechanical actuators.

Jordan Shelley (BS, Comp. Sci.) – Development and implementation of user interfaces for unmanned robotic systems. Development of automated test procedures for collecting health monitoring system training data from robots.

Propagation and Radiation

Dr. Victor Sparrow, Group Leader
vws1@psu.edu

2007 was a splendid year for the propagation and radiation group. Much of the continuing work is related to outdoor sound propagation and/or aircraft noise and is funded through and the PARTNER Center of Excellence via grants from the Federal Aviation Administration and/or 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:// partner.aero) There are several ongoing projects within PARTNER that are led by PSU faculty.

PARTNER Project 1 completed in 2007. It was a low-frequency noise study led by Dr. Anthony Atchley of the Penn State Graduate Program in Acoustics and by Kathleen Hodgdon of the Penn State Applied Research Laboratory. The goals of Project 1 were (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 included 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. Four M.S. theses in Acoustics have already resulted from Project 1, and a fifth is being completed. An extensive report on the results of Project 1 is now available (See http:// partner.aero). Follow on work is also underway by PSU faculty and students in PARTNER Project 2, Quantifying and Mitigating the Impact of Noise on People. Some of the Penn State studies underway include extensions of the Project 1 work focusing on thrust reverser noise and on developing enhanced models for aircraft noise propagation in the vicinity of airports using parabolic equation simulations.

PARTNER Project 8 is a sonic boom noise mitigation study, let by Dr. Victor W. Sparrow of the Graduate Program in Acoustics. The purposes of this research are (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. Results presented at the 2007 International Congress on Acoustics (Madrid, Spain) indicate that atmospheric turbulence substantially affects people's perception of sonic boom loudness. This work was accomplished by developing "filter functions" to account for atmospheric turbulence and playing industry-provided sonic boom signatures through the filters. In addition subjective studies were made to assess people's reactions to low-boom sonic booms in comparison with other natural and man-made sounds. Results from those tests will be available later in 2008.

NASA has also begun directly funding Sparrow through a NASA Research Announcement cooperative agreement to study sonic boom diffraction around buildings using computational simulations. The effort is focusing on develop-

ing spatially and temporally accurate acoustic scattering models for sonic boom loading on residential buildings. Such models will then be compared and validated using data taken by NASA at houses subjected to low- amplitude sonic booms at Edwards Air Force Base in the summers of 2006 and 2007.

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.

Graduate Students:

Joyce Rosenbaum, Ph.D. expected fall 2009
Thesis topic: Advanced acoustic propagation models for predicting aviation noise.
Sponsor: FAA/U.S. Dept. of Transportation Volpe Center
Advisor: A. Atchley

Kimberly Lefkowitz, Ph.D. expected Spring 2010
Thesis topic: Urban canyon effects for lowboom sonic booms.
Sponsor: NASA
Advisor: V. Sparrow

Lance Locey, Ph.D. expected summer 2008
Thesis topic: Propagation of Low-boom Sonic Booms Through Atmospheric Turbulence
Sponsor: FAA/NASA
Advisor: V. Sparrow

Sang Cho, Ph.D. expected spring 2010
Thesis topic: Sonic boom diffraction around buildings
Sponsor: NASA
Advisor: V. Sparrow

Brian Tuttle, Ph.D. expected summer 2008
Thesis topic: Nonlinear Acoustic Streaming in Conical Thermoacoustic Devices
Sponsor: Office of Naval Research
Advisor: V. Sparrow

Denise Miller, Ph.D expected summer 2009
Thesis topic: Human reaction to low-amplitude sonic booms, indoor versus outdoor responses
Sponsor: National Science Foundation
Advisor: V. Sparrow

Paul Burkhalter, M.S. expected summer 2008
Thesis topic: Microphone corrections for near-field measurement of explosion waves
Sponsor: U.S. Army Corps of Engineers
Advisors: T. Gabrielson and V. Sparrow

Bradley Dunkin, M.S. expected spring 2008
Thesis topic: Source Noise Characterization of Commercial Aircraft During Landing Operations
Sponsor: FAA
Advisors: A. Atchley

Ryan Harper, M.S. expected summer 2009
Thesis topic: Improved Modeling of Thrust Reverser Noise
Sponsor: FAA
Advisors: A. Atchley

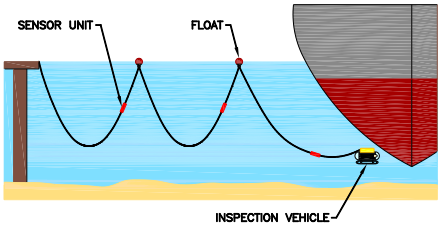
Quiet Product Design

Dr. Gary Koopmann, Group Leader
ghk1@ psu.edu

Faculty Affiliates: Dr. Ashok Belegundu Dr. Weicheng Chen, Dr. Chris Rahn
Visitors: Professor Suming Xie , Department of Mechanical Engineering, Dalian Jiaotong University.

This past year, the SBIR project sponsored by the ONR on Applications of Smart Tethers continued with KCF Technologies. Professors Chris Rahn and Gary Koopmann worked on the project led by KCF Technologies VP for Research, Richard Geiger. Tests were conducted this past summer at Panama City, FL to assess the ability of the tether to locate the position of an underwater object relative to a surface buoy that secures the tether.

The focus of this research is to develop methods of localizing underwater devices (crawlers, UU vehicles) relative to a fixed position on the surface. Initially, a tether (or series of tethers) that links the object, say an inspection vehicle, with a surface buoy (whose position is known via a GPS



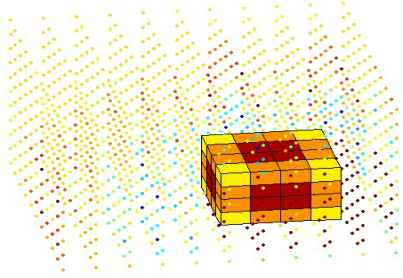
measurement) is instrumented with inclinometers and magnetometers. Using tether models (e.g. a catenary), the xyz position of the vehicle can be computed nearly in real time. This project is ongoing, Profs..Koopmann and Rahn continued on their ONR-funded FNC project entitled "Underwater Threat Neutralization: Defence of Harbor and Near-Shore Naval Infrastrucure. Their group is responsible for the control architecture of the source/receiver transmissions that focus on interdiction strategies. This past summer, the group conducted initial tests at Coddington Cove, CT. Final demonstration tests at Newport ,RI are planned for June of this year.

Completed Thesis Topics
Low-order Modeling of a Piezoelectric Energy Harvesting Device Jeffrey L. Kauffman, MS Aerospace Engineering Co-advisors: G. Lesieutre and G. Koopmann

Graduate Students and Research Projects in Progress

Germain Huang, Ph.D. expected Fall 2008
Thesis Topic: Simulation of Radiation Fields via Universal Impedances Functions in Digitized Acoustic Domains.

By working in digitized acoustic space,

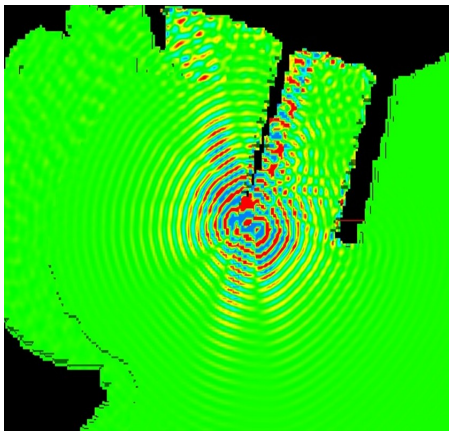


this study demonstrates that many of the cumbersome mathematical challenges inherent in boundary element methods (non-uniqueness, singularities, etc.) can be overcome. Furthermore, generating an acoustic impedance matrix provides a universal template that accommodates all geometries and boundary conditions, thus eliminating the need for matrix inversions for each geometric iteration.

Sponsor: The Graduate Program in Acoustics
Advisors: G. Koopmann and V. Sparrow

Andy Kankey, Ph.D. expected Fall 2008

Thesis Topic: The objective of this research effort is to develop a system level control architecture that integrates the detection and tracking of an intruder in the complex and dynamic underwater

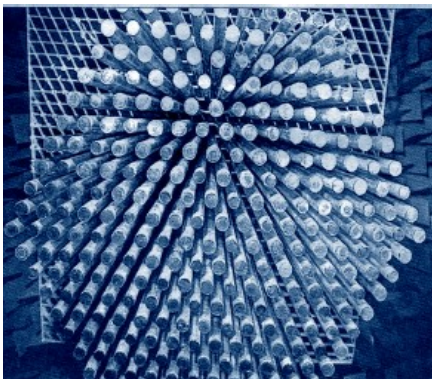


environment with sound source control "agility" to keep up with a moving target. Transfer functions (having both spatial and temporal variations) between the sources and concomitant sensors will be based on characterizing the acoustic medium with transfer functions that allow the control architecture to rapidly update the algorithm for phasing the sources to focus high intensity sound at specific coordinates.

Sponsor: Office of Naval Research
Advisors: G. Koopmann and Chris Rahn

Rebecca Buxton, MS expected summer 2008

Thesis Topic: The goal of this research is to develop and execute an acoustic finite element model demonstrating the sound-mitigating effects of a tuned periodic array. From phononic theory, a simple periodic geometry can be 'tuned' to attenuate a specific ffrequency band based on the distance between periodic elements and their total area percentage. A Matlab-based acoustic finite element code is used to generate a 3D model representing a 2D phononic array.
Sponsor: Claire Booth Luce Fellowship
Advisor: G. Koopmann



Rotorcraft Acoustics and Dynamics

Ed Smith, Group Leader
ecs5@psu.edu

The Penn State's CAV Rotorcraft Acoustics and Dynamics Group continues to be at the core of Our Vertical Lift Research Center. Penn State is Home to one of only two Vertical Lift Research Centers of Excellence in the country. Seeking cost and weight efficient solutions to lower interior noise and vibration levels, and reduced exterior noise Signatures is a high priority. Various research projects are supported by the US Army, Navy, NASA, and the industry sector. Emphasis areas include; interactional source noise, scattering, ducted fan noise, gearbox noise, actively controlled and morphing rotors, active airframe vibration control, crashworthy and impact resistant structures, anti-icing systems, variable speed rotors, and structural health monitoring.

Structural Vibration and Acoustics

Stephen A. Hambric, Group Leader
sah19@psu.edu

During the past year, the Structural Vibration and Acoustics Group organized two group meetings with seminars presented by Lee Gorny and Geon-Seok Kim (two Penn State PhD students) in Fall 2007 and by Dr. Marty Johnson of Virginia Tech in Spring 2008.

Lee and Geon-Seok presented papers they submitted to the 2007 NoiseCon conference on 'Modeling of adaptively tunable flow driven resonators for axial fan blade tone noise attenuation,' and 'Prediction of diesel engine cooling fan noise.' Their presentations to the CAV group, given prior to the conference, gave them a chance to 'dry-run' their talks, and get guidance and feedback from their professors and peers. Geon-Seok later won a best student paper award at NoiseCon 2007, and credited his CAV talk as a major reason for his award – congratulations Geon Seok!

Marty Johnson helps direct the Vibration and Acoustics Labs at Virginia Tech, and presented a summary of research conducted by students and faculty there. Marty's talk was well attended, and one of our CAV team will reciprocate by presenting CAV work at Virginia Tech in the near future.

During the 2007 Spring Workshop, the Structural Vibration and Acoustics Group highlighted two research programs, including projects in the Structural Dynamics and Controls Lab (Professor Kon-Well Wang) and ARL/Penn State's Structural-Acoustics Department (Dr. Stephen A. Hambric). To highlight the research activities, along with others by CAV team members, several recent research projects and the graduate students/staff working on the projects are summarized below:

Title: Vibration of bilaminar spheroidal shells
Sponsor: NUWC/NPT
Co-PI: Sabih Hayek (PSU) and Jeff Boisvert (NUWC)
Title: High-frequency vibration of finite elliptic-cylindrical shells
Sponsor: NUWC/NPT
Co-PI: Sabih Hayek (PSU) and Jeff Boisvert (NUWC)

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Title: Acoustic scattering from a finite bilaminar cylindrical shell panel
Sponsor: NUWC/NPT
Co-PI: Sabih Hayek (PSU) and Jeff Boisvert (NUWC)

Title: Structural intensity based health monitoring of aircraft structures
Sponsor: Army Aviation Technology Directorate (AATD)
Co-PI: Stephen Conlon and Ed Smith
Students: Two pending Ph.D. candidates

Title: Advanced health monitoring for rotor systems
Sponsor: Center for Rotorcraft Innovation (CRI)
Co-PI: Stephen Conlon and Ed Smith
Students: Walter Schmidt (M.S. candidate)

Title: Acoustic optimization of automotive transmission housings
Sponsor: Ford Motor Company
PI: Steve Hambric
Student: Micah Shepherd (Ph.D. candidate)

Title: Flow-induced self noise in torpedo sonar arrays
Sponsor: Office of Naval Research
PI: Steve Hambric

Title: Acoustics of Shaftless Propulsors
Sponsor: DARPA
PI: Steve Hambric

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

Title: Measurements of distributed dynamic impedance of fluid film bearings
Sponsors: ARL and E&F
PIs: Steve Hambric and Karl Reichard
Student: Harrison Gyurko (Ph.D. candidate)

Title: Acoustics of Large Unmanned Underwater Vehicle (LUUV) Propulsors
Sponsor: ONR
PIs: Steve Hambric and Dean Capone

Title: Commercial Nuclear Reactor Flow-Induced Vibration and Fatigue Failure
Sponsor: Nuclear Regulatory Commission
PI: Steve Hambric

Title: Fluid-elastic Lock-In of Flow Instabilities and Structural-Acoustic Modes
Sponsor: Lockheed Martin
PI: Steve Hambric
Student: Kristin Lai-Fook Cody (Ph.D. 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
Student: Ying Shan (Ph.D)
Postdoc Fellows: Mike Grissom, Mike Philen

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: Design, systems evaluation, and testing of flexible composite driveshafts
Sponsor: Center for Rotorcraft Innovation
PIs: Charles Bakis, Ed Smith, and K. W. Wang
Student: Greg Kane (M.S.)

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.)

Title: Basic research on piezoelectric materials based textile-related structures
Sponsor: Taiwan Textile Research Institute
PI: K.W. Wang
Postdoc Fellow: Jun-Sik Kim

Title: Impedance-based damage detection technology for rotor blade health monitoring
Sponsor: Center for Rotorcraft Innovation

TECHNICAL RESEARCH GROUP HIGHLIGHTS

PIs: E. C. Smith and K. W. Wang
Student: Fabio Semperlotti (Ph.D.)

Title: Rotorcraft variable speed transmission design
Sponsor: Office of Naval Research
PIs: E. C. Smith, R. C. Bill, S. Rao, and K. W. Wang
Student: Zihni Saribay (Ph.D.)

Title: Rotorcraft gust response analysis and alleviation
Sponsor: Office of Naval Research
PIs: E. C. Smith and K. W. Wang
Student: Pamela Montanye (M.S.)

Title: Highly sensitive and robust damage detection of periodic structures with piezoelectric networking
Sponsor: Air Force Office of Scientific Research
PI: K.W. Wang
Student: Ryan Struzik (Ph.D.)

Title: Fluidic flexible matrix composites for autonomous structural tailoring
Sponsor: DARPA
PIs: K.W. Wang, C.D. Rahn, and C.E. Bakis
Students: Amir Lotfi (Ph.D), Suyi Li (M.S.)
Postdoc Fellow: Ying Shan

Title: Design, fabrication, and control of flexible matrix composite skins for nastic structure actuation
Sponsor: DARPA/Teledyne
PIs: K.W. Wang, C.E. Bakis, and C. D. Rahn
Student: Ambuj Sharma (Ph.D.)
Postdoc Fellows: Ying Shan, Gautam Wagle,Alfred Tan

Title: Comprehensive modeling and analysis of rotorcraft variable speed propulsion system with coupled engine/transmission/rotor dynamics
Sponsor: NASA/NRA
PIs: K.W. Wang, E. C. Smith, and R. C. Bill
Postdoc Fellows: Jun-Sik Kim, Dong Han

Title: Rotating equipment shaft crack monitoring
Spnsor: EPRI
PI: Marty Trethewey
Students: one pending Ph.D. Or M.S. Candidate

CAV INFORMATION

Dr. Gary H. Koopmann, Director
Penn State University
157 Hammond Building
University Park, PA 16802
Tel: 814-865-2761
Fax: 814-863-7222
Email: ghk1@psu.edu

Dr. George A. Lesieure
Associate Director
Penn State University
233 Hammond Building
University Park, PA 16802
Tel: 814-865-2569
Fax: 814-865-5965
Email: g-Lesieutre@psu.edu

Karen J. Thal
Communication Coordinator
Penn State University
157 Hammond Building
University Park, PA 16802
Tel: 814-863-1673
Fax: 814-863-7222
Email: kjt3@psu.edu