CAV Review '06

CENTER FOR ACOUSTICS AND VIBRATION

CAV Workshop
May 8 - 9, 2007

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

The program for this year will feature a slightly diffferent mix of presenters. Our own technical group leaders and our international liaisons will be joined by representatives from local businesses who will discuss their research interests. 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 Tuesday evening.

Engineered Adaptive Structures V

The Center for Acoustics and Vibration sponsored the Engineered Adaptive Structures V (EAS V) Conference in Maiori, Amalfi, Italy, June 18 - 23, 2006. The conference was held at the Hotel Reginna Palace which overlooks the picturesque sea coast. There were over 35 participants with a special session for the participants of Magnetoelastic Engery Systems for Even More Electric Aircraft (MESEMA)

The format for the event was the same as the past four with morning sessions and the afternoons for colleagues to participate in informal discussions. There was also plenty of time for attendees and their guests to take in all the sights of the surrounding area.

As before EAS V focused 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

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Vertical Lift Research Center Takes Off

Seated inside the cabin of the XV-15 Flight Simulation Cabin are (l-r) Profs Joe Horn and Ed Smith both of the Penn State Aerospace Engineering Department. Standing outside of the cabin is Mark Dreier of Bell Helicopters.

On May 25, 2006 we were selected as one of only two Vertical Lift Research Centers of Excellence. We will be awarded one of the two US Army contracts after a truly extraordinary and extended process, which started with visits to the Pentagon back in January 2005! Our award is approximately $4.5M of US Army funds, in addition to considerable industry and Penn State cost sharing. Georgia Tech won the other award for an identical amount. I share with you part of our Proposal Introduction in the following paragraphs. We are grateful to many individuals who have helped us to this wonderful position. Of course, the hard working and dedicated faculty and students here on campus played a vital role, however, our Penn State credibility has been built over many decades.

At Penn State University, our vision for the collaborative industry/government/ academia future of rotary-wing aircraft is bright. We see breakthrough technologies, new vehicle configurations, and the next generation of motivated, well-trained engineers poised to advance the state-of-the-art in vertical flight. Our expanded team of faculty and students from six major research universities is dedicated to building a world-class integrated VLRCOE to serve and interact closely with the vertical lift community for years to come. We believe that only by embracing new critical technology areas, and tightly coupling them with an outstanding base in rotorcraft aeromechanics, can affordable, reliable, and survivable vertical heavy lift vehicles transform the 21st century battlefield.

One pillar of the Penn State RCOE is close interaction with industry and government labs. We worked hard to lead the University community to an effective agreement that enables wide-scale University participation in the Center for Rotorcraft Innovation (CRI). Our Center Director also serves as the sole University representative on the CRI Technical Advisory Committee (elected twice). In the past ten years, we have gained extensive experience with technology transfer mechanisms and joint projects. We have budgeted an ample amount of travel funds to enable our faculty to travel extensively to industry and government sites throughout the year. These interactions focus our attention on highly relevant topics and facilitate timely and thorough

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transfer of our new technologies and ideas into the "customer" arena. This strategy has been very effective: it has helped our RCOE secure substantial additional research funding, roughly $2-2.5 million per year beyond the NRTC funding, creating a desirable "magnet effect" that a Vertical Lift Research Center of Excellence should also demonstrate. Technologies developed at Penn State are presently in prototype development for flight test with Lord Corporation and Bell Helicopter Textron, Inc. Analysis and simulations developed at Penn State are in use with every major manufacturer, as well as both Army and Navy Laboratories. Sponsored by both Army AATD and Navy ONR, we have also worked successfully on SBIR projects with several high technology companies, transitioning our basic research to viable commercial products. These companies include Intelligent Light (Dr. Earl Duque, et al), INVERCON (Dr. Joe Szefi, Ph.D. graduate of our RCOE, State College PA), TRS Ceramics (State College PA), ART (Mountain View CA), Continuum Dynamics (Princeton NJ), and KCF Technologies (State College PA).

Penn State institutional support for rotorcraft research and education during the past decade has been unparalleled. Since 1992, the College of Engineering hired four tenure-track Aerospace Engineering faculty members in the rotorcraft area. Penn State also provided millions of dollars in equipment cost sharing and over $70,000 in undergraduate research assistantships over the past ten years. During the 2005-2006 academic year, direct Penn State financial support of roughly $80,000 enabled our RCOE to develop world-class experimental and computational facilities. We recently moved into an expansive 6000 sf, state-of-the-art, contiguous office and laboratory area for our students. A highlight of this support is the construction of a new Flight Simulation Lab featuring our new XV-15 Cab, with computation engines, graphics, and control loader motors (donated by Bell Helicopter Textron, Inc. in Ft. Worth).

Our faculty has worked diligently to build strong relationships with key industrial partners. In addition to long-standing relations with industry OEMs such as Bell, Boeing, and Sikorsky, we have maintained an excellent relationship with Lord Corp., and have developed a strong relationship with Purdy Corp. Each of these companies has pledged financial support to our VLRCOE program. Lord Corp has pledged to support our research in aeromechanical stability and airframe vibration control. Purdy Corp. has pledged to support our propulsion and drivetrain research. We are also in process of developing partnership projects with Kaman Aerospace Corporation, and several units of Goodrich Corporation.

40 graduate Students

5 Res Assoc.

Flight Sim Lab

Benchtop Labs

Bruce Ta Memorial RC Heli Lab

Vert Flight Museum

The addition of new faculty members and research associates to our VLRCOE team, in combination with the development and acquisition of new research facilities, enables us to address a broad range of technical topics over the next five years. Please do visit our website at http://www.engr.psu.edu/rcoe for more information on specific projects.

The Penn State RCOE has attracted research funding from a variety of DoD and industrial sources. We were the first of the NRTC Centers to engage heavily with the U.S. Navy. In January 2006, ONR funded a program titled "Innovative Technologies for Enhanced Safety, Survivability, and Performance of Naval Rotorcraft." In this program, we are addressing topics such as variable-speed transmissions, crashworthy mounts, and active rotors for shipboard gust response. We are also heavily engaged with CRI, to transition our basic research technology, and to explore new initiatives in both propulsion technology (gearbox windage, optimal design of drive systems) and condition-based maintenance (rotor blade damage detection). Our VLRCOE proposal has been carefully crafted to complement the existing and expanding suite of research activities in our Center.

Iin summary, it has been an intense and very rewarding year for our Rotorcraft Center. Carried by our winning proposal to the US Army, we now move forward into an exciting new era as a Vertical Lift Research Center. This summer we will be spinning up many of our new multi-year research projects, bringing our expanded new student offices and labs fully online, and continuing to actively seek opportunities (NASA, US Navy, CRI, etc) to contribute throughout the Vertical Flight arena. On behalf of all of my colleagues, and our terrific students, I personally invite you to come and visit, or contact us via email if you have any suggestions for our future activities. Many of the best research ideas and most challenging problems come from practicing professionals – just like you!

Over and out from Nittany Lion Country.

Professor Ed Smith
Director, Vertical Lift Research Center

MARK YOUR CALENDARS
Engineered Adaptive Structures VI
Big Sky, Montana
June 20 - 25, 2008

visit Big Sky at www.bigskyresort.com

EAS V held in Italy (cont.)

adaptability is common in the biological world, e.g., changes in the skin color of a chameleon to match its environment, adaptability in engineered structures is still very much an emerging technology. Applications similar to this are due to advances in four major technologies that are continuing to develop rapidly in Asia, Europe, and the USA. These include: development of modern, man-made transduction materials that both sense and actuate, e.g., piezo-ceramics, magnetostrictives, and shape memory alloys; modem digital control and decision theory; and miniaturization of electronic components used with sensors/actuators/controllers techniques for fabricating structures of composite materials with embedded sensors/actuators/controllers

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

The next EAS will be held in Big Sky, Montana, USA in 2008. If you would like more information on the upcoming conference please contact Ms. Thal.

Scholars Visit the CAV

Since November 2006 the CAV has been fortunate to have three visiting scholars associated with the Center's activities. The CAV Quiet Product Design Group is pleased to host Dr. Suming Xie, Professor in the Department of Mechanical Engineering at the Dalian Jiantong University in Dalian, China. Dr. Xie will be working with Dr. Gary Koopmann on research projects involving vibration and noise analysis. Xie is being sponsored by the China Scholarship Council for one year.

Dr. Kon-Well Wang is fortunate to have two visiting scholars at this time. Dr. Deshi Wang, a visiting researcher from the Department of Mechanical Science and Engineering of the Huazhong University of Science and Technology will be working with the Structural Dynamic and Controls Laboratory (SDCL) Feburary 2007 - January 2008. Professor D. Wang will be doing research using nonlinear system theory for drive shaft dynamics analysis. He is being sponsored by the China Scholarship Council.

Dr. Alfred C.H. Tan is at Penn State working with Drs. K.W. Wang and Chris Rahn. He received his Masters from Nanyan Technical University in Singapore and his Ph.D. from the University of Southampton, United Kingdom. He then completed a postdoctoral at the Tokyo Metropolitan University. Tan's work will involved electroosmotic pump controls. Dr. Tan will be with the SDCL for the entire 2007 year.

This photo is the marina in Maiori. The photo was taken by an EAS V participant, Huangeng Luo

Corporate Membership in the Center

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

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

Corporate Members and Representatives
Bettis Atomic Power Lab – Larry Corr
Copeland Corporation – Macinissa Mezache
Electric Boat – Gary Cooper
Fisher Controls - Al Fagerlund
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Lockheed Martin – Steve Dunn
Sincoceramics - Jingru Zhang
Trane Company – Gregory Meeuwsen
United Technologies Research Center – Rebecca Bryant
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International Liaisons and Representatives
ISVR (U.K.) – Steve Elliot
DLR (Germany) – Wolfgang Neise
CIRA (Italy) – Antonio Concillio

CAV Members Receive Awards and Honors

Bernhard Tittmann, received the Fellow of ASM Award.
Matthew Kroph, received the Best Poster Award at the Engineering Science & Mechanics Graduate Student Conference.
Edward Smith, Penn State Engineering Society Outstanding Adisory Award.
Vigor Yang, John L. and Genevieve H. McCain chair of Mechanical Engineering.

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Kankey Receives NDI Association Fellowship

Andrew Kankey, a Ph.D. candidate in Mechanical Engineering at the Pennsylvania State University, recently was awarded the National Defense Industrial Association's Undersea Systems Division Fellowship for $3000. The award was in recognition of outstanding research on high amplitude, low frequency underwater acoustic modeling, simulation, and control. Kankey is currently working with a multidiscipline team investigating acoustic means to render our nation's harbors more secure. Previously, he submitted and presented an award-winning student paper for the joint ASA/Noise-Con 2005 conference based on his Masters research at Penn State. He later expanded his paper into an article that was published in the Noise Control Engineering Journal in 2006. During one of his graduate Engineering Design courses he completed a class project that resulted in another article that was published in the online TRIZ journal in 2004.

Kankey attended the Ohio State University and was awarded his Bachelor of Science Degree in Mechanical Engineering. After a year of courses in Architecture, he decided that the physics and science of Mechanical Engineering would be more interesting. He was inducted into the Ohio State chapter of Tau Beta Pi and was a member of the Order of the Engineer, a society that works to conserve the integrity of the engineering profession.

After graduating Magna Cum Laude in 2003, he cane to Penn State where he was advised by Dr. Gary Koopmann. While he was earning his Masters degree in Mechanical Engineering he worked intimately with the Graduate Program in Acoustics and the Applied Research Lab. This peaked his interest in the study of vibration and acoustics. He received his Masters degree in the summer of 2005 and decided to continue his study to the Ph.D. level. Upon receiving his Doctorate, he plans on pursuing an academic appointment where he can help instruct the next generation of engineers.

Andrew Kankey, left receives the National Defense Industrial Association's Undersea Systems Division Fellowship from Dr. David Bradley of the Applied Research Laboratory at Penn State.

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Acoustics Characterization of Materials

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

Professor Bernie Tittmann's group has had a visitng Post Doctoral visitng from the University of Eriangen, Germany. Michal Bezdek was with the group for eight months and brought with him a special simulation program which he taught to the group members in a series of lectures. The Finite Element program is very useful for solving acoustic wave propagation problems for complex geometries.

The group has branched out into biomechanical projects and has published in the British Journal of Ultrasound in Medicine and Biology as well as in a special issue on biomedical imaging of the IEEE Transactions of Ultrasound, Ferrelectrics and Frequency Control.

Along with the above publications Tittmann delivered an invited paper on Ultrasonice Properties of Carbon/Carbon Composite and the Development of Guided Wave Sensors for Process Control at the International Congress of Ultrasonics and Acoustics at the Vienna Technical University in Vienna, Austria.

Mike Pedric, Ph.D. candidate will be graduating Spring 2007.

Interdisplinary Graduate Students, Ryan Pfaff, Ian Lucas, and Chris Fontana will be graduating.

M.S. graduating students are Dominik Pellkofer and Sahar Lueh.

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. The Air Force Office of Scientific Research (AFOSR) is sponsoring a continuing effort in "morphing" aircraft structures. The National Rotorcraft Technology Center (NRTC) supports a project that involves the active deployment of tiny trailing-edge devices to improve rotor performance. Bell sponsors a program to improve the modeling of the

dynamic behavior of helicopter lag dampers. Finally, the Department of Energy and KCF Technologies support a project in self-powered piezoelectric energy harvesting.

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. expected: May 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 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. Farhan Gandhi
Student: Michael Thiel
Ph.D. expected: May 2009

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. expected: May 2007

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. expected: August, 2007

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 defense. DARPA is supporting the development of soft robot manipulators that have robust dexterity for follow-the-leader teleoperation and whole arm manipulation in collaboration with Dr. Qiming Zhang in the Materials Research Laboratory. DARPA is also funding research on flexible matrix composite actuators and plates that change stiffness by orders of magnitude when filled with pressurized fluid in collaboration with Drs. Wang of MNE and Bakis of ESM. Drs. Koopmann and Rahn are collaborating on two projects for the Office of Naval Research. First, they are developing MEMS sensors and catenary algorithms that predict the shape of underwater tethers used for communication and power transmission for underwater vehicles. Second, they are developing underwater acoustic defense systems for Naval assets in harbors. Finally, Dr. Rahn has a seed grant from the Air Force Office of Scientific Research to study peizoelectric actuators for nano air vehicles.

Title: MAST
Sponsor: DARPA
Summary: Fluidic flexible matrix composite development for stiffness changing structures.
Title: F2MC Structures
Students: Amir Lotfi (PhD - 2009)

Sponsor: DARPA
Summary: Electroosmotic pump controls for Nastic skins
Post-doc: Alfred Tang
Title: Nastic II

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

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

Title: Piezoelectric Actuators and Wings for Nano Air Vehicles
Sponsor: AFOSR
Summary: MEMS fabrication processes used to develop piezoelectric actuators and wings for NAVs.
Students: Hareesh Kommepalli (Ph.D. - 2010), Andy Hirsh (MS- 2008).

Flow Induced Noise Control

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

Drs. Gary Koopmann and Mike Jonson are continuing to investigate 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.

Mr. William Bonness and Dr. Dean Capone continue an experimental study of low wavenumber turbulent boundary layer wall pressure spectra in a cylindrical pipe. They hope to address longstanding questions about the amount of energy in a turbulent boundary layer which couples well to marine structures. They also plan to investigate the role of fluctuating wall shear stress on structural excitation.

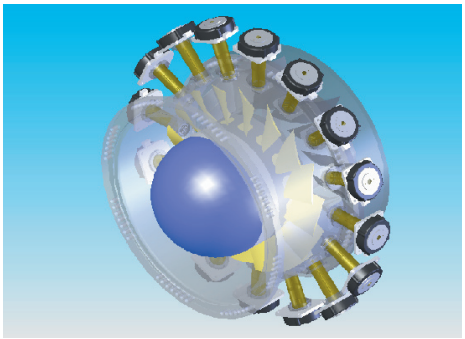
Dr. Stephen Hambric has been consulting for the NRC on flow-induced vibration and fatigue failure problems in U.S. commercial nuclear power plants.

Dr. Tim Brungart, Mr. Steve Young, and Mr. Greg Myer, in conjunction with Dr. Michael Howe of Boston University, are continuing to develop 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.

Mr. Lee Gorny and Drs. Gary Koopmann and Dean Capone are continuing to study the use of quarter wavelength resonators to reduce blade tone noise generated by axial fan systems. Currently the focus of the research is to investigate at various levels the effectiveness of tunable resonators as flow driven secondary sources used to attenuate blade tone noise of axial fans. As shown in the figures, the focus this study is to integrate tunable flow-excited, quarter-wavelength resonators into the shrouds of ducted subsonic axial fans to explore their effectiveness in attenuating axial fan blade tone noise. Resonators are positioned such that they are driven by the existing pressure fluctuations

incident on the fan shroud from passing rotor blade tips and are then tuned appropriately to generate an anti-phase secondary sound field. This is accomplished through adjustment of the opening impedance, length, and the circumferential and axial mouth positioning of individual resonators with respect to the passing rotor blades. Research on this topic has recently been conducted at the Deutsches Zentrum für Luft und Raumfahrt (DLR) in Berlin, Germany using an anechoically-ducted 358mm diameter, high pressure, axial fan facility with sixteen and eighteen blade rotors which are coupled with a sixteen vane stator set. The sixteen blade rotor set is used to test plane wave propagations while the 18 blade set radiates primarily as an m=2 mode which is used to investigate higher order mode phenomena.

To this point, sixteen surrounding resonators, as shown in the figure below, reduced plane wave propagations of fan noise by greater then 25 dB to a level within 5dB of the broadband noise level with negligible effects on efficiency of the DLR fan. Higher order mode propagations of tonal noise were attenuated by as much as 28 dB using a sixteen resonator configuration (equal to the number of stator vanes) to generate a cancelling secondary sound field. Further investigations into these results are in the process to further assess the physical mechanism by which tonal noise is attenuated. Numerical modeling of the fan system is planned such that resonator incorporation into the surrounding area of fans will be possible in the design phase rather than through strategic experimentation.



Investigations of bi-directional attenuation methods using dipole-like resonator configurations are also being conducted for plane wave propagations. Higher order mode bi-directional reduction has been accomplished for higher order modes by as much as 10 dB, and plans to further investigate this possibility at the DLR are tentatively in place. Another project is scheduled to begin shortly with Ingersoll Rand to apply this technique to an industrial cooling system fan and verify the potential of this method as a retrofit for existing technology.

Machinery Prognostics and Condition Monitoring

Dr. Karl M. Reichard, Group Leader
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The Machinery Prognostics and Condition Monitoring Technical Group is focused on methodologies and technologies for accurate and reliable assessment of equipment condition and predicting remaining useful life in machinery.

Over the years, there has been a shift in the motivation for system health monitoring. Many initial efforts in health monitoring centered on the development of health and usage monitoring systems to track equipment usage and ensure proper execution of time-based and preventive maintenance. Later, the emphasis shifted to condition based maintenance, reducing manning, and managing total life cycle cost. Today, one of the primary drivers for system health monitoring is autonomic logistics to provide faster and more effective response to needs for maintenance and support.

The Pennsylvania State University Applied Research Laboratory is currently supporting several programs in support of autonomic logistics concepts. The primary emphasis in these programs is to provide remote access to information on the health and status of military platforms. As part of these programs, ARL has instrumented a USMC MTVR tactical truck and a HMMWV. The systems installed on the platforms have the ability to report health and status information to an autonomic logistics server via satellite modem. Users can log into the server and view the equipment status and health over an internet connection.

Figure 1 MTVR and HMMWV instrumented for Autonomic Logistics at ARL.

The Applied Research Laboratory is also 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 aircraft structural components.

Several ongoing projects are examining the application of health monitoring techniques to unmanned and robotic systems. In one project, ARL is working with iRobot, manufacturers of the Packbot Explosive Ordinance Disposal robot shown on the right below, 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.

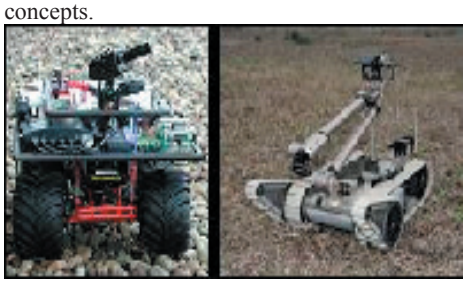

Figure 2 Robotic platforms for health monitoring studies.

Randy May, a graduate student in the Penn State Graduate Program in Acoustics is investigating the use of flexural wave active power for monitoring changes in the health of structures. Randy is applying the technique to monitor crack growth in a flexible beam. The changes in the measured flexural wave active power are being compared to changes in the frequency of structural resonant frequencies. Randy May's work is supported by ARL through its Exploratory and Foundational Research Program. Randy will complete his M.S. in Acoustics in July 2007.

Harrison Gyurko, another student in the graduate program in acoustics supported by ARL's Exploratory and Foundational Research Program, has designed and built a test rig for investigating noise radiation mechanisms in journal bearings. Harrison expects to complete his Ph.D. in Acoustics in 2008.

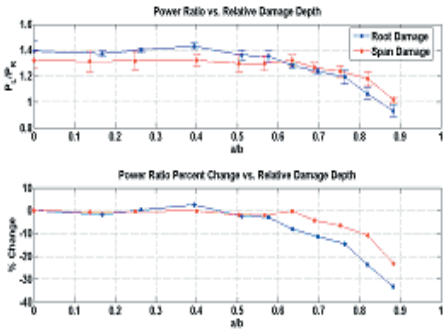

Figure 3 Structural power flow changes as a function of beam crack depth.

Bryon Rattman completed his M.S. in Acoustics in the fall of 2006. Bryon studied the ap-

plication of information metrics and compression techniques to the detection and tracking of faults in mechanical and electrical systems. Bryon's thesis applied these techniques to gearbox data collected on the ARL Machinery Diagnostic Test Bed.

Propagation and Radiation

Dr. Victor Sparrow, Group Leader
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Propagation and Radiation Group
Dr. Victor W. Sparrow, Group Leader
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The propagation and radiation group had a good year in 2006. Much of the continuing work is related to outdoor sound propagation and/or aircraft noise and is funded through the PARTNER Center of Excellence via grants from the Federal Aviation Administration and the National Aeronautics and Space Administration. The Penn State Graduate Program in Acoustics is a founding member of PARNTER (Partnership for AiR Transportation Noise and Emissions Reduction), led by MIT. (See http:// partner.aero) There are several ongoing projects within PARTNER that are led by PSU faculty.

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

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

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

Another notable activity in 2006 was a set of special sessions on sonic boom at the 4th Joint meeting of the Acoustical Society of America and the Acoustical Society of Japan. Victor Sparrow was a co-organizer of this event, held in Honolulu, HI in December. Aloha!

Graduate Students:

Lauren Falco, Ph.D. expected spring 2007
Thesis topic: A Single-Point Indicator of Acoustic Nonlinearity
Sponsor: National Science Foundation and Office of Naval Research
Advisor: A. Atchley

Kimberly Lefkowitz, expected spring 2009
Thesis topic: Urban canyon effects for low-boom sonic booms.
Sponsor: FAA/NASA
Supervisor: V. Sparrow

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

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

Brian Tuttle, Ph.D. expected fall 2007
Thesis topic: Nonlinear Acoustic Streaming in Conical Thermoacoustic Devices
Sponsor: Office of Naval Research
Advisor: V. Sparrow

Quiet Product Design

Dr. Gary Koopmann, Group Leader
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Faculty Affiliates: Dr. Ashok Belegundu Dr. Weicheng Chen
Visitors: Suming Xie, Dakian University, China

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

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. The project is at the Phase II level and tests are planned this 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.

Starting in Feburary 2006, Professors Koopmann and Rahn began an 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 summer, the group will perform initial tests at Coddington Cove, CT.

Theses Completed/ 2006 Graduations

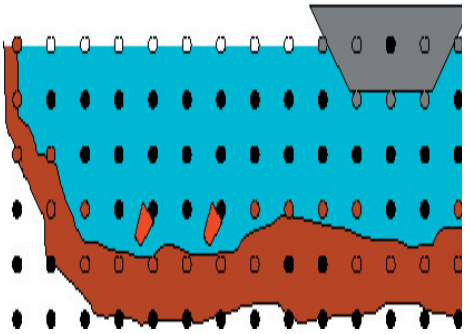
Randy Rozema, M..Engr. Spring 2006
Thesis Topic: Assesssing the Accuracy of Measuring Sound Intensity and Sound Power with an Automated Moving Probe. Sponsor: Emerson Climate Technologies
Advisor: G. Koopmann

Brian Zellers, Ph.D. Winter 2006
Thesis Topic: An Acoustic Superposition Method for Computing Structural Radiation in Spatially Digitized Domains.

TECHNICAL RESEARCH GROUP HIGHLIGHTS

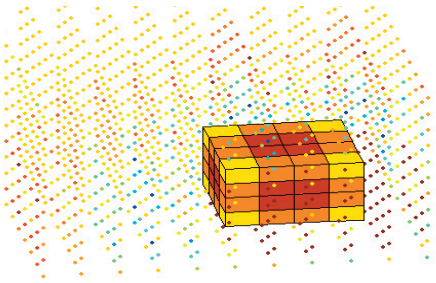
Sponsor: Office of Naval Research
Advisors: G. Koopmann and M. Jonson

David Kraige, MS Engineering, Spring 2007
Thesis Topic: Model-based Algorithm for Localization of Tethered Bodies Using Distributed Sensors.
Sponsor: KCF Technologies SBIR
Advisors: G.H. Koopmann, C. Rahn



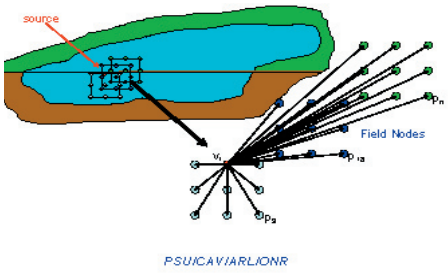
The focus of this research is to develop methods of localizing underwater devices (crawlers, UU vehicles) relative to a fixed position on the surface. Initially, a tether (or series of tethers) that links the object, say an inspection vehicle, with a surface buoy (whose position is known via a GPS measurement)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

Graduate Students and Research Projects in Progress



Germain Huang, Ph.D. expected Fall 2007
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

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



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 universal impedance 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

Rotorcraft Acoustics and Dynamics

Ed Smith, Group Leader
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The past year was truly a break-through one for Penn State's CAV Rotorcraft Acoustics and Dynamics Group. With our members leading a large multi-university team, Penn State was selected as one of only two US Army Vertical Lift Research Centers of Excellence. We also secured major new projects from the US Navy visa ONR, and from NASA's Fundamental Aeronautics program. See the cover sotry for all the exciting details

Structural Vibration and Acoustics

Kon-Well Wang, Group Leader
kwwang@psu.edu

During the past year, the Structural Vibration and Acoustics Group has organized two group meetings with seminars presented by Dr. Eric Anderson from CSA Engineering in Fall 2006 and by Dr. Marty Trethewey from Penn State in Spring 2007. Dr. Anderson's talk was on active and passive vibration control methods. He presented a series of examples from industries including aerospace, power, ground transportation, semiconductor manufacturing and medical devices. The examples illustrated a variety of passive and active methods and highlight why particular approaches were chosen. One theme is on identification of the application characteristics that necessitate the additional performance of active systems. The talk concluded with a brief assessment of open research areas in vibration control and related fields. Dr. Trethewey's presentation was on structural health monitoring using vibration-based methods.The focus of the study presented is on the development of a torsional vibration shaft crack monitoring system for reactor coolant pumps. The seminars have attracted many audiences and have stimulated some very good discussions.

During the 2006 Spring Workshop, the Structural Vibration and Acoustics Group has highlighted a couple of research programs, these include projects in the Dynamic and Structural Stability Lab (Dr. Eric Mockensturm) 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: Acoustic Scattering from Elliptic-Cylindrical Elastic Shells
Sponsor: NUW/ONR
Co-PI: Sabih Hayek (PSU) and Jeff Boisvert (NUWC)

Title: Dynamics modeling of two-layered prolate shperoidal elastic shells
Sponsor: NUWC
Co-PI: Sabih Hayek (PSU) and Jeff Boisvert (NUWC)

TECHNICAL RESEARCH GROUP HIGHLIGHTS

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

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
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