CAV Update

Spring workshop dates set
The CAV’s annual workshop will be held at the Penn State Nittany Lion Inn 3—4 May. This year the workshop will have a format similar to that of previous years with the event lasting for two full days. During each technical group’s presentation there will be a few minutes to highlight special areas of interests. As in the past laboratory tours will be given to familiarize attendees with some CAV facilities. Tuesday evening we will host a student poster session and reception. It will be held in 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).

Last year’s winners were tied for first place, Saad Ahmed and Housain Shekhani, and Phil Feurtado took third place.

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.

Temperature Resistant Spray-on Piezoelectric Transducers for Materials Characterization with Ultrasonic-Guided Waves

Material Degradation
Many advanced reactor concepts require the materials to resist various stresses in harsh environments over long service durations. Thus, at some point material degradation (e.g., creep, fatigue, embrittlement) will commence, and its progression, if unchecked, could eventually lead to failure. While degradation processes evolve differently based on material, loading, and conditions, they invariably start at the microstructure level and then progress to the macroscale, and ultimately to fracture. Since shutdowns for inspections are extremely costly, it is preferred to implement online condition monitoring to keep the plant operating until maintenance is necessary. The interaction of ultrasonic guided waves with damage make them very useful for condition monitoring, as will be described below. The requirements of the online condition monitoring system investigated herein are (i) resistance to elevated temperature and (ii) ability to detect incipient damage.

Objectives
The Nuclear Energy Enabling Technologies (NEET) program develops crosscutting technologies that directly support the Office of Nuclear Energy’s development of advanced reactor concepts and fuel cycle technologies. The Advanced Sensors and Instrumentation (ASI) subprogram develops the scientific basis for sensors and supporting infrastructure technology that address technology gaps relating to measurements at existing and advanced nuclear power plants. One of the five objectives of the ASI subprogram is to “identify and conduct research into monitoring and control technologies, including human factors, to achieve control of new nuclear energy processes, and new methodologies for monitoring to achieve high reliability and availability.” This article describes results of a Nuclear Energy University Program (NEUP)-sponsored blue-sky project (11-3046) to investigate spray-on piezoelectric transducers for online condition monitoring in high-temperature environments. The condition monitoring is based on ultrasonic-guided waves.

Materials
Ultrasonic transduction is traditionally achieved using piezoelectric ceramic materials, which convert an alternating voltage into a mechanical disturbance that propagates into and through the material to be monitored or vice versa. Traditional ultrasonic transducers use lead zirconate titanate (commonly known as PZT) as the active material because of its high coupling parameter ($d_33$), but its Curie temperature ($T_c$) limits its usage at elevated temperatures. There are piezoceramics that provide better temperature resistance, but typically at a cost of having a lower coupling coefficient. Bismuth titanate ($\text{Bi}_3\text{Ti}_5\text{O}_{12}$, or BT for short) and lithium niobate ($\text{LiNbO}_3$, or LN for short) are good examples and their relevant properties are compared with PZT in Table 1. The sol-gel technique makes processing of composites quite straightforward, as described in the subsequent section. In this research

Continues on page 3
CAV Members Receive Honors and Awards

Erika Arrojado received Second Place in the Shreyer’s Honors College ROAR Competition.

Whitney Coyle received the 2015 Kenneth T. Simowitz Memorial Citation.

Philip A. Feurtado received the Leo Beranek Student Medal for Excellence in the Study of Noise Control which was awarded by the Institute of Noise Control Engineering USA; won the student paper competition at InterNoise 2015; and received the 2015 Skudrzyk Award from the Graduate Program in Acoustics.

Scott Hromisin received a SMART scholarship from the Department of Defense.

Richard C. Marboe was approved as Senior Vice President-elect for the Technical Events and Content Sector of the American Society of Mechanical Engineers.

S. Ahmed, Zoubeida Ounaies and Mary Frecker received the Best Paper Award in Mechanics and Material Systems at the Adaptive Structures and Material Systems Branch of the ASME Aerospace Division.

Yashwanth Tummala, Aimy Wissa, Mary Frecker, and James Hubbard received the Best Paper Award in Structures and Structural Dynamics at the Adaptive Structures and Material Systems Branch of the ASME Aerospace Division.

Mary Frecker, Professor of Mechanical Engineering & biomedical Engineering promoted to Associate Department head for Graduate Programs Mechanical & Nuclear Engineering at Penn State.

Trevor Jerome received second place in the student poster session of the ASA meeting in Pittsburgh.

Martin Lawless received the 2015 Kenneth T. Simowitz Memorial Citation.

Richard Metzger has been presented with a copy of the NIST Speaker Recognition Training Part 2 and Test for his work in speaker recognition.

Jennifer Miksis-Olds received the Presidential Early Career Award in Science and Engineering.


Stephen Nichols received the 2015 Kenneth T. Simowitz Memorial Citation.

Zoubeida Ounaies was promoted to Fellow of ASME.

Kenji Uchino was the Chief Guest Speaker at 34th Annual Convocation, Sri Sathya Sai Inst. of Higher Learning, gave the Convocation Address and received the International Ceramic Award at the Global Academy of Ceramics.

Paper titled “Design and Analysis of A Supersonic Jet Noise Reduction Concept” co-authored with Anthony Pilon (Lockheed Martin), Russell Powers, Dennis McLaughlin, and Philip Morris (all PSU) was selected as the overall winner of the 2015 LM Aeronautics Best Technical Paper Competition.

Steve A.E. Miller, NASA Langley Acoustics and a CAV grad, received the NASA Early Career Achievement Medal.

Mike Doty (MS ’98, Ph.D. ’02) and a CAV grad, was promoted to Acoustics Branch chief at NASA Langley Research Center.
PZT/ BT and BT/LN composites were investigated for service temperatures up to ~400°C (e.g., for a number of light water reactor components) and ~850°C (e.g., intermediate heat exchanger for the next generation very high temperature reactor), respectively.

### Table 1. Properties of some piezoelectric ceramics

<table>
<thead>
<tr>
<th>Material</th>
<th>T_c(°C)</th>
<th>d_33(pC/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZT</td>
<td>340</td>
<td>125-340</td>
</tr>
<tr>
<td>Bi_4Ti_3O_12</td>
<td>685</td>
<td>5-20</td>
</tr>
<tr>
<td>LiNbO_3</td>
<td>1200</td>
<td>6</td>
</tr>
</tbody>
</table>

**Transducer Processing**

The processing of transducers to send and receive ultrasonic-guided waves has multiple steps. The following steps can be used in the laboratory or modified for field implementation.

1. Create a sol-gel solution consisting of the first constituent (e.g., PZT) and dope it with the second constituent (e.g., BT) to form the composite (e.g., PZT/ BT). Mix the solution with an ultrasonic horn.

2. Air-spray the mixture at low pressure onto the selected sample. Once dried, a single spray coating is roughly 20 microns thick. Spraying can be done on flat or curved surfaces; a pipe example is shown in Figure 1.

3. Drive out the organic compounds by heating the sample. This pyrolysis process reduces the volume so care is taken to minimize microcracking.

4. Repeat the spray and pyrolysis steps to achieve the desired coating thickness.

5. Partially densify the multilayer coating with an induction heating system, again taking care to minimize microcracking.

6. Deposit the electrode (e.g., gold or platinum) on the coating. Due to the porosity of the coating and elevated operating temperatures, electrode material selection and the deposition method are critical. Sputter coating and brush application of the same material can have completely different results.

7. Pattern the electrode to enable control of actuation and reception of specific preferred guided wave modes, as described in the ultrasonic-guided wave section below. Figure 2 shows a multielement comb transducer on a pipe.

8. Attach a lead wire to the electrode to serve as ground as long as it is electrically conductive.

9. Build a dam around the transducer to enable an oil bath to eliminate arcing when a large voltage is applied to the electrode. Pole the transducer by applying a large voltage at elevated temperatures.

10. Deposit a layer of Sauereisen to protect the transducer.

**Ultrasonic-Guided Waves**

Ultrasonic-guided waves can propagate long distances between transmitter and receiver, provide volumetric coverage of inaccessible material, and offer good sensitivity to damage. Energy loss is small compared to bulk waves because the boundaries of the structure (e.g., a plate or pipe) guide the energy in specific directions. However, the existence of multiple modes at a given frequency and the fact the wave speed depends on the excitation frequency must be taken into account. A comb transducer has multiple elements at a fixed spacing, and because the fixed spacing dictates the preferred wavelength generated, the comb transducer provides a means of wave mode control via the fundamental relationship, c_p = λ/ƒ; where λ is the wavelength, ƒ is the excitation frequency, and c_p is the phase velocity of the preferred mode. By knowing the phase velocity dispersion curves and the desired excitation frequency, the wavelength is computed; hence, the element spacing is known. The dispersion curves for a stainless steel pipe are shown in Figure 5 along with the activation line for a comb transducer having element spacing λ. A comb transducer for a pipe has a sequence of rings with fixed spacing λ, as shown in Figure 2. This PZT/ BT comb transducer was processed using the aforementioned 10-step procedure, where the patterning (Step 7) was performed by laser ablation to remove electrode material (i.e., transform a continuous electrode into five rings). The signal in Figure 6 was actuated and received by PZT/ BT comb transducers.
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Incipient Damage Characterization

Nonlinear ultrasonics are sensitive to the effects of microstructural features such as dislocation density, persistent slip bands, precipitates, and voids. This sensitivity is due to the small distortion of the wave caused by the lattice anharmonicity. The distortion is measurable in terms of higher harmonics in the frequency spectrum, thus the term nonlinear ultrasonics is used because the interrogation signal is at a different frequency than the excitation frequency. Nonlinear ultrasonic-guided waves are more demanding to analyze than bulk waves because the higher harmonic must lie on a dispersion curve, it must be phase matched with the primary mode, and there must be power flux transferred to it. If these so-called internal resonance conditions are met, then the higher harmonic will have an amplitude that increases as it propagates, thus it is said to be cumulative. Nonlinear-guided waves combine the advantages of large propagation distances, volumetric coverage, single-sided access, and coverage of inaccessible material with sensitivity to microstructural changes indicative of incipient damage. However, it remains to be shown that spray-on PZT/BT and BT/LN transducers can actuate guided wave modes that generate detectable higher harmonics. If so, then it should be possible to characterize incipient damage in-situ, thereby enabling condition-based remaining life estimates.
CAV student theses 2015

We continue to update our Penn State CAV student thesis database, available at: www.cav.psu.edu/thesislist.aspx Most of the theses are available as PDF downloads. Here is a list of our 2015 MS and PhD CAV graduates:

PhD:
Camin, Henry: Coherent broadband sonar signal processing with the environmentally corrected matched filter

Denes, Samuel: Ocean environmental effects on walrus communication

Ding, Ma: Holography for nonlinear imaging and metamaterial characterization

Guo, Feng: Acoustic tweezers: manipulating micro-objects with the power of sound

Lee, Abe: Fluid-structure interaction of large amplitude structure vibrations and moderately high reynolds number turbulent flows

Lurie, Michael: The prediction of unsteady aerodynamic loading in high aspect ratio wall bounded jets

Mei, Lei: Novel piezoelectric composite systems for biomedical and industry applications

Myers, Leighton: Investigation of the flowfield of two parallel round jets impinging normal to a flat surface

Olson, Derek: High-frequency acoustic scattering from rough elastic surfaces

Powers, Russell: Experimental investigation of the noise reduction of supersonic exhaust jets with fluidic inserts

Shaw, Matthew: Predicting vibratory stresses from aero-acoustic loads

MS:
Bondoux, Alexandre: Modeling, design and testing of a multi-cell periodic fluidic flexible matrix composite device

Corle, Ethan: Optimization of active flap deployment for efficient in-plane rotor noise reduction

Haidar, Ahmad: Comprehensive model and experimental validation of passive vibration suppression for supercritical rotary machines

Hildebrandt, Timothy: Like-envelope recombination: a technique for recombining dependent intrinsic mode functions

Hromisin, Scott: Laser doppler velocimetry measurements of a scale model supersonic exhaust jet impinging on a ground plane

Irwin, Jeffrey: An acoustic foundation for a fully-coupled aeroelastic and aeroacoustic phonation model using OpenFOAM

Jain, Abhishek: Trailing edge noise prediction using the non-linear disturbance equations

Kearney, Jennifer: An analysis of the dynamic response of suspension footbridges measured against human comfort criteria

Ledford, Kenneth: Practical sprayed-on transducer composites for high temperature applications

Neal, Matthew: Investigating the sense of listener envelopment in concert halls using third-order Ambisonic reproduction over a loudspeaker array and a hybrid room acoustics simulation method

Petersen, Erik: Absorption and dispersion predictions of noise from en-route subsonic and supersonic aircraft

Rufo, Joseph: From chip-in-a-lab to lab-on-a-chip: the development of a prototype for acoustofluidic nanoparticle separation

Suo, Qiuling: The implementation of a time domain impedance boundary condition

Yu, Tianliang: Vibration reduction of sandwich composites via 3-D manufactured acoustic metamaterial cores

50 Years of Acoustics Education

During the past academic year the Graduate Program in Acoustics has celebrated 50 years of acoustics education at Penn State. Founded in 1965, the Acoustics Program is the largest program of its kind in the United States offering the Master of Science, Master of Engineering, and the only educational institution that offers a Ph.D. in Acoustics. A celebratory event was held in conjunction with the May 2015 meeting of the Acoustical Society of America in Pittsburgh, PA. It was wonderful to catch up with so many alums of the Acoustics Program at the Pittsburgh event. This event and a brief history of the 50 years of the Acoustics Program were documented in an article appearing in the Fall 2015 issue of the magazine Acoustics Today, and it is available online for free at acoustics.today.

While everyone is taking the time to look back on what all has been accomplished over the years, for example, over 200 Ph.D. degrees and over 400 Masters degrees completed in Acoustics, the Program looks forward to continued growth. For example, in the upcoming 2016-2017 academic year, the Acoustics Program is offering for the first time a Master of Science (M.S.) 1-year option.

This option is a research-focused masters degree consisting primarily of coursework. This degree does require a research-based scholarly paper, but it does not involve the level of research required for a traditional thesis. This 1-year M.S. degree option is completed within one calendar year and requires students to take a slightly heavier course load (13 credits during the Fall and Spring semesters and 4 credits during the Summer term). Students in the 1-year resident M.S. program are expected to pay their own tuition and living expenses, as they don’t receive assistantships. But they are able to return to the workforce much more quickly than for students in the traditional 2-year M.S. option which requires a thesis.
Acoustics Characterization of Materials
Bernhard Tittmann, Group Leader
brt4@psu.edu

The mission of the Acoustics Characterization of Materials group is to develop a new understanding of how various types of waves, i.e., ultrasonic x-ray, thermal, optical, electromagnetic, acoustic, etc., interact with advanced materials; to translate this understanding into techniques for monitoring and controlling industrial processes; and to apply these techniques to the development of materials processes. A major thrust is in the research and development of sensors for harsh environments, including high temperature (up to 1000°C) and nuclear irradiation (Nuclear Reactors).

Our group has been fortunate to receive major funding from DOE for ATR-NSUF tests in the MIT Nuclear Reactor of 6 different piezoelectric sensors for possible use in harsh environments. The results of these tests are currently being evaluated but preliminary findings show that 4 of the sensors survived the irradiation for a period of 18 months after which the program came to an end.

The group has also been fortunate to receive rare and expensive piezoelectric wafers from Bechtel Bettis for phased array design, construction and testing for high temperature, high pressure.

One of the students graduating last year received the coveted ESM Fenlon Award for the outstanding senior capstone thesis.

Our recent graduate Dr. Matt Guers has a permanent position at the PSU Applied Research Laboratory where he is doing outstanding work for Prof. Hambric. He is also a part-time instructor in the ESM Department.

Projects and Students:
Title: Ultrasonic Phased Array Design, Construction and Testing
Sponsor: Bettis Atomic Power Laboratory
Ph: B. Tittmann
Students: Brian Reinhardt (EMS; Ph.D. Candidate), Andrew Suprock (EMS; MS)

Title: Enhancement of Spray-on Transducer Technology for Field Deployment
Sponsor: Electric Power Research Institute
Ph: B. Tittmann
Students: Janet Xu (Acoustics; MS); Chunying Wang (EMS MS)

Adaptive Structures and Noise Control
George Lesieutre, Group Leader
gal4@engr.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 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 (2018)

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 could 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 forcing contact at internal interfaces via differential thermal expansion. Ongoing research addresses thermo-mechanical topology optimization of a two-material sandwich panel core to achieve a broad range of effective thermal conductivity, as well as associated advances in 3-D printing.
Collaborators: Dr. Mary Frecker (ME), Dr. Jim Adair (MatSci)
Student: Tianliang Yu, Ph.D. December 2017 (expected)

Title: Dynamic Tensegrity for Deployable Structures
Sponsor: PSU
Summary: Tensegrity structures offer the potential of very high packing efficiency for launch to space, but are relatively soft in the classical deployed configuration. Higher stiffness should be possible with strut-to-strut load transfer, requiring dynamic cable actuation and higher joint fixity.
Student: Yaan Kildiz, Ph.D. December 2018 (expected)

Title: Deployable Solar Arrays for Cubesats
Sponsor: PSU
Summary: High power, compact solar arrays are needed to enable ever more ambitious Cubesat missions. These are initially stowed and must withstand high vibratory and acoustic launch loads. Finite-thickness panels require novel, structurally integrated current-carrying hinges.
Student: Amey Chaudhary, M.S. expected August 2016

Projects completed in 2015 and graduated students

Title: Vibration Reduction of Sandwich Composites via 3-D Manufactured Acoustic Metamaterial Cores
Summary: Composite sandwich panels provide excellent stiffness- and strength-to-weight, often at the expense of vibro-acoustic response and especially in the presence of tensile loads. Metamaterial core configuration that provide high effective vibration reduc-
tion in key frequency regions were designed, fabricated using 3-D manufacturing, and experimentally characterized.

**Student:** Tianliang Yu, M.S., Aerospace Engineering, August 2015

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. [https://wikispaces.psu.edu/display/NEO/Welcome](https://wikispaces.psu.edu/display/NEO/Welcome)

**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 multiphysics 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. A video featuring this work was recently produced by NBC Learn as part of their Science of Innovation series: [http://www.nbclearn.com/innovation/cuecard/105467](http://www.nbclearn.com/innovation/cuecard/105467)

**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)


**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 inte-

grated 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 are being performed by applying the techniques developed to an avian-scale ornithopter test platform in both Bench top and flight testing.

**Collaborators:** Dr. James James (Univ. of Maryland)

**Students:** Joseph Calogero, Ph.D. expected May 2017.

Dr. Kenji Uchino and his students are working on the following projects.

**Title:** Burst mode high power piezoelectric characterization

**Sponsor:** Office of Naval Research

**PI:** Kenji Uchino

**Student:** Husain N. Shekhan (EE PhD, expected)

**Title:** Crystallographic orientation dependence of piezoelectric losses

**Sponsor:** Office of Naval Research

**PI:** Kenji Uchino

**Student:** Minkyu Choi (MatSE PhD expected)

**Title:** Partial electrode configuration for measuring piezoelectric losses under various constraints

**Sponsor:** Office of Naval Research

**PI:** Kenji Uchino

**Student:** Maryam Majzoubi (EE PhD expected)

**Title:** DC bias field and stress effects on piezoelectric losses

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**PI:** Kenji Uchino

**Student:** Anushka Bansal (MatSE PhD expected)

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**Title:** High Damping NiTi-Based Shape Memory Alloys

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Title: Noise from Pulsating Super cavities and Its Control
Sponsor: Office of Naval Research
PI(s): Drs. Timothy A. Brungart and Jules W. Lindau
Student: Grant M. Skidmore, Ph.D. in Aerospace Engineering, May 2016
Summary: The noise radiated by pulsating super cavities has been explored experimentally in a water tunnel facility, computationally using 3D finite volume computational fluid dynamics (CFD) and analytically. 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 super cavities were found to be at least 35 dB higher in level than those from comparable re-entrant jet and twin vortex super cavities. Extensive investigations were performed into suppressing pulsation noise by modulating (i.e., adding a sinusoidal component to) the gas ventilation rate in order to shift the supercavity resonance frequency away from the interface excitation frequency. This technique, which has its roots in parametric oscillators, causes pulsating super cavities to transition to another (twin vortex) closure regime over a wide range of modulation frequencies, typically within 0.25 seconds of modulation initiation. Accompanying the transition from pulsation to twin vortex closure is a reduction in the radiated noise, to the continuum at the pulsation frequency, oftentimes 35 dB or more. Other modulation frequencies do not suppress pulsation but are effective at changing the supercavity pulsation frequency.

Title: Compressor Acoustic Diagnostics and Noise Control
Sponsor: Bristol Compressors
PI(s): Drs. Timothy A. Brungart and Steven A. Hambrick
Student(s): Seeking Acoustics Ph.D. Student for Spring 2019 Graduation
Summary: This effort is just getting underway.

Title: High Power Carbon Nanotube Thermophore Development
Sponsor: Joint Non-lethal Weapons Directorate
PI(s): Drs. Timothy A. Brungart and Benjamin S. Beck
Student: James J. Chatterley, Ph.D. in Acoustics expected December 2018
Summary: The summary has not yet been cleared by the sponsor.

Project: Glottal jet aerodynamics
Sponsor: NIH
PI: Michael Krane (ARL PSU)
Collaborators: Lucy Zhang (Rensselaer Polytechnic Inst.), Timothy Wei (Univ. Nebraska-Lincoln), Daryush Mehta (Massachusetts General Hospital), Robert Hillman (Massachusetts General Hospital), Sid Khosla (Univ. of Cincinnati Med. School)
Students: Michael McPhail (PSU Bioengineering), Jubiao Yang (RPI Mechanical Engineering)

In 2015, project was renewed for 5 more years. Has been running continuously since 2002.

Propagating and Radiation
Victor Sparrow, Group Leader
vvs1@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. Understanding the perception of sound by individuals and estimating noise impacts on people are two of the primary applications of the research.

In the 2015-2016 academic year Penn State has continued to participate in the FAA Center of Excellence in Alternative Jet Fuels and the Environment. Called ASCENT for Aviation Sustainability CEner, Dr. Vic Sparrow is continuing to work on multiple FAA ASCENT projects as well as serving as the overall ASCENT Lead Investigator at Penn State. Some of the ongoing research has focused on the understanding and overcoming the limitations of current FAA noise tools, particularly in improving the propagation modeling using updated atmospheric absorption and atmospheric profiles models. Further work has centered on improving our understanding of the limitations of metrics for sonic booms, and the sensitivity of those metrics due to atmospheric turbulence distortions.

Dr. Sparrow is also participating in a new NASA project this year, SonicBAT, which focuses on the effects of atmospheric turbulence on low-boom sonic booms. The lead for this project is Wyle, and Penn State is a subcontractor on the effort. Penn State is developing a new propagation code that includes the effects of atmospheric turbulence in addition to nonlinearity and loss mechanisms. On the topic of sonic booms, Dr. Sparrow was co-organizer of the 2nd International Sonic Boom Forum, held July 1-3, 2015 in Lyon, France, and the proceedings of that meeting are now available through the AIP Press of the American Institute of Physics.
emotional response to acoustics stimuli using neuroimaging, specifically using functional magnetic resonance imaging (fMRI). One student is using fMRI to predict the response of reward regions to room acoustics stimuli with varying levels of reverberation time. The second student’s project is in collaboration with Dr. Pamela Cole, professor of psychology at PSU and project PI, which is supported by NIH. The purpose of the project is to evaluate the developmental effects on children who are exposed to hearing angry conversations. For the final topic of aircraft noise and cardiovascular disease, she has recently completed a project in collaboration with Dr. Sparrow and two other PSU researchers, funded through PSU’s Clinical and Translational Science Institute (CTSI), to pilot predicting environmental noise around the Philadelphia International Airport using a commercially-available noise modeling program. New funding from the NIH is very likely to be awarded in Summer 2016 on a project that will be in collaboration with researchers at Boston University.

The most recent student graduates from the Propagation and Radiation Group include Mr. Matthew Neal (M.S.) and Mr. Erik Petersen (M.S.).

**Current Graduate Students:**

Mansi Biwalkar, Ph.D. expected Summer 2018
**Thesis topic:** Validation and extension of noise tools using existing airport noise data
**Sponsor:** FAA
**Advisor:** V. Sparrow

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

William Doebler, Ph.D. expected Summer 2019
**Thesis topic:** Removing turbulence from sonic boom ground measurements
**Sponsor:** FAA
**Advisor:** V. Sparrow

Beom Soo Kim, Ph.D. expected Fall 2016
**Thesis topic:** Low frequency noise of aircraft noise transmission from outdoors to indoors
**Sponsor:** FAA
**Advisor:** V. Sparrow

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

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

Peter Moriarty, M.S. expected Summer 2017
**Thesis topic:** Children’s neural processing of the emotional environment: angry voices
**Sponsor:** NIH
**Advisor:** M. Vigeant

Matthew Neal, Ph.D. expected Fall 2018
**Thesis topic:** Predicting perceived acoustical quality of concert halls using a combination of room acoustics metrics
**Sponsor:** NSF
**Advisor:** M. Vigeant

Nick Ortega, Ph.D. expected Fall 2020
**Thesis topic:** Calculating binaural room impulse responses from spherical microphone arrays using spherical harmonics
**Sponsor:** FAA
**Advisor:** V. Sparrow

Rachel Romond, Ph.D. expected Summer 2016
**Thesis topic:** Variability in noise metrics due to the effects of atmospheric turbulence on sonic boom signatures
**Sponsor:** FAA
**Advisor:** V. Sparrow

Kristina Sorensen, Ph.D. expected Fall 2020
**Thesis topic:** Study of the perception of warmth in concert halls and correlation with room acoustics metrics
**Sponsor:** FAA
**Advisor:** V. Sparrow

**Rotorcraft Acoustics and Dynamics**

**Ed Smith, Group Leader**

ces5@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 Langelaan), 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). We recently prepared and submitted a major new proposal that would fund the Center for the 2016-2021 time period. We have a suite of proposed projects in the vibration and noise control area, in addition to others in various areas related to rotorcraft technology needs. 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). Emphasis areas include: advanced flight controls and vehicle dynamics simulation, interactional source noise, acoustical scattering of rotor noise, gearbox noise, 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. Our annual Rotorcraft Technology Short Course will be offered for the 49th consecutive year on August 8-12. 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 Fluid-elastic Pitch Links  
**Sponsor:** LORD Corp.  
**PIs:** Ed Smith, Chris Rahn  
**Students:** Shawn Treacy (PhD candidate)

**Title:** Tailboom Vibration Control via F2MC Devices  
**Sponsor:** NSF.  
**PIs:** Ed Smith, Chris Rahn  
**Students:** Kentaro Miura (PhD 2016), Matt Krott (PhD Candidate)

**Title:** High Fidelity CFD Analysis and Validation of Rotorcraft Gear Box Aerodynamics  
**Sponsor:** NASA  
**PI:** Rob Kunz  
**Students:** Sean MacIntyre (PhD 2015), Qingtiao 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, PhD candidate)

**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 candidate)

**Title:** Centrifugally Powered Pneumatic Devices for Helicopter Rotors  
**Sponsor:** NASA  
**PI:** Jose Palacios, Doug Wolfe  
**Student:** Matthew Drury (MS 2016)

**Title:** Acoustic Capability for NDARC  
**Sponsor:** NRTC VLRCOE Program  
**PI:** Ken Brentner  
**Student:** Kalki Sharma (MS candidate)

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

**Title:** Fundamental Physics of Active Rotor Concepts for Acoustics and Performance Enhancement  
**Sponsor:** NRTC VLRCOE  
**PI:** Ken Brentner, Mark Maughmer, Sven Schmitz  
**Students:** Ethan Corle (PhD Candidate), 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:** Willie Costa (MS 2015), Sandilya Kambampati (PhD candidate), Taylor Hoover (MS 2015), Julia Cole (PhD Candidate)

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

**Title:** Acoustic Capability for NDARC  
**Sponsor:** NRTC VLRCOE  
**PI:** Ken Brentner  
**Student:** Kalki Sharma (MS Candidate)

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

**Title:** Autonomous Multi-Lift Systems  
**Sponsor:** NRTC VLRCOE  
**PIs:** Joe Horn, Jack Langelaen  
**Students:** 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 Disurbances 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 Lesiuret  
**Student:** Brad Sottile, (Ph.D. candidate)
Title: Efficiency, Dynamics, and Noise Characteristics of Pericyclic Transmissions  
**Sponsors:** NASA, Vertical Lift Consortium  
**PI:** Ed Smith, Bob Bill  
**Students:** Tanmay Mathur, (Ph.D. candidate), Zach Cameron (MS Candidate)

Title: Passive Tailboom Damping with Fluidic Flexible Matrix Composite Tubes  
**Sponsor:** (I'm an NSF Fellow so technically there isn't one)  
**PI:** Ed Smith, Chris Rahn  
**Student:** Matt Krott (Ph.D. Candidate)

Title: Ultra-Reliable Helicopter Design  
**Sponsor:** Army Aviation Technical Directorate (AATD)  
**PI:** Jeff Banks/Sam Evans/Lorri Bennett (ARL) Teamed with AVX Aircraft Company and General Electric  
**Student:** Leland Renoff (Aero Undergrad, former USMC, 6 years as CH-53 Crewmember)

**Structural Vibration and Acoustics**  
**Steve Hambrick, Group Leader sah19@psu.edu**

The Structural Vibration and Acoustics Technical Group investigates vibration in structures and its interaction with acoustic media. The group develops novel methods to analyze, measure, and control structural vibrations and radiated noise.

In 2015-2016 the group members investigated a wide range of topics, as shown below. We are particularly excited about a new topic we are collaborating with Sandia on: joint stiffness and damping. Trevor Jerome, a PhD student in Acoustics, will spend this summer working with Dr. Matt Brake at the Nonlinear Mechanics and Dynamics (NOMAD) institute at SANDIA National Labs. Matt coordinates an international consortium on joint friction, stiffness, and damping, and we look forward to this collaboration.

Trevor has been modeling and measuring the effects of joint dynamics on bolted structures. Two L-shaped plates have been tested with free boundary conditions, and bolted together. The nonlinear effects of bolt preload and vibration amplitude on joint stiffness and damping are being investigated. Reduced-order linearized methods for simulating these effects will be developed for FE models.

**Projects and Graduate Students:**

**Title:** Adaptive Acoustic Metamaterials  
**Sponsor:** NAVSEA 073  
**PIs:** Ben Beck  
**Student:** Aaron Stearns (PhD Mechanical Engineering)

**Title:** CNT Turnkey Thermophone  
**Sponsor:** Joint Non-Lethal Weapons Directorate  
**PIs:** Ben Beck, Tim Brungart  
**Student:** Trevor Jerome (Ph.D., Acoustics)

**Title:** High performance structural-acoustics computing  
**Sponsor:** ONR  
**PIs:** Dean Capone, Rob Campbell, John Fahnline  
**Student:** Steve Hambrick)

**Title:** Fluid-Structure Interaction Simulations of a Wind Turbine with Consideration of Atmospheric Boundary Layer Turbulence  
**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:** Performance Optimization of an Intake Port Shape Design for an Internal Combustion Engine  
**Sponsor:** Self-funded  
**PIs:** Rob Campbell, Justin Watson  
**Student:** Michael Donnelly (MS – Mechanical Engineering)

**Title:** Force Reconstruction using Force Gauges and Modal Analysis  
**Sponsor:** ARL, Walker Fellowship  
**PIs:** Tyler Dare  
**Student:** Wesley Axtell (MS – Acoustics)

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

**Title:** Nonlinear structural joint dynamics  
**Sponsor:** Pratt and Whitney and US Navy  
**PIs:** Steve Hambrick, Micah Shepherd  
**Student:** Trevor Jerome (Ph.D., Acoustics)

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

**Title:** Large chiller noise and vibration  
**Sponsor:** UTC Building and Information Systems  
**PIs:** Steve Hambrick, Tim Brungart  
**Student:** Stephen Wells (Ph.D., Acoustics)

**Title:** Small reciprocating compressor noise and vibration  
**Sponsor:** Bristol Compressors  
**PIs:** Steve Hambrick, Tim Brungart  
**Student:** TBD (Ph.D., Acoustics)

**Title:** Acoustic Scattering from Elastic cylindrical shells reinforced by internal circular plates- 3D solution  
**Sponsor:** NUWC, Newport RI  
**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)
Title: Acoustic and Vibrational Analysis of an Acoustic Guitar  
Sponsor: Self-funded  
PI: Dan Russell  
Student: Corey Taylor (MEng – Acoustics)

Title: Vibration Analysis of Foam-Filled Tennis Rackets for Reduction of Vibration at the Wrist  
Sponsor: Self-funded  
PI: Dan Russell  
Student: Kritika Vayur (MEng – Acoustics)

Title: Acoustic and Vibrational Analysis of Golf Club Drivers  
Sponsor: AR Walk Fellowship  
PI: Steve Conlon  
Students: Phil Feurtado (Ph.D., Acoustics), Angelina Conti (BS-Honors Aerospace Engineering)

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

Title: Wireless sensing technologies  
Sponsor: NAVSEA PMS 397  
PI: Steve Conlon

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

Title: Assessment of Bolted-joint Structures  
Sponsor: NAVSEA  
PI: Steve Hambric  
Student: Trevor Jerome

Title: Acoustic cell separation  
Sponsor: NIH, NSF  
PI: Tony Jun Huang  
Students: Mengxi Wu and Shujie Yang

The group leaders Lissenden and Reichard are part of a Department of Energy NEUP integrated research project to research and develop robotic inspection systems for dry cask storage of used nuclear fuel. Some of the canisters that confine the spent fuel are in environments that could be conducive to stress corrosion cracking. However, access to the canister is very limited by the shielding overpack structure, and in addition the harsh environment includes elevated temperature and radiation. Hence, robotic systems are required to deliver sensors to inspect for cracks, determine surface composition (are salts present?), measure temperature and radiation. Laser induced breakdown spectroscopy (LIBS) delivered by an optical fiber was selected to detect the presence of chloride bearing salts on the surface of the stainless steel canister. While shear-horizontal ultrasonic guided waves were chosen to inspect for cracks in the vicinity of welds using noncontact electromagnetic acoustic transducers (EMATs). A schematic of the nondestructive inspection method is shown in Fig. 1. A photo of the optical fiber delivery of a laser pulse and a preliminary LIBS result are shown in Fig. 2. EMAT and LIBS measurements will be made robotically, with the robotic inspection system entering the cask through an exhaust vent and unfolding a delivery arm on the lid of the canister. As shown in Fig. 3 sensor cars will be deployed from the arm by a tether. Final demonstration of the robotic inspection systems is planned for the fourth quarter of 2017.

Projects and Graduate Students:

Title: Multi-Sensor Inspection and Robotic Systems for Dry Storage Casks  
Sponsor: DOE NEUP IRP  
PIs: Cliff Lissenden, Arthur Motta, Igor Jovanovic, Sean Brennan, Karl Reichard, Travis Knight, John Popovics  

Title: Higher Harmonic Ultrasonic Guided Waves for Structural Integrity Assessment of Infrastructure  
Sponsor: NSF  
PI: Cliff Lissenden  
Student: Gloria Choi (PhD –Engineering Science and Mechanics)
**Title:** Health Monitoring Methods for Joints in Rotorcraft Composite Structures  
**Sponsor:** National Rotorcraft Technology Center (Army, Navy, NASA)  
**PIs:** Cliff Lissenden and Joe Rose  
**Student:** Baiyang Ren (Post Doc - Engineering Science and Mechanics)

**Title:** High-temperature Sensor Technology in Support of In-situ Monitoring of Creep Specimens  
**Sponsor:** Pacific Northwest National Lab  
**PIs:** Cliff Lissenden and Bernie Tittmann  
**Student:** Andy Suprock (PhD – Engineering Science and Mechanics)

**Title:** Submarine CBM+ Implementation  
**Sponsor:** U.S. Navy  
**PIs:** Jeffery Banks, Mitchell Lebold  
**Student:** Michael Roemer (MS – Mechanical Engineering)

**Title:** Early Entry Fuel Delivery System  
**Sponsor:** U.S. Army  
**PIs:** Karl Reichard, Eddie Crow  
**Student:** Jason Reiter (MS – Aerospace Engineering)

**Title:** CBM+ for Submarines  
**Sponsor:** U.S. Navy  
**PIs:** Jeffery Banks, Mitchell Lebold  
**Student:** Michael Roemer (MS – Mechanical Engineering)

**Title:** Hydroturbine Design  
**Sponsor:** Department of energy  
**PIs:** Arnold Fontaine, Todd Palmer, Jeffery Banks  
**Student:** Corey Hunt (MS - Mechanical Engineering)

**Graduates:**
- Vamshi Chillara, Ph.D. in Engineering Science and Mechanics, August 2015, Towards improved NDE and SHM methodologies incorporating nonlinear structural features, NSF, Cliff Lissenden
- Baiyang Ren, Ph.D. in Engineering Science and Mechanics, August 2015, Phased array transducers for structural health monitoring of aircraft structures using ultrasonic guided waves, NRTC, Cliff Lissenden

**Underwater Acoustics and Instrumentation**  
**Amanda Hanford, Group Leader**  
ald227@psu.edu

One of the missions of the Underwater Acoustics and Instrumentation Technical Group is to conduct 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. The group also conducts applied research characterizing the performance of underwater acoustic systems, design and development of in air and in water transducers and application of advanced signal processing techniques.

In 2015, our group continued many Oceanography studies using acoustic data to determine physical properties of the ocean environment. One of them consisted of an atsea experiment that took place off the coast of La Spezia, Italy. Acoustic data was collected by PSU using the cardioid aperture of The ONR Five Octave Research Array (FORA). Successful raw hydrophone data was collected in the interest of estimating the effectiveness of continuous active sonar (CAS) processing in the shallow water littoral environment.

Our group is also active in other novel technical areas for applications in under water environments such as acoustic metamaterials.

**Projects and Graduate Students:**
- **Title:** Ambient Noise  
  **Sponsor:** ONR  
  **PIs:** Dave Bradley  
  **Student:** Stephen Nichols
- **Title:** Scattering Rock Outcrops  
  **Sponsor:** ONR  
  **PIs:** Derek Olson
- **Title:** Whale Density Estimates  
  **Sponsor:** ONR  
  **PIs:** Jennifer Miksis-Olds  
  **Student:** Julia Vernon
- **Title:** Bottom Backscatter  
  **Sponsor:** ONR  
  **PIs:** Charles Holland
- **Title:** FORA Support and Clutter Statistics  
  **Sponsor:** ONR  
  **PIs:** Chad Smith
- **Title:** Sediment Mapping  
  **Sponsor:** ONR  
  **PIs:** Charles Holland
- **Title:** Infrasound Array Performance  
  **Sponsor:** DTRA  
  **PIs:** Tom Gabrielson
- **Title:** Ocean Acoustic Reverberation Modeling  
  **Sponsor:** ONR  
  **PI:** Charles Holland

The following is a current list of other projects and graduate students in our section.
Special CAV sponsored Symposium on Flow Induced Noise and Vibration – Issues and Aspects (FLINOVIA II), 27-28 April 2017

Instead of the short course which usually follows CAV workshops, next year Steve Hambric and Amanda Hanford, along with an international consortium, will organize the second two-day symposium on flow induced noise and vibration (Flinovia II). The CAV workshop will be held 25-26 April 2017, and Flinovia II will immediately follow.

The first Flinovia was held in Rome, Italy in November 2013, and hosted by The University of Rome and the Italian Research Institute for Naval Architecture and Marine Engineering (INSEAN). The proceedings are available in a book published by Springer: (http://www.springer.com/us/book/9783319097121), and feature articles by 15 invited authors.

Flinovia II will feature talks by invited authors from around the world on simulating and measuring flow-induced vibration and noise mechanisms. All CAV members are welcome to attend the symposium free of charge. The agenda will be developed later this year, and made available to CAV members.

Other organizers include Sergio De Rosa and Franco Francesco from Naples University, Elena Ciappi of INSEAN, Jean-Louis Guyader from INSA de Lyon (a CAV international liaison), and Randolph Leung from Hong Kong Polytechnic (another CAV international liaison).

CAV members co-author book

Steve Hambric, John Fabnline, and Micah Shepherd wrote and co-wrote chapters in the new book: “Engineering Vibroacoustic Analysis – Methods and Applications,” recently published by Wiley. The book was co-edited by Hambric, and his colleagues (formerly from General Motors) Don Nefske and Sue Sung.

The book describes analytical methods (based primarily on classical modal synthesis), the Finite Element Method (FEM), Boundary Element Method (BEM), Statistical Energy Analysis (SEA), Energy Finite Element Analysis (EFEA), Hybrid Methods (FEM-SEA and Transfer Path Analysis), and Wave-Based Methods. The book also includes procedures for designing noise and vibration control treatments, optimizing structures for reduced vibration and noise, and estimating the uncertainties in analysis results. Written by several well-known authors, each chapter includes theoretical formulations, along with practical applications to actual structural-acoustic systems. Readers will learn how to use vibroacoustic analysis methods in product design and development; how to perform transient, frequency (deterministic and random), and statistical vibroacoustic analyses; and how to choose appropriate structural and acoustic computational methods for their applications. The book can be used as a general reference for practicing engineers, or as a text for a technical short course or graduate course.