# CAV Review '12-'13

## CENTER FOR ACOUSTICS & VIBRATION

## CAV Update

### Spring workshop dates set

The CAV's annual workshop will be held at the Penn State Nittany Lion Inn April 29-30. This year the workshop will have the same format as that year's with the event lasting for two full days. On Monday morning, following the formal presentations, we will have a panel discussion on energy harvesting and structural health monitoring. We will be following this pattern for Tuesday's session with a panel discussion on vibroacoustics instrumentation. As in the past laboratory tours will be given to familiarize attendees with some CAV facilities. Monday evening we will again have a student poster session and reception. This will be held at Café Laura in the Keller Building. As in the past, the program will mix presentations from technical group leaders, international liaisons, several corporate sponsors, and new government liaisons. Graduate students and their advisors will be available for discussions concerning their research. While formal presentations are organized to allow for the exchange of technical information, we have lengthened the allotted time for breaks to offer ample opportunities for informal discussions.

### Student poster session held during workshop

The student poster competition will be held at our Monday evening social at the Café Laura, between 6 and 9 pm. Our corporate sponsors, government guests, and international liaisons will cast votes for the best posters, and we'll award small prizes for 1st, 2nd, and 3rd places ($200, $150, and $100).

### CAV seminars archived online

Remember that CAV members may now access our previous lunchtime seminar series online. Videos of the presentations from Fall 2009 to present may be viewed. This is a service to our members only, so please contact us for the site location.

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# Penn State Contributes to NASA Supersonics


*Fig. 1. NASA Dryden F/A-18 mission support aircraft were used to create low-intensity sonic booms during the WSPR sonic boom perception and response research project. (NASA / Jim Ross). Image and caption from http://www.nasa.gov/centers/dryden/Features/WSPR_research_complete.html*

NASA's continued interest in developing the technologies that will enable civilian supersonic travel has again included researchers at Penn State. Two NASA Research Announcement (NRA) projects related to sonic boom noise recently completed in this area, providing key information for the development of low-boom supersonic aircraft. Three Penn State investigators are involved in different aspects of the work: Kathleen Hodgdon of the Applied Research Laboratory, Victor Sparrow of the Graduate Program in Acoustics, and Joe Salamone of the Graduate Program in Acoustics and Gulfstream Aerospace Corp. Although the envisioned low-boom air vehicles will have to meet a number of environmental constraints, including requirements on emissions, subsonic take off and landing noise, and fuel efficiency, the most difficult environmental constraint to overcome is the noise heard on the ground during supersonic cruise, known as sonic boom noise. Both NRA projects focus on sonic boom noise and were led by Wyle, Arlington, VA. Penn State was a critical team member of each project, and these contributions will be described in a moment.

A sonic boom is the sound heard on the ground whenever an aircraft is flying supersonically, i.e., faster than the speed of sound. At altitude this is about 300 m/s, or 934 ft/s or 670 mph. The only civilian aircraft to routinely fly supersonically was the British-French Concorde airliner, developed in the 1960s and 70s. That aircraft is now retired. It was very successful in filling a niche need to fly at high speed between Europe and North America in the 1980s and 90s. However, Concorde was expensive to fly, was very loud at takeoff, and was restricted to overwater routes

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# Corporate Members & International Liaisons

**Corporate Members & Representatives**

Bettis Atomic Power Lab—Eric Salesky
Boeing—Joseph Wat
Electric Boat—Michael Thiel
Fisher Controls Technology International, LLC—Al Fagerlund
General Electric Global Research Center—Andrew Gorton
Gulfstream—Kristopher Lynch
KCF—Jacob Loverich
KAPL—Steve Dunn
Lord Corporation—Mark Downing
Martin Guitar—Brenden Hackett
Moog, Inc. —Eric Anderson
Newport News Shipbuilding—Kevin Smith
Pratt & Whitney— Rick Labelle and Lon Preston
Siemens Corporation—Justinian Rosca
United Launch Alliance—Ed Heyd
United Technologies Research Center—Jeff Mendoza
Volvo Construction Equipment—John Wang
Westinghouse Electric Company—Larry Corr

**International Liaisons and Representatives**

ISVR (UK) - Jeremy Astley
DLR (Germany) - Lars Enghardt
CIRA (Italy) - Antonio Concilio
INSA de Lyon—Jean-Louise Guyader
KAIST—Yang-Hann Kim
KU-Leuven—Wim Desmet
Hong Kong Polytechnic University— Li Cheng

# CAV Welcomes New Corporate Sponsors

The CAV is pleased to welcome a new corporate sponsor to the Center for 2012-13.

**Pratt & Whitney—company liaisons, Rick LaBelle and Jon Preston**

Pratt & Whitney, founded in 1925 by Frederick Brant Rentschler has withstood the changing world by following the principles and practices Rentschler began with. He believed in integrity, listening to the customer and providing them with a reliable product by building a strong team with vision to create the best possible engines. The company began a new industry during the war years by their work in liquid and air cooled engines, and then turbojets. The have met goals, created productive partnerships while becoming the most powerful corporation of its time. Today Pratt & Whitney builds large commercial engines, military engines, power systems, power, propulsion & optimization, and auxiliary power units. For more information please visit http://www.pw.utc.com

# CAV Welcomes New International Liaisons

The CAV is pleased to welcome two new international liaisons: the Noise and Vibration Research Group from Katholieke Universiteit in Leuven, Belgium, and the Consortium for Sound and Vibration Research at the Hong Kong Polytechnic University. Here is some information about our new friends.

***Noise and Vibration Research Group from Katholieke Universiteit***

The Noise and Vibration Research Group (PMA) has a well-established research experience in the field of noise and vibration analysis of mechanical structures. Machine tool stability was the origin of the research in the field of structural dynamics at PMA. In 1973 PMA was one of the first laboratories in Europe to introduce a digital FFT Analyser (HP 5451A) for noise and vibration analysis in the field of mechanical engineering.

The development by PMA researchers of analysis (modal analysis) to characterize and optimize the structural dynamic behavior raised the interest of several European industries and research institutes. Challenging and important research projects followed. Giving PMA worldwide recognition in the field of noise and vibration analysis.

Some spin-off companies were founded by former PMA collaborators to commercialize the results of PMA's structural dynamics research. The most successful among them is certainly LMS International which evolved throughout the years to become a market leader in the field of noise and vibration analysis software. The close collaboration and joint research projects between PMA and LMS–International are certainly a guarantee for the industrial relevance of the scientific research at PMA, and offers a unique forum for its research results.

***Consortium for Sound and Vibration Research at the Hong Kong Polytechnic University***

The mission of the Consortium is to carry out high-quality research and development to meet the industrial, commercial and community needs of the society. Major aims are to foster close collaborations and build up better synergy in sound and vibration research through a research network including the Hong Kong Polytechnic University, oversears research institutions, public service corporations, local industry and governmental departments; and to assist/influence government noise control policy and to enhance the competitive edges of HK in acoustical products/designs through active technology transfer.

Targeting a leading position in research in relevant areas in the world, the research activities in the Consortium cover the whole spectrum of both fundamental and applied noise and vibration research, e.g., environmental noise, computational acoustics, aeroacoustics, flow-induced vibration and noise, structural vibration, structural health monitoring and damage detection, vibro-acoustics and active control.

During the past few years the Consortium has made collective efforts to be excellent in research and consultancies. Fruitful achievements have been well recognized by its peers, partially reflected its more than 300 SCI journal publications, more than 50 funds and grants from different governmental agencies, and more than 100 consultancy projects from industry.

# New Faculty Member

## Vigeant Joins Acoustics Program

The Graduate Program in Acoustics and the CAV welcomes Dr. Michelle Vigeant to Penn State. Dr. Vigeant joined the Acoustics faculty in July 2012. She is now Assistant Professor of Acoustics (75%) and Assistant Professor in Architectural Engineering (25%). She did her Ph.D. work at the University of Nebraska under the mentorship of Acoustics alum Lily Wang. Most recently she was an Assistant Professor of Mechanical Engineering at the University of Hartford under the mentorship of Acoustics alum Bob Celmer. Dr. Vigeant is interested in many areas, but her primary research interest is Architectural Acoustics. She has already begun teaching in this area for the Department of Architectural Engineering during the Fall 2012 and Spring 2013 semesters. We are also pleased to report that Dr. Vigeant recently received a National Science Foundation Early CAREER award in the area of Architectural Acoustics. If you would like to contact Dr. Vigeant her email address is vigeant@engr.psu.edu. Please join us in welcoming Dr. Vigeant to the Acoustics program and the CAV.

(continued )
because of its large amplitude sonic boom. The aircraft was relatively heavy by today's standards, increasing the intensity of the boom, and there was no attempt to minimize the sound heard on the ground.

The main objective of NASA's recent supersonics initiatives has been to work toward establishing tools and techniques that can be used by commercial airframers to build small to medium size supersonic aircraft that have body shaping such that the sonic boom heard on the ground is minimal. The thinking is that the envisioned "low-boom" aircraft would be acceptable to the majority of the public, enabling anytime-anywhere operation of the new supersonic aircraft. Flying at Mach 1.6 to 1.8 (1.6 to 1.8 times the speed of sound) these vehicles would enable coast to coast round trips in North America in a single day, allow government personnel to get to disaster scenes twice as fast, and greatly extend the area of potential organ transplant donors to help critically ill patients on transplant waiting lists. Sonic booms can be thought of as similar to the wake of a boat traveling on a calm lake, except in three dimensions. As a listener waits for a supersonic aircraft to go by, the airplane first goes by, and in a few seconds the wake, called a sonic boom, eventually will pass by and can be heard. However, the new "low boom" sonic booms can be very quiet, and might be missed if there is any background noise present. At supersonic cruise, the aircraft might be at 40,000 to 50,000 ft altitude to get above the subsonic aircraft traffic. This cruise altitude means that the sonic boom will be heard over a plus or minus 25 mile extent to the right or left of the aircraft flight path. Thus, while the aircraft is flying supersonically, it will could be heard by anyone within a 50 mile wide "carpet" on the ground laid out during the flight. Many individuals will be exposed to the sonic boom noise during even a single flight.

NASA and industry are both interested in how communities will react to the addition of this new sonic boom noise to their local environments. Most people associate aircraft noise with the noise in and around airports, or they might hear faint aircraft noise while the planes are at high altitude. But how will a community react to the new "low-boom" sonic boom noise being added to their daily lives?

NASA's recently concluded WSPR program focused on establishing data collection methods and test protocols to assess a community's reaction to these new noises. WSPR stands for Waveforms and Sonic Boom Perception and Response program. Kathleen Hodgdon of ARL Penn State was co-principal investigator of the WSPR program with Juliet Page of Wyle. Kathy was instrumental in designing a test to expose a community to simulated sonic boom noise and then statistically evaluating the community response. Hodgdon's work at Penn State was funded as a subcontract provided by Wyle who had oversight of a large fraction of the WSPR coordination efforts. A number of additional industry partners were involved, notably Gulfstream Aerospace Corp., of Savannah, GA. In WSPR Gulfstream developed and operated novel stand-alone sonic boom community noise monitoring stations that were set up in the test area.

NASA has a way of using a conventional F/A-18 aircraft and putting the aircraft through a special dive maneuver to create "low-boom" noise in a limited area on the ground. By making carefully coordinated supersonic dives, the "low-boom" sonic booms can be directed toward a community. This is what was done at Edwards Air Force base, Edwards, CA in 2011. The statistical results for the WSPR tests are not yet publically available. However, it can be stated that NASA was very pleased with the outcomes of the research and is contemplating appropriate follow-on studies. Edwards is a community that is regularly exposed to conventional sonic booms on a regular basis, but the follow-on tests would be at a non-acclimated community unfamiliar with sonic booms.

The other research effort that recently completed in NASA's supersonics program was the SCAMP tests. SCAMP stands for Superboom Caustic Analysis and Measurement Program. The purpose of the research was to develop a capability to predict focused sonic booms. What are these?

As a supersonic aircraft accelerates up to cruise speed, it will transition from subsonic fight to supersonic flight. At the time that the aircraft reaches Mach 1, the rays of sound emanating from the aircraft cross each other, and a louder than normal sonic boom, called a focus boom, is created. This focal region of a few hundred feet thick and a few miles wide is quite small in extent compared to the 50 mile wide sonic boom carpet created during cruise. However, the focus boom region is not minimized like the cruise signature, and hence is the loudest event during a supersonic flight. Studying the focus boom is important to assess the "worst case" of what an individual on the ground might hear.

NASA's SCAMP project was also overseen by Juliet Page of Wyle with Penn State as a subcontractor. Gulfstream was a subcontractor to Penn State, enabling Joe Salamone as both a Penn State graduate student and Gulfstream employee to fully participate in the research, under the direction of Victor Sparrow, Professor of Acoustics and Interim Head, Graduate Program of Acoustics.

In 2011 Wyle coordinated an enormous field experiment with multiple companies providing instrumentation to a remote location in the desert where NASA aircraft could place these focused sonic booms. A nearly two-mile long array of microphones was used for data collection. In parallel to the field measurements several computer algorithms were assessed for their capabilities to predict the focused sonic boom signatures, given only near field information about the aircraft. Comparisons were made between the Wyle field experiment dataset and the computer algorithm predicted signatures. Many of the results of this work were recently described at a special session organized at the AIAA Aerospace Sciences Meeting in Grapevine, TX in January 2013.

Penn State Graduate Program in Acoustics graduate student Joe Salamone developed an improved Lossy Nonlinear Tricomi Equation solution method to predict these focused sonic booms, and he was very successful in matching the great majority of the Wyle measurements. Further, this work, including the comparisons between prediction and field measurement, was accepted for publication in the AIAA Journal with the coauthors Salamone, Sparrow, and Wyle investigator Kenneth Plotkin.

Just like the WSPR work of Hodgdon, the SCAMP work of Salamone and Sparrow have created methodologies that will be helpful for NASA to assess the impact of future supersonic civilian aircraft on communities. These have been wonderful opportunities for these Penn State researchers to contribute to NASA's programs and to help minimize the future potential environmental impacts of supersonic transport on the public. And although a number of challenges remain to be solved, it is looking more and more like acceptable civilian supersonic flight will be possible in the years to come.

*Penn State Contacts: For the WSPR program - Kathleen Hodgdon, kkh2@psu.edu. For the SCAMP program - Victor Sparrow, vws1@psu.edu.*

*Fig. 2. NASA Dryden WSPR project principal investigator Larry Cliatt, Wyle's Christopher Hobbs, Gulfstream's Joseph Salamone (wearing the Penn State ball cap) and NASA Dryden engineer Erin Waggoner install one of 13 remote sonic boom sensors. The sensors were placed throughout the Edwards AFB residential community to remotely measure sonic booms for the WSPR project. (NASA / Tom Tschida). Image and caption from http://www.nasa.gov/centers/dryden/Features/WSPR_research_complete.html*

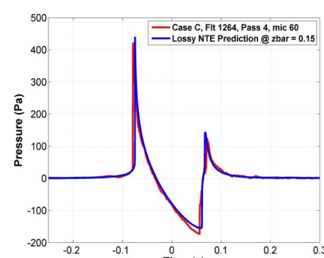



*Fig. 3. Example focus sonic boom comparison between Salamone's LNTE prediction and Wyle field measured data. For more information see J. Salamone, V. Sparrow, K. Plotkin, and R. Cowart, "SCAMP: Solution of the Lossy Nonlinear Tricomi Equation for Sonic Boom Focusing," AIAA Paper 2013-0935, 51st AIAA Aerospace Sciences Meeting, 7-10 January 2013, Grapevine, TX.*

## CAV Members Receive Honors and Awards

**Dr. Steve Conlon** - elected to the Board of Directors, and to the position of Vice President of Technical Activities, for the Institute of Noise Control Engineering (INCE-USA)

**Dr. Steve Hambric**—named Fellow of the American Society of Mechanical Engineers

**Dr. Richard Marboe** - began a June 2012-June 2015 term as ASME Vice President, Programs & Activities at the national level

**Dr. Philip Morris** -2012 Rayleigh Lecturer for the Noise Control and Acoustics Division of ASME, "Jet Noise - A Historical Perspective and Future Directions"

**Dr. Jose Palacios** – received the American Helicopter Society Bagnoud Award, this is given to a Society member under the age of 35 for their career-to-date outstanding contributions to vertical flight technology, May 2012

**Dr. John Preston** - elected a fellow of Acoustical Society of America, October 2012

**Dr. Edward Smith** - Penn State President's Award for Engagement with Students March 2013

**Brett Bissinger** – received the Kenneth T. Simowitz Memorial Citation for "Model-based signal processing for passive source localization"

**Russell Hawkins** – received the Kenneth T. Simowitz Citation for "Variation in Underwater Ambient Sound Level Estimates Based on Different Temporal Units of Analysis"

**Justin A. Long** - recipient of the Anthony E. Wolk Senior Thesis award for 2011 -2012, "Investigation of Static Load Effects on Active

Vibration Based Structural Health Monitoring."

**Stephen Nichols** - received the Kenneth T. Simowitz Citation for "Are the world's oceans really that different?"

**Andrew Pyzdek** – received the NDIA award

**Brian Reinhardt** – received the Thomas June Beaver Award for his entrepreneurial and graduate work for in regards to the new 3D tomography techniques.

**Alexander Sell** - best student paper award at INTERNOISE 2012 for "Using broadband, ship-radiated noise in shallow water environments to perform physics-based localization"

**Matthew Shaw** – received the Skudrzyk Award for "On the measurement of airborne, angular-dependent sound transmission through supercritical bars"

**Micah Shepherd** – received the Skudrzyk Award for "Comment on plate modal wavenumber transforms"

**Kyle Sinding** - received the Evan Pugh Scholar Award for Juniors

**Grant Skidmore** - selected as the inaugural recipient of the Pauling-Eisenhuth Award, this award is "to honor and recognize outstanding academic achievement by a master's degree student whose studies focus on national defense or homeland security."

**Ed Zechmann** - received approval from the INCE Executive Committee that he is INCE Board Certified; won a US Public Health Service Engineering Literary Awards (ELIT) for a paper on damping jack hammer chisels

*Steve Hambric addresses attendees at the Internoise 2012 opening ceremony*

## CAV Members Organize Conference

Steve Hambric, General Chair, and Steve Conlon, Technical Chair, directed Internoise 2012, the annual international conference on noise control engineering. Internoise 2012 was held in New York City in August 2012, and was the largest Internoise ever held, with over 1,000 technical papers and nearly 1,500 participants. The theme of the conference was 'Quieting the World's Cities', and featured special talks and sessions on City noise, along with many others. Several Penn State faculty organized sessions at the conference, including George Lesieutre and Phil Morris of Aerospace Engineering, Vic Sparrow of the Graduate Program in Acoustics, and Steve Conlon, Andrew Barnard, Micah Shepherd, and Michael Jonson of the Applied Research Lab. Phil Morris also gave the ASME Rayleigh lecture at the conference, with the topic "Jet Noise Prediction - A Historical Perspective and Future Directions". Several Penn State graduate students volunteered to help support the day-to-day operations of the conference: Jason Bostron, Rachel Ramond, Matt Shaw, Paul Bauch, Whitney Coyle, and Abe Lee. The students were coordinated by a recent Penn State Acoustics Graduate, Kim Riegel.

# Technical Research Group Highlights

## Acoustics Characterization of Materials

*Bernhard R. Tittmann, Group Leader*
*brt14@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.

The Acoustics Characterization Group of Materials is currently mainly focused on sensors for harsh environments which include high temperatures and nuclear radiation. Current generation light water reactors (LWRs), sodium cooled fast reactors (SFRs), small modular reactors (SMRs), of various types, and potentially next generation nuclear plants (NGNPs) all provide harsh environments in and near the core that can severely test material performance, and limit their operational life. As a result of this several Department of Energy Office of Nuclear Energy (DOE-NE) research programs require that the long duration radiation performance of fuels and materials be demonstrated. Such demonstrations take place in a Material and Test Reactor (MTR) and require enhanced instrumentation to detect microstructural changes under the irradiation conditions with unprecedented accuracy and resolution.).

Clearly, ultrasonic techniques offer the potential to obtain high-fidelity, high-accuracy data required to characterize the behavior and performance of new candidate fuels during irradiation testing at high temperatures that are required to assess the performance of advanced fuels, such as accident-resistant fuels under development by DOE-NE. However, it is recognized that full-scale deployment of ultrasonic tools for in-pile measurements remains challenging and will only be achieved in successive phases: Relevant to this effort are a number of theses by group graduate students Manton Guers who graduated and is now working at ARL, Cliff Searfass who graduated in 2012 and is now working in State College at the Structural Integrity Associates. and David Parks who is now working at Navico, Marine Electronics in Tulsa OK.

Current student members of the group are Brian Reinhardt, Xiaoning Xi, Kyle Sinding, Xin Li Jeong Kim and Alison Orr.

Relevant funding is comprised by an ATR-NSUF Program for insertion into the MIT Reactor for long term irradiation of candidate transducers.

## Adaptive Structures

*George Lesieutre – Group Leader*
*g-lesieutre@psu.edu*

The mission of the Adaptive Structures and Noise Control Technical Group is to pursue strategies for reducing vibration and noise in engineering systems. This involves the development of active materials and devices, accurate modeling approaches, passive control methods, discrete and distributed sensors and actuators as well as placement strategies, structural integration methods, fast and stable adaptive control algorithms, and experiments to evaluate real-world performance. In complex mechanical/acoustical systems with multiple sensing and source/actuator locations, significant challenges remain.

Professor George Lesieutre and his students are pursuing a number of projects in vibration control and active structures.

**Title:** Damping Models for Shear Beams with Applications to Spacecraft Wiring Harnesses
**Sponsor:** Air Force Research Laboratory
**Summary:** Power and data cabling is attached to a spacecraft bus structure at many points and can account for a significant fraction of spacecraft dry mass. This combination leads to coupled spacecraft and cable dynamics that require a model to predict the effects of this interaction. While current models can accurately predict vibration frequencies, typical proportional damping models are inadequate for time-domain simulations. Instead, a viscous damping model that produces approximately frequency-independent modal damping in Euler-Bernoulli beams is considered. The relevant viscous damping terms (as well as those commonly employed in proportional damping approaches) are extended and modified for application to shear beams. Careful selection of damping coefficients can produce a large range of approximately frequency-independent modal damping.

**Student:** Jeff Kauffman, Ph.D. August 2012 (now at University of Central Florida)

**Title:** Multilayered Radial Bearing Isolator for Helicopter Noise Reduction
**Sponsor:** Fellowship
**Summary:** Multilayered radial isolators are considered for attenuation of vibration from a helicopter gearbox to the cabin. A detailed finite-element (FE) model and an augmented assumed-modes model were developed to predict the dynamic behavior of such isolators at the location where the input shaft enters the gearbox housing. The two models are in good agreement when predicting the natural frequencies, mode shapes and transmissibility of a nominal isolator. The augmented assumed-modes model is an excellent design tool since it yields results of acceptable accuracy while running almost 2000 times faster than the FE model. Two experimental prototypes were developed, built and tested. Transmissibilities on the order of 20% were measured over the frequency range from 900 to 2500 Hz. Experimental results validate the augmented-assumed modes model and show that multilayered 2-D isolators can exhibit "stop-band" behavior similar to that of 1-D multilayered isolators.

**Collaborator:** Dr. Edward Smith (Aerospace)
**Student:** Pauline Autran, M.S. August 2012 (now at Hispano-Suiza (SAFRAN), Paris. )
**Student:** David Materkowski, M.Eng. December 2012

**Title:** Compact Piezoelectric Air Mover for Electronics Cooling
**Sponsor:** Fellowship
**Summary:** Many electronic devices use fans for cooling. Modern thin-form-factor systems often have very small internal gaps. Designing centrifugal blowers to operate inside of channels with these limited internal heights is very challenging. Alternative air movers that can operate in internal small gaps are of great potential interest. Such air movers must meet pressure, flow rate, noise and vibration requirements.

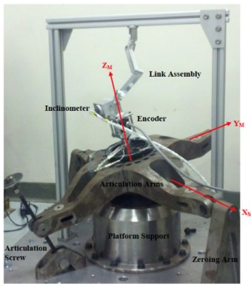
**Student:** Pierre Thurier, M.S. expected August 2014

**Title:** High Power Density Energy Harvesting Device
**Sponsor:** Lord Corp.
**Summary:** There are numerous potential applications of energy harvesting devices on helicopters and other aerospace vehicles. This project is exploring various approaches to vibration energy harvesting with the goal of maximizing power density in a given vibration environment.

**Collaborators:** Dr. Edward Smith (Aerospace)
**Student:** Raheel Mahmood, M.S. expected August 2014

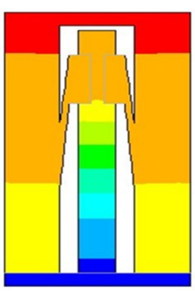
# Technical Group Research Highlights

**Title:** Calibration of a Stewart Platform Position Sensor
**Sponsor:** Lord Corp.
**Summary:** A constrained 4-DOF Stewart platform with four embedded linear displacement sensors was calibrated to improve the accuracy of estimated platform orientation and position. An existing test fixture was used to drive the platform to known static angles about three axes. A calibration algorithm was developed to minimize the error of the orientation angles calculated from the linear displacement sensor measurements by updating the positions of the embedded displacement sensors relative to their as-designed values. The calibration was shown to reduce the maximum error in the predicted orientation angles by a factor of 10.




**Collaborator:** Dr. Edward Smith (Aerospace)
**Student:** Anna Winslow, M.S. December 2012 (now at Lord Corp.)

**Title:** Variable Thermal Conductivity Structures for Spacecraft Thermal Control
**Sponsor:** AFOSR
**Summary:** Thermal baseplates are sized to limit high temperature excursions when spacecraft electronics modules are generating peak thermal loads. Because of relatively high nominal conductivity, at low loads makeup heat is required to maintain acceptable temperatures, adding weight associated with batteries, heaters, and thermal control. Contact-aided Cellular Compliant Mechanisms (C3M) employ internal contact mechanisms to enable high effective strains in response to mechanical loads. When active, these contacts also introduce new thermal conductive pathways and, using multiple materials, provide a novel avenue to passive thermal control. Initial results indicate that multi-material C3M devices have the potential to create a large switch ratio between high-conductivity and low-conductivity modes. Complex heat paths and different thermal characteristics between the metal and ceramic elements help to increase thermal resistance for the low-conductivity mode and generate higher thermal deformation at targeted points.



**Collaborators:** Dr. Mary Frecker (ME), Dr. Jim Adair (MatSci)
**Student:** Rebecca Stavely, M.S. expected August 2013 (NASA Langley Research Center)

**Dr. Chris Rahn**, Professor of Mechanical Engineering and co-director of the Battery and Energy Storage Technology (BEST) Center, will be working with **Dr. Susan Trolier-McKinstry** on the energy harvesting microstructures thrust of a newly announced Nanosystems Engineering Research Center (NERC) for Advanced Self-powered Systems of Integrated Sensor Technologies (ASSIST). Penn State, North Carolina State University, the University of Virginia and Florida International University will collaborate on a national nanotechnology research effort to create self-powered devices to help people monitor their health and understand how the surrounding environment affects it. ASSIST will be funded by an initial five-year $18.5 million grant from the NSF.

ASSIST researchers will use nanomaterials and nanostructures — a nanowire is thousands of times thinner than a human hair — to develop self-powered health monitoring sensors and devices that operate on small amounts of energy. ASSIST researchers will make devices from thermoelectric and piezoelectric materials that use body heat and motion, respectively, as power sources.

Dr. Rahn will work with a graduate student to develop models and optimize the design of piezoelectric energy harvesting devices that can derive maximum power from human movement.

## Flow-Induced Noise

*Dean 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 ongoing work of the members of the Flow-Induced Noise Technical Group is presented below.

**Project Topic**: Fluid-Structure Interaction (FSI) of a Flexible Strut with Strong Turbulent Upstream Vortices
Fluid-structure interaction (FSI) of a flexible stut with a strong turbulent flow will be performed using in-house and open-source computational tools. A *tightly-coupled* FSI analysis is important when the amplitude of structural vibration is large enough such that it alters the near-by fluid flow significantly. The FSI scheme that has been developed in the ARL-water tunnel based on in-house finite-element code (FEANL) and the open-source CFD library package OpenFOAM will be employed to analyze the structural dynamics of a flexible strut in response to strong turbulent vortices generated by an upstream cylinder structure. Computational data will be compared to the 12'' diameter water tunnel measurements.

**Student:** Abe H. Lee (Ph.D in Acoustics)
**Advisors:** Dr. S. A. Hambric, Dr. R.L. Cambpell

**Systems and Structures Health Management Technical Group**
*Karl Reichard, kmr5@psu.edu, Group Leader*
*Cliff Lissenden, lissenden@psu.edu, Group Leader*

The Systems and Structures Health Management Technical Group formerly the Machinery Prognostics and Condition Monitoring Technical Group, recognizes the importance of structural and machinery health management and the importance of acoustics and vibrations in both fields. The new technical group encompasses members of the Machinery Prognostics Technical Group and participants in Penn State University Ben Franklin Center of Excellence in Structural Health Management. The new technical group is lead jointly by Dr. Cliff Lissenden and Dr. Karl Reichard.

The mission of the Systems and Structures Health Management Technical Group is to develop new methodologies and technologies to manage the life cycle of systems and structures. This includes the full range of material state awareness, health and usage monitoring, and condition based maintenance, to support both autonomic and conventional operations with logistics informed by reliable remaining useful life prediction. The underlying goal of the group is to maximize safety, minimize life cycle cost and increase capability. Key areas of investigation include sensor systems, signal processing, pattern recognition, reasoning techniques, and modeling of damage progression to failure.

**Development of an Optical Fiber Pressure Sensor for Nuclear Power Plant Monitoring Applications**
**Mark Turner, Karl Reichard**

The goal of this project is the development of a pressure sensor for nuclear power plant applications based on optical fiber Bragg grating sensors as reported in last year's CAV review. An average nuclear power plant in the United States contains between 1,000 and 2,000 pressure transmitters). Traditional nuclear power plant pressure sensors are based on a capacitive cell design and include integrated electronics to condition the measurement signals and provide low-noise transmission of the measurement signals from the measurement location to the monitoring location.

# Technical Group Research Highlights

The presence of the measurement electronics limits the life of these sensors and drives maintenance and sustainment costs. The all-optical pressure sensor removes the transducer interface and communication electronics from the sensing environment— extending the sensor's life and reducing sensor maintenance and lifecycle costs. Funding for this project was provided by the Electric Power Research Institute (EPRI).

The initial phase of this project examined the design and experimentally evaluated an optical fiber Bragg grating senor mounted on a circular stainless steel pressure diaphragm. To minimize measurement bias, a separate fiber Bragg grating temperature compensation sensor was used to calculate a temperature independent diaphragm strain measurement. Testing also showed that the time dependence of temperature induced strain compensation caused the fiber Bragg grating sensing diaphragm to exhibit a large temperature error.

In the second phase of the project a new sensor design was constructed that uses a single fiber Bragg grating sensor with integrated strain and compensation temperature measurement, shown in Figure 1. This eliminates one source of variability in the measurements since both the strain and temperature-sensing elements are mounted to a single substrate instead of being mounted separately to the pressure diaphragm as in the earlier phase of the project. The new sensor design uses a housing / pressure chamber specifically designed to produce a more linear strain response to pressure in the fluid within the chamber. The sensor can be configured to provide either single-point or differential pressure measurement using a single optical fiber sensor and has the potential advantage of reducing the impact of sensor noise on the differential pressure measurement. Figure 2 shows the sensor mounted in the pressure test loop. The design has been demonstrate over a pressure range of 0-2400 psi (single-ended) and +/-2400 psi (differential). The response of the sensor is linear and repeatable. The new design has improved compensation for the temperature of the fluid as well as for environmental temperature fluctuations.

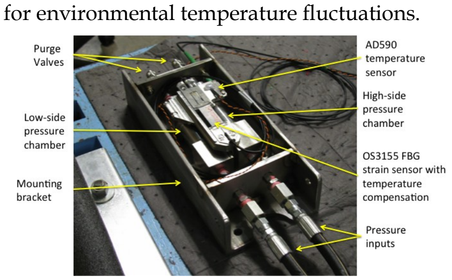



*Figure 1. Updated optical fiber pressure sensor design, which includes to opposing pressure vessels. The new sensor design uses an optical fiber Bragg grating sensor with integrated temperature compensation, and is capable of measuring both single and differential pressure.*

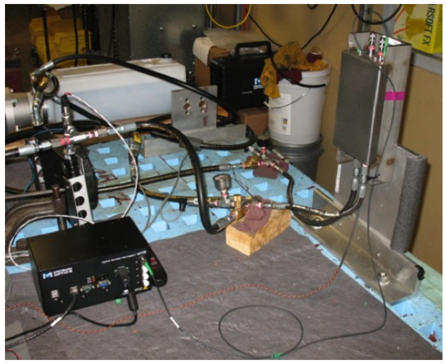


*Figure 2. Photograph of the new optical fiber pressure sensors installed in a pressure test loop. The sensor is configured for differential pressure measurement.*

**Vibration-Based Sensor Design To Detect Lubrication Levels Contained Within Differential Gear Housings**
**Stephen Wells, Karl Reichard**

A root cause of failure of many gear and bearing system failures is loss of lubrication. A loss of lubrication leads to high friction and excessive wear in gears and bearings, which leads to component failure. Currently, the drive differentials for most vehicles do not possess a sensor to detect the lubrication level within the differential casing. Due to the lack of space and the dynamics of the gear system inside of the differentials, it is impractical to place a sensor inside of the housing; nevertheless, installing an external sensor on the differentials is reasonable and can be an after-market addition to most vehicles. Tests were performed on two different military vehicle differentials to determine if the lubrication level could be detected using an externally mounted vibration sensor on the main drive differential. These tests consisted of monitoring the vibration levels generated by the differential at different speeds and lubrication levels. It was confirmed that, at different speeds and lubrication levels, the vibration levels in certain frequency ranges could be correlated to speed and lubrication level. By monitoring these vibrations, the lubrication level contained within the differential can successfully be determined with a practical amount of certainty.

Vibration sensors were mounted on the bolts holding together the two parts of the differential housing on a US Army Stryker armored vehicle, as shown in Figure 3. The measured vibration spectra showed repeatable changes in the vibration spectra as a function of the lubrication level. Measurements were made at different operating speeds. The results showed greatest sensitivity to the changes in lubrication level at resonant frequencies within the spectra (Figure 4). Subsequent finite element analysis, see Figure 5, showed that these resonances correspond to modes of the bolts on which the sensors were mounted (a common practice in vibration monitoring of transmissions and other types of machinery).

Based on measurements of the vibration spectra at different lubrication levels and vehicle speeds, a simple detection algorithm was developed to indicate whether the vehicle has full lubrication, is low on lubrication or has lost all lubrication. The vibration based technique is much more responsive than a temperature-based technique. Measurements were made on three different types of vehicles. Future studies will focus on creating a sensor that can be installed on any differential, detect the lubrication level and eventually send warning messages if a leak has formed. Imminent complete lubrication loss can then be immediately corrected, preventing a catastrophic failure.

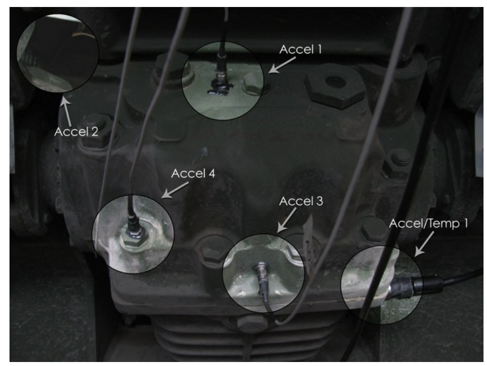



*Figure 3. Vibration sensors were mounted at different locations on the third and fourth differentials on a US Army Stryker armored vehicles. Accelerometers were mounted on existing bolts through the differential housing.*

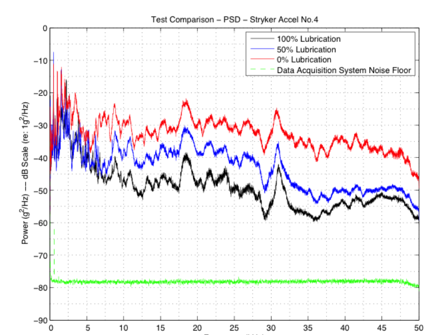



*Figure 4. Comparison of measured vibration spectra on the Stryker differential housing for different lubrication levels. The peaks in the spectra correspond to resonant frequencies of the bolt on which the accelerometer was mounted.*

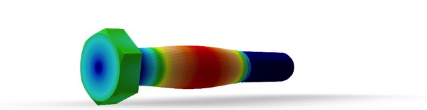


*Figure 5. Sixth bolt resonance at approximately 32042 Hz. This torsional mode causes the bolt to turn axially around its center and move in and out of the threads used to fasten the bolt. The mode correlates very well to the sharp structural resonance shown in the PSD plots at approximately 31000 Hz.*

# Technical Group Research Highlights

## Nonlinear Ultrasonics

Principal Investigator: Cliff Lissenden, lissenden@psu.edu
Graduate Students: Yang Liu, Vamshi Chillara, Xiaochu (Frank) Yao, Gloria Choi
Undergraduate Students: Brett Corl, John Weigle
Sponsor: Nuclear Energy Universities Program (DoE)

This research builds upon an investigation to develop a unified constitutive model intended for design-by-analysis of the intermediate heat exchanger (IHX) for a very high temperature reactor (VHTR) design of next generation nuclear plants (NGNPs). The research is aimed at characterizing the microstructure mechanisms activated in Alloy 617 by mechanical loading and dwell times at elevated temperature. The acoustic harmonic generation method is being employed for microstructural characterization. It is a nonlinear acoustics method with excellent potential for nondestructive evaluation, and even online continuous monitoring once high temperature sensors become available. We note that high temperature sensor development (i.e., high temperature spray-on piezoceramic transducers) is ongoing research in collaboration with Professor Bernhard Tittmann. The unique potential of the nonlinear ultrasonics method lies in the ability to quantitatively characterize microstructural features well before macroscale defects (e.g., cracks) form. Ultrasonic bulk wave experiments based on the nonlinear acoustics beta parameter are ongoing on mechanically deformed creep and fatigue samples. Ultrasound results are being correlated with microscopy results.

Nonlinear ultrasonic guided wave theory, simulation, and experiments are being researched to enable nondestructive characterization of microstructure evolution in plate and shell structures. The immediate application is to hollow cylinder mechanical test specimens, but heat exchanger tubing and piping are the primary nuclear power plant components of interest. As modeling is more straightforward in the Cartesian coordinate system, we started with plates first. The interactions between primary and secondary modes were analyzed in order to investigate higher harmonic generation from both shear-horizontal (SH) and Rayleigh-Lamb (RL) waves [1,2]. In so doing, nonlinear elastic finite element simulations were created and experiments conducted with magnetostrictive transducers. The experimental results that show the second harmonic to be cumulative are shown in Figs. 6 and 7 and a finite element simulation corroborates the experiments as shown in Fig. 8. We have shown that in the asymptotic limit guided wave modes in hollow cylinders approach those in plates [3]. An analogous nonlinear ultrasonic wave propagation analysis has been performed for hollow cylinders [4,5].

The next newsletter will summarize progress toward on-line condition monitoring with spray-on piezoceramic transducers at high temperature (DoE sponsored), multi-element piezoelectric fiber composite strip transducers for structural health monitoring (NSF sponsored), structural health monitoring of adhesively bonded composite joints (Vertical Lift Research Center of Excellence sponsored), and mixing of primary ultrasonic guided wave modes to generate cumulative harmonics at sum and difference frequencies that are sensitive to microstructure evolution (NSF sponsored).

[1] V.K. Chillara, C.J. Lissenden, 2012, "Interaction of guided wave modes in isotropic nonlinear elastic plates: higher harmonic generation," *J. Appl. Phys.*, Vol. 111(12) 124909.
[2] Y. Liu, V. Chillara, C.J. Lissenden, 2013, "On selection of primary modes for generation of strong internally resonant second harmonics in plate" *J. Sound and Vibration*, in-press.
[3] V.K. Chillara, C.J. Lissenden, 2013, "Analysis of second harmonic guided waves in pipes using a large radius asymptotic approximation for axis-symmetric longitudinal modes," *Ultrasonics* 53:862-869.
[4] Y. Liu, E. Khajeh, C.J. Lissenden, J.L. Rose, 2013, "Interaction of torsional and longitudinal guided waves in weakly nonlinear circular cylinders," *J. Acoustic Soc. Am.*, in-press.
[5] Y. Liu, C.J. Lissenden, J.L. Rose, 2013, "Cumulative second harmonics in weakly nonlinear plates and shells," In: *Health Monitoring of Structural and Biological Systems, Proceedings of SPIE*, Vol. 8695, T. Kundu, Ed., paper 869528.

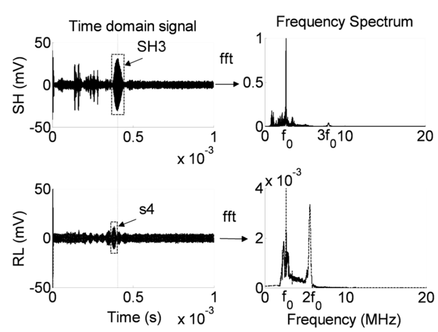



*Figure 6. Received SH (w-displacement component) and RL (u-displacement component) signals for primary SH3 excitation and s4 second harmonic. The corresponding frequency spectra are shown at right. Signals were sent and received with magnetostrictive transducers.* $f_0 = 2.63$ *MHz.*

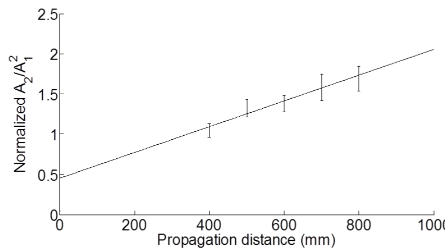



*Figure 7. Cumulative second harmonic for SH3-s4 mode pair, where* $A_1$ *and* $A_2$ *are determined from the frequency spectra for SH and RL signals, respectively, in Figure 1.*

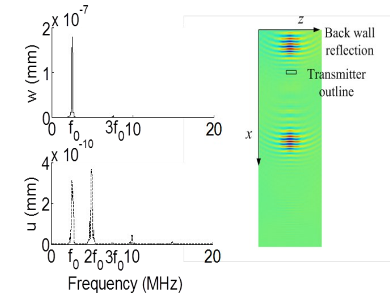



*Figure 8. Frequency spectra for SH (w) and RL (u) signals generated by a 20 mm wide transducer for the SH3-s4 internal resonance point predicted by finite element analysis. A snapshot of the displacement contours shows the nonplanar wavefront.*

## Propagation and Radiation

***Victor Sparrow—Group Leader***
***vws1@psu.edu***

The mission of the Propagation and Radiation Technical Group is to develop a new understanding of how sound is generated and propagated in realistic environments, to translate this understanding into techniques for making decisions about the use and control of sound, and for making inferences about sources and the environment, and to apply this understanding to the design of devices and systems.

The Propagation and Radiation Group has been very active in the period 2012 to 2013. Several ongoing projects have successfully wrapped up. For example, a collaboration with Wyle, Arlington, VA has provided an improved capability for NASA to predict the focusing of sonic booms occurring during a supersonic aircraft's initial climb to supersonic cruise. NASA Langley Research Center was the lead, and Gulfstream Aerospace Corporation of Savannah, GA had substantial contributions to the effort.

In addition two projects related to outdoor propagation wrapped up. Both projects were subcontracts with Blue Ridge Research and Consulting of Asheville, NC. The first was a project related to the optimization of aircraft flight paths, and

# Technical Group Research Highlights

the Penn State work has led to an improved optimization system for military aircraft landings and departures at air bases. The second project investigated noise propagation in outdoor environments including complex terrain, mixed ground impedances, and realistic atmospheric profiles. A new Green's function parabolic equation prediction method was compared to extensive field test measurements acquired by Blue Ridge in a remote area of the Smoky Mountains with good results.

The Propagation and Radiation Group also continued its work for the Federal Aviation Administration through the FAA/NASA/Transport – Canada PARTNER Center of Excellence (www.partner.aero). One of the ongoing PARTNER research projects is to better synthesize sonic boom signatures that might be heard on the ground in the vicinity of buildings, incorporating the sound reflecting from the buildings. In 2012 the group began including realistic diffraction (sound bending around corners) in the simulations. One new task in 2012 in the FAA Center of Excellence has been to assess the possibility of using the same atmospheric model for both noise and air quality simulations, and that research is ongoing.

**Graduate Students:**
Sang Cho, Ph.D. expected spring 2013
**Thesis topic:** Finite-difference time-domain modeling of low-amplitude sonic boom diffraction around building structures
**Sponsor:** NASA
**Advisor:** V. Sparrow

Andrew Christian, M.S. expected spring 2013
**Thesis topic:** A multi-objective evolutionary optimization approach to procedural noise mitigation for near-ground aircraft
**Sponsor:** Blue Ridge Research and Consulting / U.S. Navy
**Advisor:** V. Sparrow

Whitney Coyle, M.S., completed December 2012
**Thesis topic:** Using the Green's function parabolic equation method to predict sound propagation outdoors in the presence of weather and complex terrain
**Sponsor:** Blue Ridge Research and Consulting / U.S. Navy
**Advisor:** V. Sparrow

Alexandre Jolibois, Ph.D. expected summer 2013
**Thesis topic:** Optimal design of low-height barriers near trams
**Sponsor:** Graduate Program in Acoustics and French building research center (CSTB)
**Advisors:** V. Sparrow, D. Duhamel, J. Defrance

Beom Soo Kim, Ph.D. expected spring 2014
**Thesis topic:** Low frequency noise of aircraft noise transmission from outdoors to indoors
**Sponsor:** FAA
**Advisor:** V. Sparrow

Amanda Lind, M.S. spring 2011, Ph.D. expected fall 2013
**Thesis topic:** Diffraction effects for predicting the impact of low-boom sonic booms around buildings
**Sponsor:** FAA
**Advisor:** V. Sparrow

Joseph Salamone, Ph.D. expected summer 2013
**Thesis topic:** Prediction of sonic boom focusing using the lossy nonlinear Tricomi equation
**Sponsors:** Gulfstream Aerospace Corporation / Wyle / NASA
**Advisor:** V. Sparrow

Rachel Romond, Ph.D. expected fall 2014
**Thesis topic:** Atmospheric models for subsonic aircraft noise prediction
**Sponsor:** FAA
**Advisor:** V. Sparrow

## 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 three NRTC Vertical Lift Research Centers of Excellence (VLRCOE) in the country. In summer of 2011, our Center was successfully renewed for another 5 years. As part of our new program, we started 12 new research projects. We are grateful to our industry partners at LORD Corp., Timken, Goodrich (now UTAS), Bell, and Sikorsky for their support of our proposal. New projects include: airfoil design methods for unsteady flow (Prof. Maughmer), rotor hub flow physics for drag reduction (Prof. Schmitz), Icing physics, modeling, and detection (Dr. Palacios, Prof. Brentner, Dr. Lindau), autonomous multi-lift systems (Profs. Horn and Langelaan), nano-tailored composites for improved toughness and durability (Profs. Bakis and Adair), aeroelastically tailored wing extensions and winglets for large Civil Tiltrotors (Profs. Smith and Maughmer), control redundancy on compound rotorcraft for performance, handling qualities, and survivability (Profs. Horn, Brentner, and Gandhi), physics of active rotors for performance and acoustics (Profs. Schmitz, Maughmer, and Brentner), comprehensive analysis of gearbox loss of lubrication (Prof. Kunz and Drs. Saribay and Bill), health monitoring for joints in composite structures (Profs. Lissenden and Rose), advanced response types/cueing systems for naval operations (Prof. Horn), and autonomous shipboard take-off and landing (Prof. Langelaan). This Center currently supports more than 40 full-time graduate students and involves more than 20 Penn State faculty members in a wide range of technologies supporting rotary-wing aircraft. Seeking cost and weight efficient solutions to lower interior noise and vibration levels, and reduced exterior noise signatures is a high priority. We have experienced particular growth in programs focused on structural health monitoring, and ultrasonic ice protection systems. Acoustics and dynamics issues associated with active rotor systems, and variable speed compound rotorcraft are driving many of our technical objectives. Our various research projects are presently supported by the US Army, US Navy, NASA, and the industry sector (including large airframe manufacturers, sub-system vendors, and numerous small high- technology companies). In 2012-13, we started 4 new industry sponsored projects with Bell Helicopters TEXTRON, and several with Boeing Rotorcraft. Emphasis areas include; interactional source noise, acoustical scattering of rotor noise, gearbox noise, actively controlled and morphing rotors, active and passive airframe vibration control, crashworthy and impact resistant structures, anti-icing systems, variable speed rotors, structural health monitoring, and rotor loads monitoring. Several new facilities have recently been brought online. The Adverse Environment Rotor Test Stand (rotor icing chamber) has proven to be a versatile and heavily used facility. Additionally, experimental testing has also been recently conducted for new compact energy harvesters, tiltrotor whirl flutter wind tunnel models, rotor hub-flow visualizations, and new rotor system dampers.

**Projects and Graduate Students:**
***LORD Corp***
**Title:** Conceptualization, Modeling, and Characterization of a CF Driven Multi- State Lead-Lag Bypass Damper
**Sponsor:** LORD Corp.
**PIs:** Ed Smith, George Lesieutre
**Student:** Conor Marr PhD 2012

**Title:** Vibration Control via Coupled Fluidic Pitch Links
**Sponsor:** LORD Corp.
**PIs:** Ed Smith, Chris Rahn
**Student:** Lloyd Scarborough (PhD candidate)

**Title:** High Efficiency Energy Harvesting for Helicopter Airframe Vibrations
**Sponsor:** LORD Corp.
**PIs:** Ed Smith, George Lesieutre
**Student:** Raheel Mahmoud

**Title:** High Fidelity CFD Analysis and Validation of Rotorcraft Gear Box Aerodynamics
**Sponsor:** NASA
**PIs:** Rob Kunz
**Student:** Sean MacIntyre (PhD Candidate)

# Technical Group Research Highlights

**Title:** Wind Turbine Ice Protection Coating Performance Evaluation
**Sponsor:** GE Global Research
**PI:** Jose Palacios

**Title:** Experimental Measurement of Ice Crystal Dynamics
**Sponsor:** NASA
**PI:** Jose Palacios

**Title:** Helicopter Icing Physics, Modeling and Detection
**Sponsor:** NRTC VLRCOE Program
**PIs:** Jose Palacios, Ken Brentner, Jay Lindau

**Title:** Durability Evaluation of Single Crystal Energy Harvesters
**Sponsor:** NRTC Vertical Lift Consortium
**PIs:** Steve Conlon, Ed Smith, Karl Reichard
**Student:** Michael Wozniak

**Title:** Evaluation of Pericyclic Transmission Concepts
**Sponsor:** NRTC Vertical Lift Consortium
**PIs:** Suren Rao, Zihni Saribay, Bob Bill, Ed Smith
**Student:** Eric Froede

**Title:** Development of Nanoparticle-Enhanced Towpreg for Filament Wound Composites
**Sponsor:** NASA
**PIs:** Chuck Bakis
**Student**: Todd Henry (PhD Candidate)

**Title:** Centrifugally Powered Pneumatic Deicing for Helicopter Rotors
**Sponsor:** NASA
**PIs:** Jose Palacios, Doug Wolfe

**Title:** Modeling of Rotor Blade Ultrasonic Deicing and Experimental Comparison with Electrothermal Ice Protection Systems
**Sponsor:** NRTC Vertical Lift Consortium
**PIs:** Jose Palacios, Ed Smith
**Students**: Austin Overmeyer, Nic DiPlacido

**Title:** Time Frequency Transforms and Symbolic Dynamic Filtering for Rotor Stability Identification
**Sponsor:** NRTC Vertical Lift Consortium
**PIs:** Joe Horn, Asok Ray
**Students:** Siddharth Sonti

**Title:** Cable Angle Feedback for Active External Load Control
**Sponsor:** NRTC Vertical Lift Consortium
**PIs:** Joe Horn
**Student:** Jayanth Krishnamurthi

**Title:** Civil Certification Noise Prediction Tools
**Sponsor:** Bell Helicopter TEXTRON
**PI:** Ken Brentner
**Student**: Abhishek Jain

**Title:** Analysis of Rotor Startup/Shutdown in Complex Winds
**Sponsor:** Bell Helicopter TEXTRON
**PIs:** Ed Smith, Rob Kunz, Jianhua Zhang

**Title:** Alternate Control Laws for Fly-by-Wire Helicopters
**Sponsor:** Bell Helicopter TEXTRON
**PI:** Joe Horn
**Student**: Michael Spires (PhD candidate)

**Title:** Tailboom Vibration Control via F2MC Devices
**Sponsor:** Bell Helicopter TEXTRON
**PIs:** Chris Rahn, Ed Smith
**Student**: Kentaro Miura

**Title:** Fundamental Physics of Active Rotor Concepts for Acoustics and Performance Enhancement
**Sponsor:** NRTC VLRCOE
**PIs:** Ken Brentner, Mark Maughmer, Sven Schmitz
**Students**: Frank Kody, Tenzin Choephel (PhD Candidate), Tianxiao Yang (PhD Candidate)

**Title:** Rotorcraft Airfoil Design for Unsteady Aerodynamics
**Sponsor:** NRTC VLRCOE
**PIs:** Mark Maughmer
**Student**: Bernardo Vieira (PhD Candidate)

**Title:** Tailored Wing Extensions and Winglets for Large Civil Tiltrotors
**Sponsor:** NRTC VLRCOE
**PIs:** Ed Smith, Mark Maughmer
**Students**: Julia Cole (PhD Candidate), Sam Johnson

## Structural Acoustics and Vibration

***Steve Hambric—Group Leader***
***sah19@arl.psu.edu***

The mission of the Structural Vibration and Acoustics Technical Group is to better understand the mechanisms of vibration generation and propagation in structures and the interaction of structural vibrations with acoustic media, and to develop novel methodologies for the analysis, measurement, and control of structural vibrations and radiated noise.

<u>Projects and Graduate Students:</u>
**Title:** Sound from Acoustic Guitars
**Sponsor:** Martin Guitar
**PIs:** Micah Shepherd, Steve Hambric, Dave Swanson

**Title:** Characterization of the CAV Anechoic Room and Sound Transmission Loss capability
**Sponsor:** ARL Walker Fellowship Program
**PIs:** Andrew Barnard, Steve Hambric
**Student:** Paul Bauch (M.S. candidate)

**Title:** Carbon Nanotube (CNT) Loudspeakers
**Sponsor:** JNLWD
**PI:** Andrew Barnard, Timothy McDevitt, Timothy Brungart

**Title:** High speed structural-acoustics computing
**Sponsor:** ONR
**PIs:** Dean Capone, Rob Campbell, John Fahnline

**Title:** Large journal bearing modeling and measurements
**Sponsor:** NAVSEA PMS 397
**PI:** Rob Campbell

**Title:** Offshore wind turbine flow-induced vibration and structural integrity
**Sponsor:** DoE
**PIs:** Rob Campbell (part of interdisciplinary PSU team)
**Student:** Javier Motta-Mena (MS – Mechanical Engineering)

**Title:** Artificial pulmonary valve fluid structure interaction modeling
**Sponsor:** ARL Walker Fellowship
**PIs:** Rob Campbell, Brent Craven
**Student:** Ken Aycock (PhD – Biomedical Engineering), Bryan Good (Phd, Bioengineering)

**Title:** Behavior of marine propellers in crashback conditions
**Sponsor:** NAVSEA 073R
**PI:** Steve Hambric and Rob Campbell
**Student:** Abe Lee (Ph.D., Acoustics)

**Title:** Development of Acoustically Tailored Composite Rotorcraft Fuselage Panels
**Sponsor:** NASA
**PIs:** Steve Hambric, Kevin Koudela, and Ed Smith

**Title:** Optimization of TBL-excited ribbed aircraft panels to minimize sound radiation
**Sponsor:** NASA
**PIs:** Steve Hambric
**Student:** Micah Shepherd (Ph.D., Acoustics)

**Title:** Aircraft jet engine sonic fatigue modeling
**Sponsor:** Pratt and Whitney
**PIs:** Steve Hambric, Rob Campbell
**Student:** Matt Shaw (Ph.D., Acoustics)

**Title:** Acoustic radiation and scattering from finite submerged bilaminar plate- 3 D solution
**Sponsor:** NAVSEA/ONR
**PI:** Sabih Hayek and J.E.Boisvert

**Title:** Acoustic scattering from finite multilayered plates-3D elasticity
**Sponsor:** NUWC/ONR
**PI:** S.I. Hayek and J.E. Boisvert

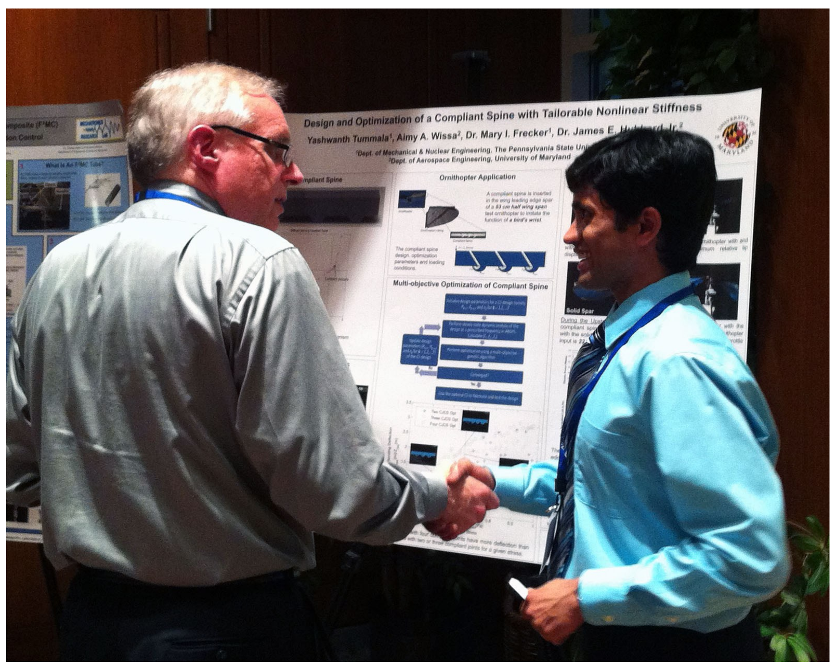
# NASA Recognizes Four Student Volunteers

Recently, four Penn State Graduate Program in Acoustics students were recognized for their exceptional support to NASA. Jason Bostron, Sam Denes, Abe Lee, and Stephen Wells volunteered their time to help with the Farfield Investigation of Noboom Thresholds (FaINT) task of the NASA Supersonics Project. This research was conducted at the Edwards Air Force Base October 25 to November 9, 2012.

The students helped with the preparation, setup, acoustic recording and the tear down of over 120 microphones and associated equipment needed during the tests. They worked 12 hour days in the desert with temperatures fluxuating between near freezing to extremely hot temperatures. They also helped with duties such as launching a tethered blimp, laying microphone wires, repositioning the array and then dismantling it.

In a letter sent to the Acoustics Program by Joseph Piotrowski, Aeronautics Mission Director wrote, "In Conclusion, our FaINT research team could not have accomplished their mission without the aid of your students."

# First Ever Student Poster Competition Held




A new event, the Student Poster Competition was added to the CAV Workshop in 2012. This event took place during the Monday night social which was held at the Hintz Alumni Center. The students were offered an opportunity to showcase their research with a chance of winning a monetary prize.

Corporate sponsors and guest, international liaison, industry guests, and government guests were asked to judge the entries. They were given a small booklet with abstracts and a ballot. To make things interesting we did not provide the judges with any instructions as to what to look for.

Prizes were awarded for first, second and third places. Abe Lee was awarded $150 as the first place winner with "Coupled Detached-Eddy-Simulation and Structural Vibration of a Cylinder Due to Vortex-Shedding at Turbulent Reynolds Numbers." There was a tie for second place with each student receiving $100. Whitney Coyle placed with "Realistic Terrain and Atmospheric Profiles in the GFPE" and Lloyd Scarborough placed with "Rigid Pitch Links." Third place prize of $50 went to Yashwanth Tummala (shown right) for "Design and Optimization of a Compliant Spine with Tailorable Nonlinear Stiffness."

The event was so well received that it will be held at this year's workshop.

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# MARK YOUR CALENDARS

## for upcoming events

**CAV Workshop 2014**
**Tuesday—Wednesday**
**April 29—30**
**Nittany Lion Inn**

**CAV Workshop 2015**
**Tuesday—Wednesday**
**May 5—6**
**Nittany Lion Inn**

**CAV Workshop 2016**
**Tuesday—Wednesday**
**May 3—4**
**Nittany Lion Inn**

**Any short course will be scheduled for the day immediately following the workshop**