CAV Review '14-'15

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 5—6 May. This year the workshop will have a similar format to that of previous years with the event lasting for two full days. On Tuesday morning, we will have a special presentation acknowledging the 50th Anniversary for the Graduate Program in Acoustics . During each technical group's presentation there will be a few minutes to highlight special areas of interests in that groups areas. As in the past laboratory tours will be given to familiarize attendees with some CAV facilities. Tuesday evening we will once again host a student poster session and reception. It will be held in the newly renovated Café Laura. The program will bring a mix of presentations from technical group leaders, international liaisons, and several corporate sponsors. Graduate students and their advisors are available for discussions concerning their research. While formal presentations are organized to allow for the exchange of technical information, we 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 Tuesday evening social in Café Laura, between 6 and 9 pm. Our corporate sponsors, government guests, and international liaisons will be asked to cast votes for the best posters, and we will award 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.

HAPPY 50TH ANNIVERSARY TO THE GRADUATE PROGRAM IN ACOUSTICS

2015 is the 50th anniversary of the Penn State Graduate Program in Acoustics. Founded in 1965, it is the largest Acoustics Program in the United States and, along with its Master of Science and Master of Engineering offerings, is the only U.S. institution granting the Ph.D. degree in Acoustics. Students from all over the U.S. and abroad come to Penn State, and the Acoustics Program now has over 600 graduates, including over 200 Ph.D. degrees in Acoustics. The Acoustics Program was founded out of a need to provide civilians trained in underwater acoustics and related areas for the U.S. Navy, but it quickly diversified into a broad-based program spanning many technical areas including acoustics, vibrations, signal processing, transducers, physical acoustics, architectural acoustics, psychoacoustics, etc. Currently there are over 40 members of the Graduate Faculty in acoustics with primary appointments in Penn State's Applied Research Laboratory, The College of Engineering, the College of Earth and Mineral Sciences, the College of Science, and the College of Health and Human Development. There are approximately 55 in-residence graduate students and about 80 distance education graduate students all seeking degrees. Many adult students simply take courses "a la carte" to bolster their technical understanding without seeking a degree. The degree-seeking students take 30 graduate credits, and some of the required 3-credit courses include Elements of acoustics of fluids, Elements of vibrations and waves, Digital signal processing, and Electroacoustic transducers. Some of the elective courses regularly taught include Nonlinear acoustics, Noise control engineering, Outdoor sound propagation, Computational acoustics, Structural acoustics and vibrations, and Ocean acoustics. Information on any of these courses can be obtained from the website of the Graduate Program in Acoustics: www.acs.psu.edu.

Pictured above is Dr. Jiri Tichy the first Program Chair and his administrative aide Mrs. Barbara Crocken.

Pictured below are the Program Chairs since 1973, (from left) Dr. Victor W. Sparrow (Interim 2010 – present), Dr. Jiri Tichy (1973 - 1997) and Dr. Anthony A. Atchley (1997 – 2010

Corporate Members & International Liaisons

Corporate Members & Representatives
Bechtel Marine Propulsion Corp. —Eric Salesky (PA), Steve Dunn (NY)
BIS—John Wang
Boeing—Joseph Wat
Bose—Ray Wakeland
Fisher Valves and Instruments— Shawn Anderson
Gerard Daniel Worldwide—Darren McClure
Gulfstream—Kristopher Lynch
Harman—Donald Butts
ITT—Mark Downing
KCF—Jacob Loverich
K-Flex—Tony Ribaudo
Martin Guitar—Albert Germick
Moog, Inc— Chris Layer
Newport News Shipbuilding—Kevin Smith
Pratt & Whitney— Kerwin Low
United Launch Alliance—Ed Heyd
United Technologies Research Center—Jeff Mendoza
Westinghouse Electric Company— Greg Meyer
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 Members

The CAV is pleased to welcome four new corporate members, BIS, ITT, and K-Flex to the group.

UTC Building & Industrial Systems (BIS) is the world's largest provider of building technologies. Its elevator, escalator, fire safety, security, building automation, heating, ventilation, air conditioning and refrigeration systems and services promote integrated, high performance buildings that are safer, smarter and sustainable. UTC Building & Industrial Systems is a unit of United Technologies Corp., a leading provider to the aerospace and building systems industries worldwide. The Sound & Vibration, Air Management and Ride Quality engineering groups lead BIS research and development activities in the fields of Acoustics and Vibration. You can read more about BIS at www.bis.utc.com. The company liaison is John Wang.

Bridgestone Americas Tire Operation is a division of The Bridgestone Group. Their mission is based on the words of its founder: "Serving Society with Superior Quailty." To fulfill this mission, Bridgestone Group has used the concept of "foundation" to demonstrate the sustained commitment of employees to provide its customers with world class products and services and to serve the communities where Bridgestone does business. To read more about this please visit www.bridgestone-firestone.com. Hans Dorfi is the company's liaison with the CAV.

ITT Corporation is a leading manufacturer of highly engineered, customized solutions for the energy, transportation and industrial markets. Our legacy of innovation is reflected in our trusted products and brands including Goulds and Bornemann pumps, KONI shock absorbers, Cannon connectors and Enidine energy absorption devices. We continue to build on this heritage and to partner with customers to solve their most critical problems. ITT is composed of four businesses—Industrial Process, Motion Technologies, Interconnect Solutions and control Technologies that are working in close harmony and leveraging their collective power to better serve the energy, transportation and industrial end markets. The business is headquartered in Valencia, CA. For more information please visit: http://www.itt.com/. Mark Downing is the company liaison.

K-FLEX is a leading manufacturer of elastomeric, closed cell insulation products that are easy-to-use and deliver reliable and lasting performance. Innovative and responsive to the market, K-FLEX USA partners with customers to provide solutions for demanding insulation applications. In April 2012, K-FLEX USA was awarded with ISO 9001 certification by FM Approvals for commitment to quality. K-FLEX USA is a member of the IK Insulation Group. Form more on this please visit http://www.k-flex.com . Tony Ribaudo is the company's liaison to the CAV.

George Lesieutre served as General Chair for the AIAA Science and Technology Forum and Exposition in Orlando, Florida, January 2015. AIAA SciTech is the world's largest gathering of aerospace researchers and technologists.

CAV Members Receive Honors and Awards

Andrew Acquaviva—received a Best Student Paper award in Engineering Acoustics at the Acoustical Society of America

Yuchao Chen—received both the Penn State Alumni Association Dissertation Award and the Thomas and June Beaver Award

Whitney Coyle— received the Kenneth T. Simowitz Memorial Citation, Graduate Program in Acoustics

Philip Feurtado—received the Skudrzyk Award, Graduate Program in Acoustics

Dr. Tony Jun Huang—named Fellow, American Institute for Medical and Biological Engineering (AIMBE) and Fellow, Institute of Physics (IoP); earned the Institute of Electrical and Electronics Engineering Sensors Council Technical Achievement Award

Martin Lawless—received the Kenneth T. Simowitz Memorial Citation, Graduate Program in Acoustics

Dr. George Lesieutre—served as General Chair for the AIAA Science & Technology Forum and Exposition in Orlando, FL

Dr. George Lesieutre—received his Penn State Chair for 25 years of service to the University

Dr. Richard Marboe—received recognition from American Society of Mechanical Engineers for completion of his term as ASME Vice President, Program & Activities

Stephen Nichols - received the Kenneth T. Simowitz Citation, Graduate Program in Acoustics

Brian Reinhardt—received the Longenecker Scholarships for work on Nuclear Waste Management Sensors.

Matthew Shaw—received the Kenneth T. Simowitz Memorial Citation, Graduate Program in Acoustics

Kyle Sinding—received the Longenecker Scholarships for work on Nuclear Waste Management Sensors

Andrew Suprock—received the Longenecker Scholarship for work on Nuclear Waste Management Sensors

Yuliang Xie—received the Harold K. Schilling Dean's Graduate Scholarship

Yanhui Zhao—received 1st place Best Poster Award at the 5th Biophotonics Summer School

Randall To Teach CAV Short Course

Bob Randall of University of New South Wales, Australia, will teach this year's CAV short course. The course to be taught is on Cepstrum Analysis of Machinery Vibration and Structural Health. This will be held on Thursday, 8 May at University Park.

While we are all familiar with the use of Fast Fourier Transform (FFT) techniques to analyze the frequency content of time signals, not many vibration and acoustics engineers have used Cepstrum transforms. The Cepstrum is the inverse Fourier transform of the logarithm of the frequency spectrum, and is useful for clearly showing the presence of periodic signals, like harmonics, sidebands, and echoes, that appear in damaged rotating structures (like gear systems). The Cepstrum also allows separation of forcing and transfer functions from vibration signals of operating structures, enabling operational modal analysis. The short course begins by defining Cepstral concepts and terms, like the real and complex 'cepstra' (instead of spectra), 'quefrency' (instead of frequency), and 'liftering' (instead of filtering), and then goes into detail on a wide range of mechanical applications, including echo detection and removal, and machine diagnostics and modal analysis, including important guidance as to the artefacts that can arise and how to deal with them. More recent applications involve dealing with time histories from machines operating at variable speed by transforming between the time domain, where harmonic orders are smeared but resonances correctly represented, and the order domain where the opposite is the case.

Bob Randall is a professor Emeritus of the School of Mechanical and Manufacturing Engineering at the University of New South Wales (UNSW) in Australia. He is an expert in signal processing, modal analysis, and vibration-based condition monitoring. Prior to joining UNSW, Bob spent 17 years with

Bruel and Kjaer, helping develop much of their signal analysis and machine diagnostics software, along with teaching courses to B&K customers. While at UNSW, he directed the Defence Science and Technology Organisation (DSTO) Centre of Expertise in Vibration Analysis, later the DSTO CoE for Helicopter Structures and Diagnostics. Bob has published four books, hundreds of journal articles and conference papers, and is on four refereed journal editorial boards. He is a fellow of the Australian Acoustical Society and the International Institute of Acoustics and Vibration.

Hambric helps organize NOVEM 2015 Conference

Steve Hambric worked with colleagues from Europe and Asia to help organize the 2015 conference on Noise and Engineering Emerging Methods (NOVEM 2015), held in Dubrovnik, Croatia 13-15 April 2015. The conference topics focused on structural vibration, vibro-acoustics, flow-induced noise and vibration, and noise and vibration control. CAV international liaisons from ISVR, INSA de Lyon, Hong-Kong Polytechnic Institute, and KAIST also helped organize the conference.

Technical Research Group Highlights

Acoustics Characterization of Materials

Bernhard R. Tittmann – Group Leader
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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.

This year three of the graduate students from this group received Longnecker scholarshops to attend and contribute to the Annual Waste Management conference in New Mexico. Representing Penn State will be brian Reinhardt, Kyle Sinding, and Andrew Suprock.

The group has been fortunate to receive equipment from Bechtel Bettis which includes a phased array design, construction and testing for high temperature, high pressure and a loan of various equipment with possible donating it to Penn State in the future.

Current Projects

Title: Field Deployment of Spray-on Ultrasonic Transducer on Pipe Elbows in Heat Exchangers
Sponsor: EPRI

Title: High Temperature Spray-on Phased Array for high temperature crack growth measurement
Sponsor: EPRI

Title: Leave-in place ultrasonic transducers for Valve Body structural health monitoring
Sponsor: Fisher Emerson Valves

Title: Characterization of ceramic honeycomb structures in green state, intermedidate processing stage and fired stage
Sponsor: Dow Corning—Ceramic Filters

Graduating this year are Alison Orr with a M.S. in Acoustics and Kyle Sinding with a M.S. in Engineering Science and Mechanics. Ken Ledford has joined the group and is working towards a M.S. in Acoustics.

Adaptive Structures

George Lesieutre – Group Leader
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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 adaptive structures.

Title: Placement of Circular Force Generators for Vibration Cancellation
Sponsor: Sikorsky
Summary: Relatively new devices, "circular force generators" can be used to cancel hub forces and moments in helicopters, typically at N/rev. We seek optimal approaches to placement of such devices, along with heuristic insight into the best approaches.
Student: Brad Sottile, Ph.D. expected

Title: Sandwich Panel Damping via Optimal Core Design
Sponsor: PSU
Summary: Composite sandwich panels provide excellent stiffness- and strength-to-weight, sometimes at the expense of vibro-acoustic response. Topology optimization is being used to guide the design of sandwich panel core configuration that provide high effective vibration reduction in key frequency regions. These cores will be designed to exploit novel 3-D manufacturing methods.
Student: Tianliang Yu, M.S. expected August 2014

Title: Cable Actuation for Shape and Vibration Control of Deployable Space Apertures
Sponsor: PSU
Summary: Physical figure of space antennas and reflectors must be accurately maintained in the presence of dynamic disturbances to meet performance specifications. For cable-tensioned deployable designs, actuation enables active adjustment of the figure. Lightweight, precise actuators are needed for cable actuation.
Student: Amey Chaudhari, Ph.D. expected August 2017

Title: A Two-Material Topology Optimization Method for the Design of Spacecraft Structures under Thermo-Mechanical Loads
Sponsor: AFOSR
Summary: Passive spacecraft thermal control systems would be lighter and simpler than the electrically-driven systems that are in wide use today. Thermal control of a two-dimensional sandwich panel could be achieved by driving contact at internal interfaces via differential thermal expansion. Using a SIMP interpolation scheme, an algorithm was developed to optimize structural topology using two materials and voids. Initial designs without contact demonstrate the importance of thermomechanical coupling. Continuing development will address thermally-activated contact to achieve a broad range of effective thermal conductivity.
Collaborators: Dr. Mary Frecker (ME), Dr. Jim Adair (MatSci)
Student: Pierre Thurier, M.S. August 2014

Title: Unsteady Force Measurement for a Beam using Small Piezoelectric End Sensors
Sponsor: ARL Walker Assistantship
Summary: Unsteady forces across propeller blades are generated from the interaction of the blade with a rotating pressure field. The oscillating nature of this excitation, particularly at higher harmonics, suggests that unsteady lift fluctuations nearly cancel out over the blade span, and that it is possible to find the total unsteady force across the propeller from measurements at the root and tip. Appropriate parameters were determined from an approximation provided by the Method of the Stationary Phase. An apparatus for the measurement of total unsteady force across a propeller blade based on this theory is being developed.
Collaborators: Dr. Michael Jonson (ARL)
Student: Margalit Goldschmidt, M.S. August 2014; Ph.D.

Title: Visco-Electric Energy Harvesting
Sponsor: Lord Corp.
Summary: There are numerous potential applications of energy harvesting devices

Technical Group Research Highlights

on helicopters and other aerospace vehicles. This project is exploring vibration energy harvesting from thermoelectric conversion of heat generated in elastomeric elements.

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

Professor Mary Frecker and her students are pursuing a number of projects related to active structures

Title: Multi-field responsive origami structures: advancing the emerging frontier of active compliant mechanisms.
Sponsor: NSF & AFOSR
Summary: The objective is to develop methods to design origami structures that actively fold from an initially flat sheet to complex three-dimensional shapes in response to multiple fields (e.g., electric, thermal, magnetic). These multi-field responsive origami shapes are being developed through collaboration with a visual artist. The artistically inspired shapes provide targets for designing novel active compliant mechanisms, which along with predictive multi-scale modeling and multi-physics simulations, guide the development of new active materials. A design optimization framework is being developed to integrate the modeling, design and active materials efforts and enable system trade studies from the nano to the macro scale.
Collaborators: Dr. Zoubeida Ounaies (ME), Dr. Paris von Lockette (ME), Dr. Tim Simpson (ME & IE), Prof. Rebecca Strzelec (Visual Art), Dr. Jyh-Ming Lien (George Mason University)
Students: Landen Bowen, Ph.D. expected May 2016, Kara Springsteen, B.S. expected May 2017, Elaine Sung, B.S. expected May 2016, Wei Zhang, Ph.D. expected May 2018

Title: Spatially Distributed Compliant Passive Elements for Aerodynamic Structural Tailoring
Sponsor: AFOSR
Summary: The objectives are to develop methods to design spatially distributed passive 3D compliant elements and to develop the associated models to predict the dynamic coupling between those elements. The compliant elements are being structurally integrated to create an appropriate spatially distributed wing stiffness. The modeling efforts include an analytical spar structural model and a numerical compliant element design and optimization model. Validation and verification will be performed by applying the techniques developed to an avian-scale ornithopter test platform in both Bench top and flight testing.
Collaborators: Dr. James Hubbard (Univ. of Maryland)
Students: Joseph Calogero, Ph.D. expected May 2017.

Chris Rahn's Mechatronics Lab group is working on several vibration projects. First, with support from the National Science Foundation ASSIST Engineering Research Center, Chris, undergraduate student Greg Fobben, and graduate students Xiaokun Ma and Andrew Wilson are developing energy harvesters for the low frequency and sporadic excitation associated with human movement. They developed a new compliant mechanism harvester that ensures optimal strain distribution in a piezoelectric unimorph. Experimental tests conducted this year demonstrate significantly higher power product than traditional proof mass cantilever harvesters. Chris is also collaborating with Ed Smith in Aerospace Engineering to develop fluidlastic damping and vibration absorption treatments for stiff aerospace structures. Funding from Bell Helicopter has enabled theoretical and experiment work on tailboom damping augmentation.

The International Center for Actuators and Transducers (ICAT), directed by Kenji Uchino, Professor of Electrical Engineering and Computer Science, Materials Science and Engineering, is the world-leading research center in piezoelectric actuators and sensors, with a spin-off company, Micromechatronics Inc. (MMech) working together. They are currently developing theoretical modeling on how the heat is generated physically in piezoelectric and magenetostrictive devices during the operation, in terms of intrinsic materials' aspect, device designing and drive/control viewpoints. ICAT integrated these physical models into ATILA FEM software (MMech Product) and developed various high power piezoelectric materials.

The ICAT keeps various patents on compact piezo-motors and transformers, which have now been commercially available in laptop computers, mobile phones and medical catheters. MMech is recently developing innovative devices: (1) piezoelectric energy harvesting device utilized in 25 mmϕ bullets as Programmable Air Burst Munition (PABM) sponsored by Army, and (2) high voltage (300 kV – 1 MV) supply for neutron accelerator Gamma-ray scan system in the airport security system with using piezoelectric transformers (Homeland Security).

Flow-Induced Noise
Ken Brentner – 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 ongoing work of the members of the Flow Induced Noise Technical Group is presented below:
Project Topic: Noise from Pulsating Supercavities and its Control
Summary: The noise from pulsating supercavities is being studied experimentally in water tunnel facilities and computationally with finite volume CFD. The noise was found to be single frequency and monopole in nature with a spectrum level given by the level of the cavity interior pressure and attenuation due to spherical spreading from the interface. The radiated noise levels from pulsating supercavities were found to be at least 35 dB higher than those radiated by comparable re-entrant jet and twin vortex supercavities. The computations appear to capture the complete spectrum of cavity closure conditions, including pulsation.
Initial investigations have been performed into suppressing pulsation noise by modulating (i.e., adding a sinusoidal component to) the ventilation gas flow rate in order to shift the supercavity resonance frequency away from the interface excitation frequency. This technique, which has its roots in parametric oscillators, caused pulsating supercavities to transition to another (twin vortex) closure regime over a certain range of modulation frequencies. Other ventilation gas modulation frequencies caused the supercavity pulsation and

Technical Group Research Highlights

resonance frequency to increase over its steady (no-modulation) ventilation flow rate frequency but pulsation persisted and the radiated noise levels remained largely unchanged. More extensive water tunnel investigations and computation of this means of ventilated supercavity pulsation noise control are currently underway.
Advisors: Drs. Timothy A. Brungart and Jules W. Lindau
Student: Grant M. Skidmore, Ph.D. in Aerospace Engineering expected May 2016

Project topic: Glottal jet aerodynamics
Summary: Investigation of aeroacoustic sources of the human voice, using analytical, experimental, and computational approaches.
Sponsor: National Institutes of Health
PI: Michael Krane
Student: Michael McPhail (BioEng, expected graduation date 5/17)

Project topic: Characterization of Fluid-structure interaction in a turbulent wake
Summary: Measurement of flexible structure motion and flow, to provide benchmark data.
Sponsor: U.S. Navy
PI: Michael Krane
Student: Grant Dowell (AeroEng, expected graduation date 8/15)

Project topic: Helicopter Icing Physics, Modeling and Detection
Summary: The overall goal of the task is to gain fundamental understanding of physics involved in the accretion of ice to helicopter rotor blades. In the acoustics part of the project an investigation of the noise has revealed that the rotor broadband can be used in the test facility to identify the initial formation of ice on the rotor blades and can be used to quantify surface roughness. Work is ongoing to determine the feasibility of ice detection on either manned or unmanned rotorcraft of different scales.
Sponsor: U.S. Department of the Army, Vertical Lift Research Center of Excellence, Task 3.
PI(s): Dr. Kenneth Brentner (ice detection by acoustic measurements portion of task)
Student: Baofeng Cheng, Ph.D. expected December 2015

Project topic: Control Redundancy to Enhance Rotorcraft Performance, Handling Qualities, and Survivability
Summary: The objective of this research is to examine the potential for enhanced performance, handling qualities, and survivability with the exploitation of redundant controls on compound rotorcraft. In the acoustics portion of the task the goal is to minimize noise in desired regions (e.g., ahead of the vehicle) from a compound rotorcraft through optimal trim (using redundant control devices) for greatest noise reduction while minimizing or eliminating any performance penalties. This project will also explore fast but approximate methods for modeling the noise of coaxial rotors for compound rotorcraft.
Sponsor: U.S. Department of the Army, Vertical Lift Research Center of Excellence, Task 7.
PI(s): Dr. Kenneth Brentner, Dr. Joe Horn
Students: Greg Walsh, August 2016

Project topic: Fundamental Physics of Active Rotor Concepts for Acoustic and Performance Enhancement
Summary: This task is focused on fundamental research to provide noise reduction and performance enhancement, simultaneously. The project is comprised of three closely coupled and coordinated sub-tasks: 1) Use the PSU-WOPWOP noise prediction code to understand the physics of the three-dimensional pressure field data surrounding a rotor blade needed for in-plane noise reduction, 2) comprehensive analysis and CFD development on deployable distributed active rotor devices, and 3) singularity-free vortex wake development and analysis. The acoustic physics are studied analytically and with simple loading models to develop candidate configurations and schedules.
Sponsor: U.S. Department of the Army, Vertical Lift Research Center of Excellence, Task 8.
PI(s): Dr. Kenneth Brentner
Student: Tianxiao Yang, Ph.D. expected December 2015

Project topic: Acoustic Capability for NDARC
Summary: Methods to rapidly predict credible acoustic signals of vertical lift aircraft designs are proposed as extensions to the NASA Design and Analysis of RotorCraft (NDARC) code. This project will enable acoustic assessments as an integral part of the conceptual design process. The methods developed will rely principally on aircraft design parameters available within the NDARC code; but it is anticipated that additional NDARC input parameters may need to be defined to ensure the accuracy and/or efficiency of the some of the acoustic predictions. As part of the development, it will be assessed whether or not fast, simplified methods using aircraft design parameters available through NDARC are suitable for credible predictions of each noise source. If not, an alternate, generalized approach will be developed to use data tables generated off-line using more rigorous analytic methods.
Sponsor: U.S. Department of the Army, Vertical Lift Research Center of Excellence, Task 13.
PI(s): Dr. Kenneth Brentner
Student: Kalki Sharma, M.S., expected August 2016.

Project topic: Rotorcraft Noise Abatement Operating Conditions Modeling
Summary: This project has the goal to develop rotorcraft noise abatement procedures through computational and analytical modeling, and develop a comprehensive flight test plan to validate the effectiveness of resulting noise abatement flight procedures. The second goal of the project is objective is to use the computational and analytical modeling tools to demonstrate the ability to provide vehicle noise data for notional vehicles with advanced technology in a manner than can be used in the FAA Aviation Environmental Design Tool (AEDT). To accomplish these goals, a suite of research tools has been coupled together to provide both medium and high fidelity rotorcraft trim, loads, and noise prediction. The tools will be validated through comparisons with flight test data, including a recent flight test of the Bell 430 helicopter conducted by NASA, Bell, and the U.S. Army.
Sponsor: Federal Aviation Administration as part of ASCENT Center of Excellence, Project 6
PI(s): Dr. Kenneth Brentner and Dr. Joe Horn
Student: Yaowei Li, M.S., expected August 2015, Willca Villafana, M.S., expected August 2016.

Project Topic: Modelling and Measurement of Turbulent Boundary Layer Un-

Technical Group Research Highlights

steady Shear Stress in Elastomer Layers Summary: This project is investigating novel measurement techniques to measure the unsteady shear stress induced in elastomer layers expose to turbulent boundary layer flow. Measurements of both shear stress and unsteady pressure will be made on the top of and below an elastomer layer.
Advisors: Dr. D.E. Capone, Dr. T.A. Brungart
Student: Cory Smith expected Ph.D. in 2015

Project Topic : Fluid Structure Interaction (FSI) of a Flexible Strut with Strong Turbulent Upstream Vortices
Summary: Fluid structure interaction (FSI) of a flexible strut 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.
Advisors: Dr. S.A. Hambric, Dr. R.L. Campbell
Student: Abe Lee, Ph.D. expected May 2015

Project Topic: Scaled Demonstration of Fluidic Inserts for Jet Noise Reduction for Tactical Aircraft
Sponsor: Office of Naval Research
PI(s): Dr. Philip J. Morris and Dr. Dennis K. McLaughlin
Students: Matthew J. Kapusta, Scott M. Hromisin

Project Topic: Analytical Approach for Quantifying Noise from Advanced Operational Procedures"
Sponsor: Federal Aviation Administration as part of ASCENT Center of Excellence
PI: Dr. Philip J. Morris
Student: Mrunali C. Botre

Project Topic: University Support on the Prediction of Jet and Shock-Induced Unsteady Wall Pressure Fluctuations
Sponsor: Pratt & Whitney
PI: Dr. Philip J. Morris
Student: Claudio Notarangelo

Project Topic: Experimental Study of Impinging Jets Flow-Fields
Sponsor: Office of Naval Research
PI(s): Dr. Philip J. Morris and Dr. Dennis K. McLaughlin
Student: Leighton M. Myers

Propagation and Radiation
Victor Sparrow—Group Leader
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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 academic year of 2014 to 2015 has shown continued growth for the Propagation and Radiation Group. Much of the activity is still centered in the FAA's ASCENT Center of Excellence, and ongoing projects have focused on aircraft noise propagation, the noise of future supersonic civilian aircraft, the transmission of sound into building structures, and outreach to the public. The work began in late 2013 and is formally known as the FAA Center of Excellence in Alternative Jet Fuels and the Environment. Called ASCENT for Aviation Sustainability CENTer, the Center is led by Washington State University, and Penn State is a strong contributor. Dr. Vic Sparrow is pleased to serve as Penn State's PI for this effort.

Dr. Sparrow's research centers on sound propagation, most notably the noise from civilian aircraft. Recent works have included a study on en-route noise from aircraft at cruise altitude, a study on sensitivity of noise metrics to the variability of supersonic aircraft noise (sonic boom) due to meteorological factors, and research on improved models for the atmospheric absorption of noise at all altitudes. Dr. Sparrow also continues his service to the International Civil Aviation Organization, a specialized agency of the United Nations, as the Research Focal Point for the United States to aid in the development of future civilian supersonic aircraft certification requirements.

Dr. Michelle Vigeant joined Penn State in 2012 as an Assistant Professor of Acoustics and Architectural Engineering, and is continuing to grow her lab – the Sound Perception and Room Acoustics Laboratory (SPRAL). She is currently pursuing research in three areas: (1) concert hall acoustics, specifically the study of listener envelopment, (2) the emotional response to room acoustics stimuli with varying reverberation times, and (3) aircraft noise and cardiovascular disease. She has two graduate students, David Dick and Matthew Neal, who are working on the first topic and a third student, Martin Lawless, working on the second topic. For the first topic, subjective listening tests are currently underway using both stimuli from measurements taken in the Peter Kiewit Concert Hall in Omaha, NE and simulations. These stimuli are being presented over the recently completed 3D 30 loudspeaker array, which has been installed in the CAV anechoic chamber. For the second topic, the emotional response to the stimuli is being obtained using functional magnetic resonance imaging (fMRI) user the scanner on campus. Pilot data have been collected and show a significant correlation with stimuli with high preference ratings and activations in regions of the brain associated with positive emotions. Finally, she has recently received funding through Penn State's Clinical and Translational Science Institute (CTSI) to establish the infrastructure to create noise maps to study the effects of aircraft noise on cardiovascular disease. She expects to have 1-2 more graduate students joining her group in Fall 2015.

Recent student graduates from the Propagation and Radiation Group include Dr. Sang Cho, Dr. Alexandre Jolibois, Dr. Joseph Salamone, Mr. Andrew Christian, and Ms. Whitney Coyle.

Graduate Students:

Beom Soo Kim, Ph.D. expected Fall 2015
Thesis topic: Low frequency noise of aircraft noise transmission from outdoors to indoors

Technical Group Research Highlights

Sponsor: FAA
Advisor: V. Sparrow

Amanda Lind, M.S. spring 2011, Ph.D. expected Spring 2016
Thesis topic: Diffraction effects for predicting the impact of low-boom sonic booms around buildings
Sponsor: FAA
Advisor: V. Sparrow

Joshua Palmer, M.S. expected Summer 2015
Thesis topic: Variability in noise metrics due to the effects of atmospheric turbulence on sonic boom signatures
Sponsor: FAA
Advisor: V. Sparrow

Erik Petersen, M.S. expected Summer 2015
Thesis topic: Contributions of carbon dioxide to atmospheric absorption and dispersion of noise
Sponsor: FAA
Advisor: V. Sparrow

Rachel Romond, Ph.D. expected Spring 2016
Thesis topic: Simplifications of atmospheric models for subsonic aircraft noise prediction
Sponsor: FAA
Advisor: V. Sparrow

David Dick, Ph.D. expected Spring 2016
Thesis topic: Listener envelopment in concert halls through listening tests and spherical microphone array measurements
Sponsor: NSF
Advisor: M. Vigeant

Martin Lawless, Ph.D. expected Spring 2018
Thesis topic: Emotional response to room acoustics stimuli using functional neuroimaging
Sponsor: Penn State College of Engineering
Advisor: M. Vigeant

Matthew Neal, M.S. expected Spring 2015
Thesis topic: Listener envelopment in concert halls through virtual acoustics simulations over multichannel loudspeaker array
Sponsor: NSF
Advisor: M. Vigeant

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. Kinzel), autonomous multi-lift systems (Profs. Horn and Langelaan), nanotailored 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 50 full-time graduate students and involves more than 25 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, pneumatic ice protection systems, and naval-oriented flight dynamics/controls. 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 2013-14, we won on 4 new projects from the Office of Naval Research, and continued progress on recent industry-sponsored projects with Bell Helicopters TEXTRON, Boeing, Timken, and LORD Corporation. Emphasis areas include; advanced flight controls and vehicle dynamics simulation, 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. In 2014-15, efforts towards development of a major new rotorcraft sustainment and safety laboratory continued in earnest. Our annual Rotorcraft Technology Short Course will be offered for the 48th consecutive year on August 10-14. Topics in the comprehensive course include rotorcraft aerodynamics, dynamics, acoustics, composite structures, flight controls and propulsion.

Projects and Graduate Students:
Title: Flutter Stability of Rotors with Fluidlastic Pitch Links
Sponsor: LORD Corp.
PIs: Ed Smith, Chris Rahn
Student: Shawn Treacy (PhD candidate)

Tailboom Vibration Control via F2MC Devices
Sponsor: Bell Helicopter. NSF.
PIs: Ed Smith, Chris Rahn
Student: Kentaro Miura (PhD candidate), Matt Krott (PhD Candidate)

Title: High Efficiency Energy Harvesting for Helicopter Airframe Vibrations
Sponsor: LORD Corp.
PIs: Ed Smith, George Lesieutre
Student: Raheel Mahmoud (MS December 2014)

Technical Group Research Highlights

Title: Gearbox Noise Reduction via High Frequency F2MC Devices
Sponsor: LORD Corp.
PIs: Ed Smith, Chris Rahn
Student: Alexandre Bondeaux (MS Candidate, August 2015)

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

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
Student: Sihong Yan (MS 2015)

Title: Helicopter Icing Physics, Modeling and Detection
Sponsor: NRTC VLRCOE Program
PIs: Jose Palacios, Ken Brentner, **Michael Kinzel**
Students: Yiquian Han (PhD 2015), Baofeng Chen (PhD 2015), David Hanson (PhD 2016)

Title: Optimized Design and Structural Mechanics of a Single-Piece Composite Helicopter Driveshaft
Sponsor: NASA PI: Chuck Bakis
Student: Todd Henry (PhD August 2014)

Title: Centrifugally Powered Pneumatic Deicing for Helicopter Rotors
Sponsor: NASA
PIs: Jose Palacios, Doug Wolfe
Students: Matthew Bailey (MS 2014), Matthew Drury (MS 2016)

Title: Modeling of Rotor Blade Ultrasonic De- icing and Experimental Comparison with Electrothermal Ice Protection Systems
Sponsor: NRTC Vertical Lift Consortium
PIs: Jose Palacios, Ed Smith
Students: Austin Overmeyer (MS 2013), Nicola DiPlacido (MS candidate)

Title: Civil Certification Noise Prediction Tools
Sponsor: Bell Helicopter TEXTRON
PI: Ken Brentner
Student: Abhishek Jain (PhD Candidate)

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

Title: Rotorcraft Airfoil Design for Unsteady Aerodynamics
Sponsor: NRTC VLRCOE
PI: 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: Sam Johnson (MS 2014), Willie Costa (MS 2015), Sandilya Kambampati (PhD candidate), Taylor Hoover (MS Candidate), Julia Cole (PhD Candidate)

Title: Innovative Method for Real-Time Damage Alleviation
Sponsor: US Navy NAVY SBIR - Subcontract to Technical Data Analysis, Inc.
PI: Joe Horn
Student: David Caudle (MS 2014)

Title: Control Redundancy to Enhance Rotorcraft Performance, Handling Qualities, and Survivability
Sponsor: NRTC VRCOE
PIs: Joe Horn, Ken Brentner
Student: Adam Thorsen (MS 2014, PhD Candidate), Greg Walsh (MS Candidate)

Title: Acoustic Capability for NDARC
Sponsor: NRTC VRCOE
PIs: Ken Brentner
Student: Kalki Sharma (MS Candidate)

Title: Advanced Response Types and Cueing Systems for Naval Operations
Sponsor: NRTC VRCOE
PI: Joe Horn
Student: Albert Zheng (MS Candidate)

Title: Autonomous Multi-lift Systems
Sponsor: NRTC VRCOE
PIs: Joe Horn, Jack Langelaan
Student: ZuQun Li (MS 2015), Jacob Enciu (Postdoc)

Title: Rotorcraft Noise Abatement Operating Conditions Modeling
Sponsor: FAA
PI: Ken Brentner
Students: Yaowei Li (MS Candidate), Willca Villafana (MS Candidate),

Title: Flight Test Measurement of Airwake Disturbances for Validation of Virtual Dynamic Interface Simulations
Sponsor: Office of Naval Research
PI: Joe Horn
Student: Sylvie Shafer (MS Candidate)

Title: Pilot-in-the-Loop CFD Method Development
Sponsor: Office of Naval Research
PI: Joe Horn
Student: Ilker Oruc (PhD Candidate)

Title: Autonomous Control Modes for Shipboard Landing in High Sea States
Sponsor: Office of Naval Research
PI: Joe Horn
Student: Junfeng Yang (PhD Candidate)

Title: Fundamental Physics of Rotor Hub Flows Towards Reduction of Helicopter Parasite Drag
Sponsor: NRTC VLRCOE
PIs: Sven Schmitz, Steve Willits
Student: David Reich (PhD Candidate)

Title: Placement of Circular Force Generators for Vibration Cancellation
Sponsor: Sikorsky Aircraft
PI: George Lesieutre
Student: Brad Sottile, Ph.D. expected

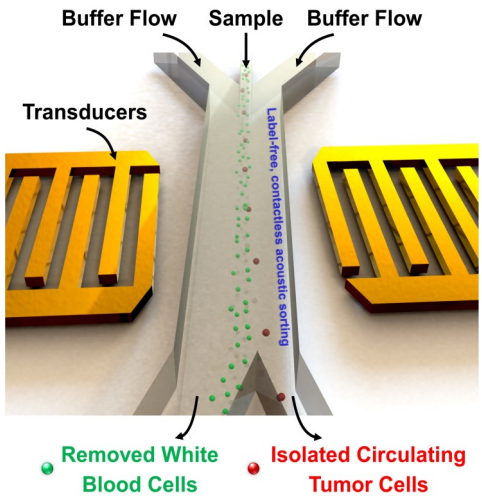
Technical Group Research Highlights

Structural Vibration and Acoustics
Steve Hambric, - Group Leader
sah19@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.

In 2014, our group completed a four year project with NASA Langley to design, construct, and test a quiet rotorcraft roof panel. The panel, constructed of two lightweight honeycomb core sandwich panels treated with ultra-thin viscoelastic layers and separated by an air gap, reduces both air-borne and structure-borne sound by 8-15 dB between 1 and 4 kHz. The picture below shows Drs. Hambric and Shepherd with the optimized panel (brown) as well as a baseline panel (green) representative of current design. The project was performed in collaboration with Bell Helicopter and Kansas State University, and the testing was performed in NASA Langley's SALT transmission loss testing facility.

Tony Jun Huang and his students Peng Li and Yuchao Chen have worked with Penn State Hershey and other researchers to develop an acoustic-based microfluidic device called 'acoustic tweezers', to separate cancer cells from blood cells for diagnostic, prognostic, and treatment purposes. The image below shows the concept, where high frequency acoustic waves in an inexpensive disposable chip are used to 'push' cancerous cells out of a stream of blood into a separate channel for collection.



Below is a current list of other projects and graduate students in our section.

Projects and Graduate Students:

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: Fluid Structure Interaction Modeling of Blood Clot Migration and Entrapment in the Inferior Vena Cava
Sponsor: ARL Walker Fellowship
PIs: Rob Campbell, Brent Craven
Student: Ken Aycock (PhD – Biomedical Engineering)

Title: Wireless sensing technologies
Sponsor: NAVSEA 073R
PI: Steve Conlon

Title: Improved Advanced Hybrid Propulsor
Sponsor: NAVSEA PMS 450
PI: Steve Conlon

Title: Quiet Structure Design Using Embedded Acoustic Black Holes
Sponsor: ARL Walker Fellowship
PI: Steve Conlon
Students: Phil Feurtado (Ph.D., Acoustics), Angelina Conti (B.S –Honors Aerospace Engineering)

Title: Airframe Active Vibration-Based Damage Detection and Localization
Sponsor: PSU Aerospace Engineering/ VLRCOE
PI: Steve Conlon
Students: Justin Long (MS Aerospace Engineering), Morton Lin (B.S –Honors Aerospace Engineering)

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

Title: Accelerated fatigue characterization of composites
Sponsor: NAVSEA 073R
PI: Steve Hambric and Rob Campbell
Student: Chester Kupchella (MS, Acoustics)

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

Title: Nonlinear flow-induced structural damping
Sponsor: Pratt and Whitney
PI: Steve Hambric and Micah Shepherd
Student: Trevor Jerome (PhD, Acoustics)

Title: Ohio Replacement Program Propulsor
Sponsor: NAVSEA 073R
PI: Steve Hambric

Technical Group Research Highlights

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

Title: Hybrid Multi Material Propulsor
Sponsor: DARPA
PIs: Kevin Koudela

Title: Acoustic radiation from point excited multi-layered finite cylindrical shells submerged in water
Sponsor: NUWC/ONR
PI: Sabih Hayek and J.E.Boisvert

Title: Acoustic cell separation
Sponsor: NIH, NSF
PI: Tony Jun Huang
Students: Peng Li and Yuchao Chen (Ph.D., ESM)

Systems and Structures Health Management Technical Group

Karl Reichard – Co-Group Leader
kmr5@psu.edu,
Cliff Lissenden, - Co-Group Leader
lissenden@psu.edu

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.

Update on Development of an Optical Fiber Pressure Sensor for Nuclear Power Plant Monitoring Applications
Principle Investigators: Mark Turner, Karl Reichard
Sponsor: EPRI

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. 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.

Figure 1: Photographs of installation of sensor (left) in PSU Steam Plant to measure pressure across the boiler feedwater valve (right).

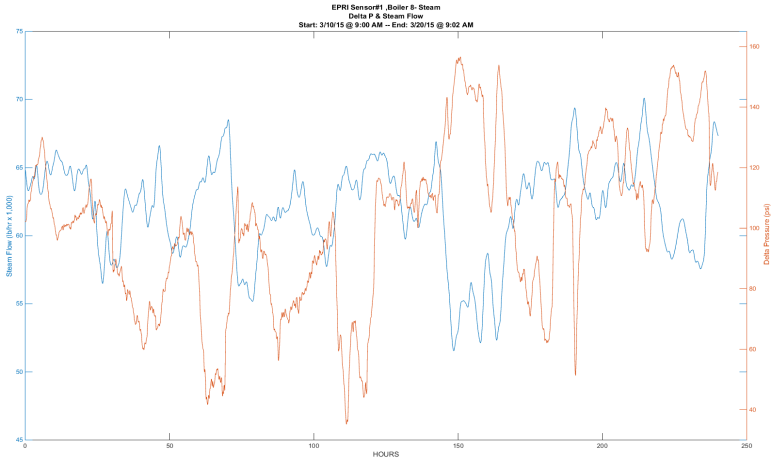


Figure 2: Differential pressure (blue) versus steam flow (orange) over a 10-day period.

During the past year, this sensor was installed in two locations on the Penn State campus to characterize its response over longer operating intervals. The first location was in a water reheat system where the system measured the differential pressure across a centrifugal pump. The second installation was in the PSU Steam Plant across a feedwater valve for one of the boilers. Figure 1 shows photographs of the valve and the feedwater valve in the PSU Steam Plant. Figure 2 shows plots of the sensor output (differential pressure) versus time and the steam flow versus time over a ten-day period in March. The steam flow was measured with the steam plant's existing instrumentation and the plot shows that the differential pressure tracks the steam flow (opposite sign convention) over the represented time period.

Technical Group Research Highlights

Expeditionary Fuel Delivery System Automation
Principle Investigator: Karl Reichard
Sponsor: US Army TARDEC

The goal of this project is to demonstrate the automation of control and monitoring for an expeditionary fuel delivery system (EFDS). The EFDS is rapidly emplaced and retrieved and provides a means to deliver fuel or water from a source to a supply point located up to 50 miles away. The EFDS is composed of diesel-driven fluid pumps located from 2-5 miles apart and connected by rigid pipe of flexible hose. The military EFDS is similar to temporary pipelines used in the oil and gas industry to deliver fresh or recycled water from a source or storage facility to a well site.

The goal of the project is to demonstrate next-generation capability in the monitoring and control system. The control system must support manual, local automatic and remote automatic modes. In addition, the demonstration will include autonomous response to degraded operating conditions and machinery failures. Monitoring systems on each pump station and along the pipeline will allow remote monitoring of the health and condition of critical system components, integration of health information into the operational control of the system, and a reduction in the manning required to support preventive maintenance checks and services.

Figure 3 shows a photo of the existing EFDS known as the Inland Petroleum Delivery System. An initial failure mode and effects analysis was conducted based on data from the existing system and specifications for the new replacement EFDS. The control and monitoring systems will be demonstrated using a combination of existing military and commercial pumps.

Student Theses
Taylor, Troy, "Terrain Classification for Conditioned Based Maintenance," M.S. in Acoustics, December 2014.

Ultrasonic Guided Waves for Structural Health Monitoring

Principal Investigators: Cliff Lissenden, lissenden@psu.edu; Joseph Rose, jlr9@psu.edu
Sponsors: Nuclear Energy University Program (DoE), National Science Foundation (CMMI), Vertical Lift Research Center of Excellence (Army, Navy, NASA), Sikorsky
Graduate Students: Yang Liu, Vamshi Chillara, Baiyang Ren, Gloria Choi, Xiaochu (Frank) Yao, Aaron Lesky, Hwanjeong Cho, Mostafa Hasanian, Devren Yener, Jinling Zhao
Undergraduate Students: Stephen Williamson, Clayton Dickerson

Projects entitled "Monitoring microstructural evolution of Alloy 617 with nonlinear acoustics for remaining useful life prediction: multiaxial creep-fatigue and creep-ratcheting," and "High temperature transducers for online monitoring of microstructure evolution," sponsored by the Nuclear Energy University Programs were completed. Both of these projects are aimed at condition monitoring of stationary components in nuclear power plants and focus on the earliest characterization of incipient damage. The first project focuses on nondestructive inspection. Figure 1 shows results from magnetostrictive transducers on Alloy 617 tubes that had been subjected to axial-torsional creep-fatigue-ratcheting degradation at 850C. The third harmonic shear-horizontal wave amplitude is sensitive to the amount of microstructural degradation. In the second project on-line monitoring in high-temperature environments was investigated. Higher harmonic generation was correlated with the early stages of material degradation to provide a basis for condition based maintenance. Figure 2 shows a photo of two PZT/bismuth titanate comb transducers processed by Prof. Bernhard Tittmann's group that were designed to preferentially actuate the L(0,4) longitudinal wave mode in the pipe. The A-scan indicates through the computed group velocity that the L(0,4) mode is indeed actuated.

"Higher harmonic ultrasonic guided waves for structural integrity assessment of infrastructure," is jointly sponsored by three NSF programs. This project enabled us to purchase an instrument with two gated amplifiers (RITEC RAM 5000) so that higher harmonics can be generated by ultrasonic guided wave mode mixing (mutual nonlinear interaction between two primary modes). A provisional patent application was filed in October 2014 entitled, "System and method for characterization of materials using nonlinear acoustic guided wave spectroscopy".

The project "Health monitoring methods for joints in rotorcraft composite structures," is sponsored by the Vertical Lift Research Cen

Technical Group Research Highlights

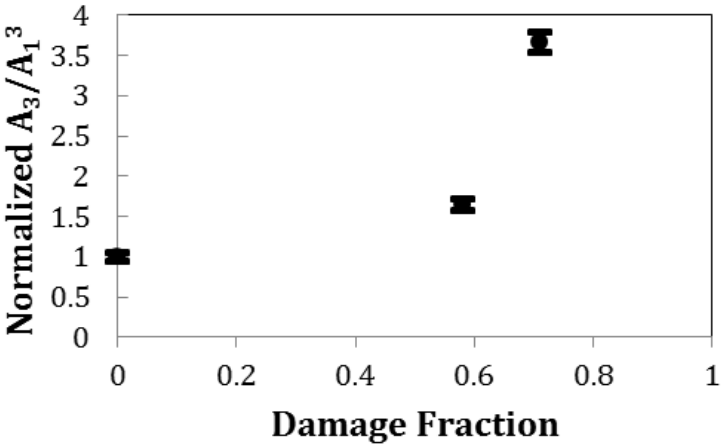


Figure 1. Amplitude of third harmonic shear-horizontal mode SH0 increases in Alloy 617 tubes due to creep-fatigue-ratcheting.

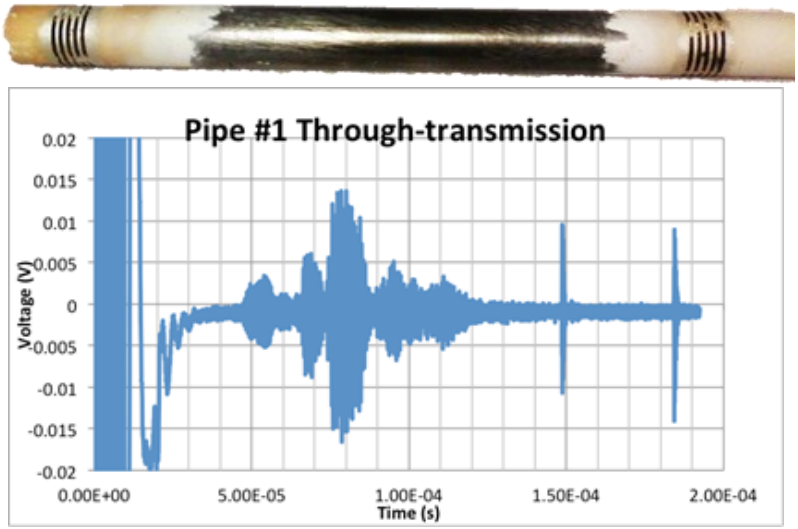


Figure 2. Spray-on PZT/bismuth titanate comb transducers on a stainless steel pipe generate the L(0,4) longitudinal guided wave mode, and others.

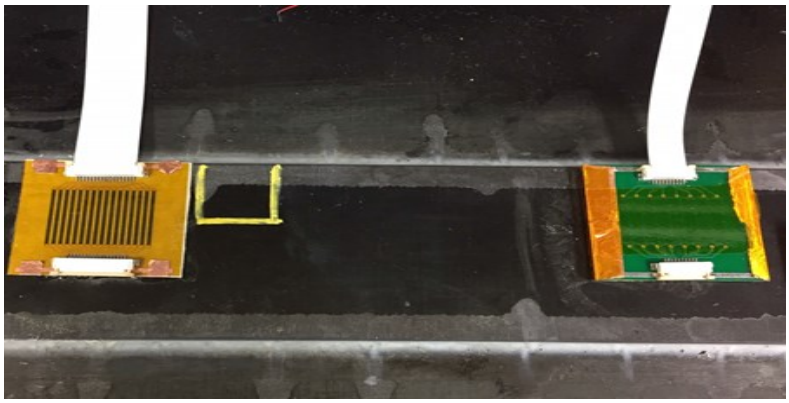


Figure 3. Phased array transducers mounted to an adhesively bonded CFRP joint with defect; the 16-element PVDF receiver is on the left and the 8-element piezoelectric fiber composite actuator is on the right.

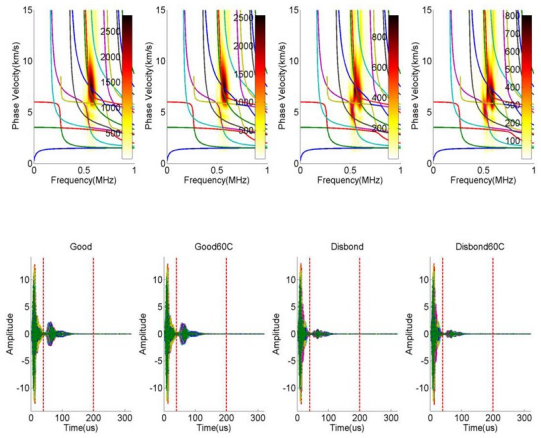


Figure 4. Results from transducers shown in Figure 3 clearly indicate the defect in adhesive bond due to mode conversion from mode 10 at 600 kHz to mode 5 and that the mode conversion is insensitive to a 60C temperature change.

ter of Excellence. In this project we have researched and developed stay-in-place phased array transducers for monitoring the structural integrity of bonded joints in composite structures. We have researched, designed, and fabricated transducers from piezoelectric fiber composites to enable us to generate guided wave modes without full knowledge of the material properties, as well as to determine highly excitable portions of dispersive curves. The transducers shown in Figure 3 provide capabilities to identify modes and mode conversion that did not exist previously. Light weight, low profile, conformable, low cross-talk PVDF arrays have been shown to be sensitive to material degradation by using mode conversion as shown in Figure 4.

Penn State was awarded a 3-year $3M Integrated Research Project through the Nuclear Energy University Programs in the Department of Energy entitled, "Multi-Sensor Inspection and Robotic Systems for Dry Storage Casks," with Cliff Lissenden serving as the PI. Dry storage casks for used nuclear fuel were intended as an intermediate staging point of the fuel cycle, maintaining waste storage after wet storage and before transport to an underground repository for disposal. Now dry storage casks are needed to provide safe containment for a much longer duration. Inspection is necessary, but the casks were not designed with condition monitoring in mind. Potential degradation mechanisms that could threaten safe containment and future transport of used fuel must now be addressed through an inspection protocol that includes the mode of delivery, modern sensors, and ability to compare measurements over time. The goal of our project is to develop multi-sensor inspection and robotic systems for this purpose. Measurements inside the cask ventilation system will characterize the: temperature distribution, radiation field, salt concentration (if any), and cracking in the canister (if any). Measurements on the

Technical Group Research Highlights

outer surface of the overpack will characterize the condition of the concrete.

Some of the peer reviewed articles published this year are listed below.

C.J. Lissenden, Y. Liu, J.L. Rose, 2015, "Use of nonlinear ultrasonic guided waves for early damage detection," *Insight*, Vol. 57(4), pp. 206-211.

V.K. Chillara, C.J. Lissenden, 2014, "Nonlinear guided waves in plates: a numerical perspective," *Ultrasonics* Vol. 54, pp. 1553-1558.

Y. Liu, C.J. Lissenden, J.L. Rose, 2014, "Higher order interaction of elastic waves in weakly nonlinear circular cylinders. I. analytical foundation," *J. Appl. Phys*. Vol. 115:214901.

Y. Liu, E. Khajeh, C.J. Lissenden, J.L. Rose, 2014, "Higher order interaction of elastic waves in weakly nonlinear circular cylinders. II. physical interpretation and numerical simulation," *J. Appl. Phys*. Vol. 115:214902.

Underwater Acoustics and Instrumentation Technical Group
Amanda Hanford, - Group Leader
ald227@arl.psu.edu,

The Underwater Acoustics and Instrumentation Technical Group conducts basic and applied research related to the propagation of sound in the ocean and the systems, natural and manmade, that generate and receive sound underwater. Projects in propagation often involve large scale multi-vessel ocean acoustic experiments for studies such as low-frequency continuous active sonar for sonar clutter and reverberation, or adaptive sonar for seabed characterization. Data acquired during field measurements are analyzed and incorporated into theoretical and numerical modeling of acoustic propagation and scattering to develop advanced propagation and reverberation models that better account for ocean environmental complexities. Several projects aim to develop an understanding and prediction of effects of seabed fluctuations on acoustic reflection, scattering, propagation and reverberation and seabed parameter estimation with rigorous uncertainties from seabed acoustic interaction measurements.

Oceanography studies use acoustic data to determine physical properties of the ocean environment by applying acoustic technologies to biological, ecological, and conservation challenges in the aquatic environment. This year, Jennifer Miksis-Olds was elected co-director of the new university Center for Marine Science and Technology (CMaST) whose purpose is to coordinate and promote diverse activities in the area of marine science and technology across campus. Results of oceanography research are used to inform and develop more effective mitigation strategies and risk assessment relating to the effect of sound on marine mammals and the marine ecosystem. This year, research using continued access to the Comprehensive Test Ban Treaty Organization (CTBTO) database has focused on global soundscapes, ocean noise trends and pattern, detection area estimates for passive acoustic monitoring (PAM) systems, density estimation from PAM data, and innovative acoustic approaches to assess biodiversity within a region.

Other applied research efforts include characterizing the performance of underwater acoustic systems, design and development of in air and in water transducers and application of advanced signal processing techniques. Current projects in this area are involved with research in infrasound and infrasound-array maintenance for the US monitoring stations that support the Comprehensive Nuclear Test Ban Treaty.

CAV Information

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MARK YOUR CALENDARS

CAV Workshop 2016

Tuesday—Wednesday
May 3—4
Nittany Lion Inn

Short Course will be scheduled for May 5

The Penn State Acoustics Program is celebrating 50 years of excellence...and we'd like to see you there.

For 50 years, Penn State has set the standard for acoustics education by teaching acoustics fundamentals to last a lifetime and conducting leading-edge research used in the public and private sector.

Come help us celebrate our strong foundation and learn about our future plans to continue our legacy as a world-class acoustics program.

We look forward to seeing you on May 20, 2015.

Date

Wednesday, May 20, 2015

Coincides with the Acoustical Society of America Spring 2015 meeting in Pittsburgh

Time

6:00pm

Cash reception

7:00pm - 9:00pm

Dinner and program

Cost

$40 per person

Location

Wyndham Grand Pittsburgh Downtown
600 Commonwealth Place
Pittsburgh, PA 15222

Registration Details

Tickets are available from the ASA via their website acousticalsociety.org. Additional information is available from Karen Thal at kjt3@psu.edu.