CAV Review '13-'14

CENTER FOR ACOUSTICS & VIBRATION

CAV Update

Spring workshop dates set

The CAV's annual workshop was at the Penn State Nittany Lion Inn April 29-30. This year the workshop had the same format as the previous year's with the event lasting for two full days. On Tuesday morning, following the formal presentations, we had a panel discussion on sound propagation in air and water. We will be followed this pattern for Wednesday's session with a panel discussion on effects of vibration and sound on humans and animals. As in the past laboratory tours were given to familiarize attendees with some CAV facilities. Tuesday evening we once again had a student poster session and reception. It was held in the Keller Lobby of Mateer Building. As in the past, the program mixed presentations from technical group leaders, international liaisons, several corporate sponsors, and new government liaisons. Graduate students and their advisors were available for discussions concerning their research. While formal presentations were 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 was held at our Tuesday evening social in the Keller Lobby, between 6 and 9 pm. Our corporate sponsors, government guests, and international liaisons casted votes for the best posters, and we awarded 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.

Reconstruction of the CAV Hemi-Anechoic Chamber

Interior picture of the updated hemi-anechoic chamber in the Hammond Building.

The Center for Acoustics and Vibration (CAV) hemi-anechoic chamber located in the basement of the Hammond Building was originally constructed in the 1997 under the direction of Dr. Weicheng Chen, who was a key contributor to the foundation and early success of the CAV. The facility was built to provide an anechoic termination for transmission loss measurements of Boeing airplane fuselages using the adjacent reverberation chamber, which was constructed in 1970.

Paul Bauch recently characterized the transmission loss suite as part of his M.S. thesis in the Graduate Program in Acoustics, which was supervised by Dr. Steve Hambric and Dr. Andrew Barnard. The semi-anechoic chamber was found to meet or exceed the ISO 3745-03 (*Acoustics - Determination of Sound Power Level of Noise Sources - Precision Methods for Anechoic and Semi-anechoic Rooms*) [1] requirements for 160 to 10,000 Hz. In terms of transmission loss (TL) measurements, flanking transmission between the two chambers was measured in accordance with ASTM E90-02 (*Laboratory Measurement of Airborne Transmission Loss of Building Partitions and Elements*). The results showed that the maximum TL of a partition that can be reliably measured through the 33" square window is approximately 45 dB for 400 to 10,000 Hz. Therefore, it was concluded that it is possible to make accurate TL measurements of lighter composite materials and thin panels, but not for heavy panels. Based on visual inspection, the primary flanking paths were assessed to be through the ceiling and walls.

During Summer and Fall 2013, a major renovation was undertaken to improve the sound isolation of the hemi-anechoic chamber and to remove irregularities in the room's geometry. Mr. Rick Auhl, CAV Laboratory and Equipment Manager, led and coordinated the reconstruction, with input provided by Dr. Michelle Vigeant, Dr. Andrew Barnard, and CAV directors Dr. George Lesieutre and Dr. Stephen Hambric. Mr. Auhl worked with a total of six students on the construction of the new chamber over a period of approximately four months.

Continued pg 3

Corporate Members & International Liaisons

Corporate Members & Representatives
Bettis Atomic Power Lab—Eric Salesky
Boeing—Joseph Wat
Bose—Ray Wakeland
Fisher Controls Technology International, LLC— Shawn Anderson
Gerard Daniel Worldwide—Darren McClure
Gulfstream—Kristopher Lynch
KCF—Jacob Loverich
KAPL—Steve Dunn
LORD Corporation—Scott Redinger
Martin Guitar—Albert Germick
Moog, Inc— Chris Layer
Newport News Shipbuilding—Kevin Smith
Pratt & Whitney— Rick Labelle and Lon Preston
United Launch Alliance—Ed Heyd
United Technologies Research Center—Jeff Mendoza
Volvo Construction Equipment—Hongan Xu
Westinghouse Electric Company—Larry Corr

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

Barnard supports PCB with educational papers

In 2013-2014, CAV vendor liaison PCB Piezotronics, Depew, NY, contracted with Dr. Andrew Barnard of the Pennsylvania State University Applied Research Laboratory to provide educational materials to their customers. Dr. Barnard has produced two white papers covering topics in acoustics. The first covers how to use windscreens and nose cones to make successful acoustics measurements in the presence of flow noise. The second covers the topic of measuring the sound power levels of an acoustic source. Dr. Barnard has also provided two one-day seminars covering introductory and advanced acoustic measurements using microphones.

CAV Welcomes New Corporate Members

The CAV is pleased to welcome two new corporate members, Bose Corporation and Gerard Daniel Worldwide to the group.

Bose Corporation was founded in 1964 by Dr. Amar G. Bose, then a professor of electrical engineering at the Massachusetts Institute of Technology. Today, the company is driven by its founding principles, investing in long-term research with one fundamental goal: to develop new technologies with real customer benefits. Bose® innovations have spanned decades and industries, creating and transforming categories in audio and beyond. Bose products for the home, in the car, on the go and in public spaces have become iconic. From the company's home entertainment systems and Wave® music systems, to noise cancelling and audio headphones, digital music systems, *Bluetooth*® speakers and professional solutions, Bose has changed the way people listen to music. Bose Corporation is privately held. The company's spirit of invention, passion for excellence, and commitment to extraordinary customer experiences can be found around the world -- everywhere Bose does business. You can read more about Bose and their work at http://worldwide.bose.com/com/en_us/web/our_story/page.html. The company liaison is Ray Wakeland.

Gerard Daniel Worldwide has been a provider of wire cloth for over 60 years. Servicing aerospace, automotive, filtration we have been able to establish products and services not generally associated with "industrial wire cloth". Our investments in quality and engineering have allowed Gerard Daniel to become a premiere supplier to many OEM and After Market customers whose needs reach beyond the standard supply sources. Our engineering group has the capability to offer custom solutions to your specialized engineering and design challenges. To learn more about Gerard Daniel Worldwide please visit http://www.gerarddaniel.com. The company liaison is Darren McClure.

Trethewey Awarded 2014 Milton S. Eisenhower Award for Distinguished Teaching

Dr. Martin Trethewey, Arthur L. Glenn Professor of Engineering is the recipient of the 2014 Milton S. Eisenhower Award for Distinguished Teaching.

The award recognizes excellence in teaching and student support among tenured faculty who have been employed at Penn State for at least five years with undergraduate teaching as a major portion of their duties. The award is named after Milton S. Eisenhower, brother of former U.S. President Dwight D. Eisenhower, who served as the president of Penn State from 1950—1956.

Dr. Trethewey, a member of the mechanical engineering faculty for 32 years, uses real-life activities to prepare students to make the transition from student to professional engineer. The students are assigned to teams that work as small professional consulting companies to hone their teamwork and communication skills.

Trethewey developed the Global Capstone Project Team which allows Penn State students to gain international experiences without leaving the country. The students are partnered with students from an overseas university to work with an industry sponsor dealing with communication challenges such as the time-zone differences.

In 2013 Dr. Trethewey was the recipient of the Penn State Engineering Society Outstanding Teaching Award and is a member of the Structural Vibration and Acoustics technical group.

Hemi Anechoic Chamber Continued . . .

The reconstructed chamber is approximately 11′ long by 14′ wide by 8.5′ high with the 12″ x 12″ x 18″ foam wedges in place. The new chamber is smaller than the original one, which was approximately 12′ x 16′ x 11′ since thickness was added to the walls and ceiling, and the irregularities in the geometry were removed. Where possible, materials from the original chamber were recycled, including all of the foam wedges. A total of 714 wedges are installed in the new chamber.
The walls consist of 2″ x 4″ studs spaced approximately 16″ on center, with the following construction:

- (1) layer of ¾″ plywood on the outer most edge attached directly to the studs
- 3″ of fiberglass insulation between the studs
- Resilient channels attached to the studs about 12″ on center
- (1) layer of ¾″ plywood attached to the resilient channel, which creates a ½″ gap between the stud and the plywood.
- Strips of ¼″ plywood offset from the wall by 1″ to mount the wedges to the walls

Interior shot of the hemi anechoic chamber during construction.

The ceiling is a similar design to the walls, except that 2″ x 8″ joists were used in place of the studs and no resilient channels were used. The ceiling had to be constructed in 4′ sections by first attaching the sheets of plywood to the joists and then lifting the individual assemblies into place to attach it to the wall headers. The sections were then filled with 6″ of fiberglass and the outer layer of ¾″ plywood was attached.

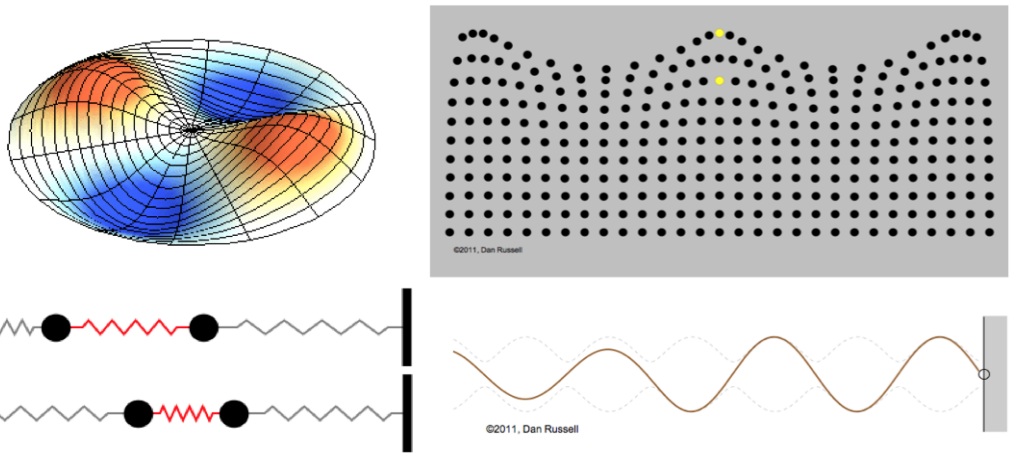
A complete new base for the chamber was also constructed, which raises the chamber off the floor by about 2′. The floor has a similar construction to the ceiling, with the exception that there are two layers of wood on the inside of the chamber. The wood subfloor is covered with 3/8″ Berber (loop-pile) carpet and 3/8″ pad. For hemi-anechoic conditions, the carpet can be covered with sheets of plywood, and for conditions closer to anechoic, additional wedges can be placed on the floor.

CAV researchers are very excited to begin using the new facility and are grateful for the support of the CAV and in particular wish to acknowledge **Mr. Rick Auhl** and his students for the successful construction of this new hemi-anechoic chamber.

[1] Bauch, P. (2013). "Traditional and Angle-Dependent Characterization of Penn State's Panel Transmission Loss Suite." *Master's Thesis, Graduate Program in Acoustics, The Pennsylvania State University*

Animation is a valuable educational tool

Dr. Dan Russell (Professor of Acoustics and Director of Distance Education for the Graduate Program in Acoustics) has long been an advocate of the adage that "if a picture is worth a thousand words, then an animation is even more valuable." 20 years ago, as a graduate student at Penn State, he began using *Mathematica* to create animations to illustrate wave and oscillation phenomena to aid his own understanding. Since then, he has been using his animations as effective educational tools while teaching acoustics and vibration to undergraduate and graduate students for the last 19 years. His website "Acoustics and Vibration Animations" (http://www.acs.psu.edu/drussell/demos.html) is very well known in the acoustics educational community, with several awards, and is used by thousands of educators and consultants around the world. The website currently has links to about 50 different animations showcasing various acoustics and vibration phenomena, including: reflection and refraction of waves; impedance and the standing-wave-ratio; the Doppler effect; forced oscillation and resonance; response to base excitation; coupled oscillators; dynamic absorbers; modes of multiple -dof systems; vibrational modes of membranes, bars, baseball bats, hockey sticks, beer bottles, acoustic and electric guitars; particle motion for traveling and standing longitudinal, transverse and surface waves; sound radiation from simple acoustic sources; vibration and sound radiation from tuning forks; plane and evanescent waves; scattering from spheres and cylinders. Most animations are presented as animated GIF images that automatically load and play on a web browser (including mobile devices). In addition, the site has links to several interactive plots and animations that allow the user to move sliders to adjust parameters and change the resulting plots or animation behavior. Finally, the site has links to several YouTube movies of physical demonstrations of acoustic phenomena.



Example of animation seens on Russell's web page.

CAV Members Receive Honors and Awards

Dr. Andrew Barnard - 2013 Applied Research Laboratory Publication Award

Dr. George Lesieutre - delivered the keynote SDM Lecture at the 55th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference in National Harbor, MD

Dr. Cliff Lissenden - named Fellow of the American Society of Mechanical Engineers

Dr. Peter Newman—won the 2013 GWS Social Science Achievement Award

Dr. Marty Trethewey - 2014 Milton S. Eisenhower Award for Distinguished Teaching

Dr. Gordon Warn — selected for a National Science Foundation Early Career Development Award

Kenji Uchino—Ferroelectrics Recognition Award from IEEE/UFFC; IEEE/UFFC Opening Plenary Lecture July 2013

Beth Bimber – received the NSF Graduate Research Fellow

Jason Bostron—Skudrzyk Award in Acoustics Program

Guillermo Costa—received the AHS Alfred L. Wolfe Scholarship

Ethan Corle—Vertical Flight Fellowship

Whitney Coyle— National Science Foundation GROW Fellowship; National Science Foundation Research Fellowship; Best Young Presenter award at the San Francisco ASA conference; Kenneth T. Simowitz Memorial Citation

David Dick—Kenneth T. Simowitz Memorial Citation

Grant Dowell – received 1st place in the student poster competition at the 66th Meeting of the American Physical Society Division of Fluid Dynamics

Matthew Krott—AHS 2014 Vertical Flight Foundation Scholarship

Abe Lee—Skudrzyk Award in Acoustics Program

Adam Lesky - won 2nd prize at ESM Today for his presentation "Wave Damage as a Sensitive Feature"; received the Aero Technologies E-A-R Acoustics Scholarship; Kenneth T. Simowitz Memorial Citation

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

Alison Orr—Joseph and Irene Tobis Graduate Fellowship

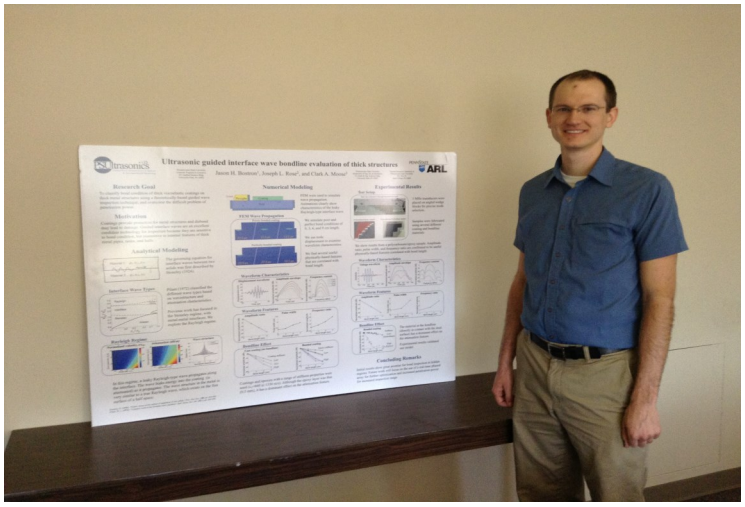
Andrew Pyzdek—Kenneth T. Simowitz Memorial Citation

Rachel Romond—Kenneth T. Simowitz Memorial Citation

Pierre Thurier— awarded first prize at the Penn State 2014 Engineering Graduate Exhibition Poster contest

Ed Zechmann - awarded CDC 2014 Federal Engineer of the Year; PHS 2014 Federal Engineer of the Year; INCE 2013 Michiko So Finegold Award for the paper "

Bostron and Powers Tie for First Place



Jason Bostron standing with his wining poster

Jason Bostron, doctoral student in the Graduate Program in Acoustics tied for first place in the second Student Poster Session of the CAV Workshop, April 29—30, 2013. Jason's poster showed the results of ultrasonic guided interface wave bondline evaluation of thick structures. Dr. Joseph L. Rose and Clark A. Moose are his advisors

Russell Powers, doctoral student in aerospace engineering was the other first prize winner. His poster showed the results of his research in experimental comparison of supersonic jets exhausting from military-style nozzles with interior corrugations and fluidic inserts. Dr. Dennis McLaughlin is his advisor.

Placing second was Michael Wozniak, with results from his research of single crystal vibration energy harvester for diagnostics. Wozniak is a graduate research assistant with advisors, Drs. Stephen Colon, Edward Smith, and Karl Reichard.

Congratulations to all.

Hambric helps organize FLINOVIA Conference

Steve Hambric worked with colleagues from Italy and France to help organize the 1st international workshop on Flow Induced Noise and Vibration Issues and Aspects (Flinovia), held at Consiglio Nazionale delle Ricerche (CNR) at La Sapienza (University of Rome) and at INSEAN (Marine Technology Research Institute), November 11-13, 2013. Most of the papers focused on panel vibration and radiated sound induced by turbulent boundary layer flow. The proceedings will be published as a bound volume by Springer in late 2014.

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.

Group members include Francesco Costanzo, Joseph Cusumano, Reginald Hamilton, Clifford Lissenden and Joseph Rose. New members to the group include Professor Albert E. Segall. Dr. Segall is specializing in friction and wear. He is a faculty member of the Department of Engineering Science and Mechanics.

Dr. Tittmann's group is now under contract with Bechtel Bettis to develop sensors and devices for flaw detection.

Current Projects

Title: Ultrasonic Transducer Irradiation Test
Sponsor: ATR-NSUF

Title: Ultrasonic Flaw Detection
Sponsor: Bechtel Bettis

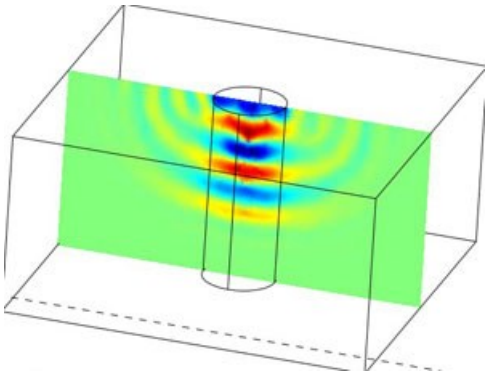
Title: High Temperature Transducers
Sponsor: NEUP-DOE
Co-PI: Cliff Lissenden

Title: Characterization of Plant Cell Walls
Sponsor: EFRC-DOE
Co-PI: D. Cosgrove

Title: Post Irradiation Test Support
Sponsor: NEET-DOE

New students to the group include Brian Reinhardt and Xiaoning Xi. These are Ph.D. candidates. Graduating this year is Kyle Sinding with a B.S. in Engineering Science and Mechanics. He is a Schreyers College Honor's student and is a IGU student studying for an M.S. in Engineering Science. John Mulry graduate with a B.S. in Engineering Science and Mechanics. Also, the group has coming a Master's student from Switzerland the Technical University of Zuerich, Marius Scharf.

Current M.S. students are Alison Orr, Andrew Suprock, and Galeston Machertich.



The Materials Evaluation Group is developing 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 materials manufacturing processes; and to apply these techniques to the development of materials processes.

Research topics include:

- Use of physical acoustics to understand the linear and nonlinerar behavior of advanced materials with emphasis on composite materials
- Use of acoustic microscopy to infer microstructural features in advanced materials, such as composites
- X-ray radiography to evaluate such phenomena as residual stress
- Sensors for materials process monitoring and control
- Nondestructive evaluation of advanced materials
- Optical, fiberoptical, and laser ultrasonic techniques for materials evaluation
- Infrared thermography
- Atomic force microscopy
- Confocal laser microscopy

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 active structures.

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 activated contract to achieve a broad range of effective thermal conductivity.
Collaborators: Dr. Mary Frecker (ME). Dr. Jim Adair (MatSci)
Student: Pierre Thurier, M.S. expected 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. expected August 2014

Title: Visco-Electric Energy Harvesting
Sponsor: LORD Corp.
Summary: There are numerous potential applications of energy harvesting devices on helicopters and other aerospace vehicles. This project is exploring vibration energy harvesting from thermoelectric conversion of heat generated in elastomeric elements.
Collaborator: Dr. Edward Smith (Aerospace)
Student: Raheel Mahmood, M.S. expected August 2014

Technical Group Research Highlights

Title: Sandwich Panel Damping via Optimal Core Design
Sponsor: Penn State
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 December 2014

Dr. Gordon Warn, Associate Professor of Civil Engineering and his students are working on research that involves seismic isolation, seismic protection of nonstructural components and high value building content, and robustness of civil infrastructure to extreme and unforeseen loading.

Title: CAREER: A performance-based multi-objective optimization framework to define innovative structural concepts and support the seismic design of critical buildings
Sponsor: NSF
Summary: Performance-based seismic design (PBSD) provides a methodology to quantify a building's design using broad performance metrics that are meaningful decision variables for stakeholders. Examples of performance metrics include post-event functionality and economic loss. However, in its current form. the PBSD process is likely to lead to a satisfactory but not necessarily optimal design solution. Furthermore, the heuristic nature of the PBSD process does not facilitate a clear understanding of the tradeoffs that are likely to exist between conflicting design objectives. This research addresses these shortcomings by developing an integrated computational framework that simultaneously identifies innovation structural concepts through topology optimization and tradeoffs between the conflicting design objectives to support decision-making using many-objective search and visual analytic techniques.
Student: Mehment Unal, Ph.D. expected August 2015

Title: Stability of Elastomeric and Lead-Rubber Seismic Isolation Bearings under Extreme Earthquake Loading
Sponsor: NSF
Summary: Laminated rubber bearings are used to protect important structures from earthquake ground shaking. Current macro-models used for the design and seismic performance assessment of base-isolated structures do not adequately account for the influence of vertical forces on the lateral stability of the individual bearings. This project seeks to identify the mechanics controlling the stability of elastomeric bearing subjected to simultaneous lateral displacement and vertical force. This insight will guide the development of a mechanistic bearing model that is both parsimonious and practical for numerical earthquake simulation. Such a model will facilitate more accurate probabilistic seismic performance assessments of base-isolated structure and allow the stability of global isolation system to be quantified thereby eliminating overly conservative bearing designs.
Student: Xing Han, Ph.D. graduated December 2013

Dr. Zoubeida Ounaies and her students are interested in developing and characterizing polymer based composites that exhibit electro-mechanical coupling for use in sensing, actuation, energy harvesting, and energy storage applications. A particular project that is ongoing relates to the processing, characterization and modeling of a flexible active fiber composite as described briefly below. Flexible active composites with superior long term performance and enhanced coupled response enable future system designs to be more controllable and reliable than is presently possible. In addition, flexible active composites are industrially relevant with broad potential applications, such as structural health monitoring, active vibration control and adaptive deployable devices.

Title: Flexible active fiber composites for vibration control
Sponsor: NSF IIMEC
Summary: The objective of this research work is to use a combination of experimental and numerical approached to examine the overall behavior of an active fiber composite (AFC) and to propose a re-design of an improved AFC device with optimized electro-mechanical coupling response. The investigation involves mechanical, electrical and electro-mechanical experiments under different loading rates and environment conditions (temperature, frequency, duration). The numerical approach is FEM-based and consists of conducting a parametric study on important design parameters. The outcome of these studies is that uncovering the physical mechanisms responsible for the time-dependent response and the cyclic loading-induced property degradation in AFCs in particular and active composites in general is key to implementing materials-based and processing-based solutions. Resolving these challenges will lead to materials ameliorations resulting in significantly transformed next-generation active composites.
Student: Hasene Ben Atitallah, Ph.D. expected December 2014

Dr. Mary Frecker and her students are pursuing a number of projects in design of adaptive structures.

Title: Multi-filed responsive origami structure: 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, Adrienne Crivaro, M.S. expected August 2014, Kevin McGough, M.S. expected May 2014, Carrie Tedesco, B.S. expected May 2014

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 wind 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: Yashwanth Tummala, Ph.D. expected December 2013, Joseph Calogero, Ph.D. expected May 2017.

Title: A Two-Materials 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. expected August 2014

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

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

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

Flow-Induced Noise

Dean Capone – Group Leader
dec5@psu.edu

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

Project Topic: Fluid-Structure Interaction (FSI) of a Flexible Strut with Strong Turbulent Upstream Vortices
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 December 2014

Project Topic: Modelling and Measurement of Turbulent Boundary Layer Unsteady 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 December 2014

Other Projects:

Title: High Cycle Fatigue Simulations and Measurements
Sponsor: Pratt & Whitney
PI(s): Dr. Philip Morris
Students: Michael Lurie, Ph.D.

Title: Adjoint Design for Low Noise
Sponsor: ONR
PI(s): Dr. Philip Morris
Students: Nidhi Sikarwar, Ph.D.

Title: Simulation of Jet Noise Reduction Devices
Sponsor: ONR
PI(s): Dr. Philip Morris
Student: Matthew Kapusta, M.S.

Title: Rotorcraft Broadband Noise Predictions
Sponsor: Bell TEXTRON Helicopter
PI(s): Dr. Kenneth Brentner, Dr. Philip Morris
Student: Abhishek Jain, M.S.

Title: Nonlinear Sound Propagation from Distributed Sources
Sponsor: None
PI(s): Dr. Philip Morris
Student: Donald Hyatt, M.S.

Title: *Modification of PSU-WOPWOP for Civil Certification Noise Prediction*
Sponsor: Bell Helicopter Textron, Inc
PI(s): Dr. Kenneth Brentner, Dr. Philip Morris
Students: Benjamin Goldman, M.S., Abhishek Jain, M.S.

Title: Vertical Lift Research Center of Excellence: *Task 3: Helicopter Icing Physics, Modeling and Detection*
Sponsor: U.S. Department of the Army
PI(s): Dr. Kenneth Brentner (ice detection by acoustic measurements portion of task)
Student: Baofeng Cheng, Ph.D. expected December 2014

Title: Vertical Lift Research Center of Excellence; Task 7: *Control Redundancy to Enhance Rotorcraft Performance, Handling Qualities, and Survivability*
Sponsor: U.S. Department of the Army
PI(s): Dr. Kenneth Brentner, Dr. Joe Horn
Students: Heather Barron, M.S., Yaowei Li M.S. expected August 2015

Title: Vertical Lift Research Center of Excellence; Task 8: *Fundamental Physics of Active Rotor Concepts for Acoustic and Performance Enhancement*
Sponsor: U.S. Department of the Army
PI(s): Dr. Kenneth Brentner
Student: Tianxiao Yang, Ph.D. expected December 2014

Title: *Modification of PSU_WOPWOP for Very Large Parallel Noise Prediction Problems*
Sponsor: NASA Langley Research Center
PI(s): Dr. Kenneth Brentner
Student: Yaowei Li, M.S. expected August 2015

Propagation and Radiation

Victor Sparrow – Group Leader
vws1@psu.edu

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

The academic year of 2013 to 2014 has been a period of growth for the Propagation and Radiation Group. We have had a few new contributors come to Penn State who have identified with the Propagation and Radiation Group.

2013–2014 has been the last year for the Federal Aviation Administration's PARTNER Center of Excellence (partner.aero). PARTNER has been a successful center for 10+ years, and it has been

Technical Group Research Highlights

Penn State's pleasure to participate in this activity. 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.

With PARTNER winding down, the FAA had a competition for its next Center of Excellence with a focus on the environmental impact of aviation. Penn State applied with some of the other PARTNER schools supplemented with additional schools with expertise in alternative jet fuels. In late 2013 an award was announced for a new FAA Center of Excellence in Alternative Jet Fuels and the Environment. Called ASCENT for Aviation Sustainability CENTer, the new Center is led by Washington State University, and Penn State is expected to be a strong contributor. Penn State is looking forward to participating in the new ASCENT Center and Dr. Victor Sparrow is pleased to serve as Penn State's PI for this new effort.

In July 2013, Dr. Peter Newman began serving as the new Head of the Department of Recreation, Park, and Tourism Management in the College of Human Development. Dr. Newman comes to us from Colorado State University, and he is internationally known for his work on understanding the soundscape of parks, and how to improve acoustic management in parks. We welcome Peter to Penn State, and we look forward to participating in collaborative projects on noise.

Dr. Michelle Vigeant, Assistant Professor of Acoustics and Architectural Engineering, has been active in setting up her research program since coming to Penn State in 2012. She has successfully established the new SPRAL lab, standing for Sound Perception and Room Acoustics Laboratory. Initially funded through her 5-year National Science Foundation Early CAREER Award, Dr. Vigeant has also garnered new support from FAA to understand the impacts of aviation noise on children's learning. She has also started work in the area of emotional response to room acoustics stimuli with varying reverberation times using functional neuroimaging (functional magnetic resonance imaging). Dr. Vigeant is now working with a number of new graduate students, including David Dick, Matt Kamrath, Martin Lawless, and Matthew Neal. We welcome all of these students to Penn State and the Center for Acoustics and Vibration.

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

Current Students:

Beom Soo Kim, Ph.D. expected fall 2014
Thesis Topic: Low frequency noise of aircraft noise transmission from outdoors to indoors
Sponsor: FAA
Advisor: Dr. Victor Sparrow

Amanda Lind, M.S. spring 2011, Ph.D. expected summer 2015
Thesis Topic: Diffraction effects for predicting the impact of low-boom sonic booms around buildings
Sponsor: FAA
Advisor: Dr. Victor Sparrow

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

Rachel Romond, Ph.D. expected summer 2015
Thesis Topic: Atmospheric models for subsonic aircraft noise prediction
Sponsor: FAA
Advisor: Dr. Victor 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: Dr. Michelle Vigeant

Matthew Kamrath, Research Assistant Fall 2013—Summer 2014
Research Topic: Impact of aviation noise on children's learning
Sponsor: FAA
Advisor: Dr. Michelle 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: Dr. Michelle 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: Michelle 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 the 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 (Drs. Palacios, Brentner, and Lindau), 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 performances, 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 (Profs. Kunz and Drs. Saribay and Bill), health monitoring for joints in composites structures (Profs. Lissenden and Rose), advanced response types/cueing systems for navel 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 navel-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 simulations, 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.

Technical Group Research Highlights

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 2013-2014, 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 47th consecutive year on August 11-15. Topics in the comprehensive course include rotorcraft aerodynamics, dynamics, acoustics, composite structures, flight controls and propulsion.

Current Projects:

Title: Vibration Control via Coupled Fluidic Pitch Links
Sponsor: LORD Corp
PI(s): Ed Smith, Chris Rahn
Student: Lloyd Scarborough, Ph.D. expected May 2014

Title: High Efficiency Energy Harvesting for Helicopter Airframe Vibrations
Sponsor: LORD Corp
PI(s): Ed Smith, George Lesieutre
Student: Raheel Mahmoud, M.S. expected August 2014

Title: Gearbox Noise Reduction via High Frequency F2MC Devices
Sponsor: LORD Corp
PI(s): Ed Smith, Chris Rahn
Student: Alexandre Bondeaux, M.S. expected August 2015

Title: High Fidelity CFD Analysis and Validation of Rotorcraft Gear Box Aerodynamics
Sponsor: NASA
PI(s): Rob Kunz
Student: Sean MacIntyre, Ph.D. 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

Title: Helicopter Icing Physics, Modeling and Detection
Sponsor: NRTC VLRCOE Program
PI(s): Jose Palacios, Ken Brentner, Jay Lindau

Title: Durability Evaluation of Single Crystal Energy Harvester
Sponsor: NRTC Vertical Lift Consortium
PI(s): Steve Conlon, Ed Smith, Karl Reichard
Student: Michael Wozniak, M.S. May 2013

Title: Development of nanoparticle-Enhanced Towpreg for Filament Wound Composites
Sponsor: NASA
PI(s): Chuck Bakis
Student: Todd Henry Ph.D. candidate

Title: Centrifugally Powered Pneumatic Deicing for Helicopter Rotors
Sponsor: NASA
PI(s): Jose Palacios, Doug Wolfe

Title: Modeling of Rotor Blade Ultrasonic Deicing and Experimental Comparison with Electrothermal Ice Protection System
Sponsor: NRTC Vertical Lift Consortium
PI(s): Jose Palacios, Ed Smith
Student: Austin Overmeyer, M.S. candidate

Title: Civil Certification Noise Prediction Tools
Sponsor: Bell Helicopter
PI(s): Ken Brentner

Title: Analysis of Rotor Startup/Shutdown in Complex Winds
Sponsor: Bell Helicopter TEXTRON
PI(s): Ed Smith, Rob Kunz, Jianhaua Zhang

Title: Alternate Control Laws for Fly-by-Wire Helicopters
Sponsor: Bell Helicopter
PI(s): Joe Horn
Student: Michael Spires Ph.D. candidate

Title: Tailboom Vibration Control via F2MC Devices
Sponsor: Bell Helicopter TEXTRON
PI(s): Chis Rahn, Ed Smith
Students: Kentaro Miura, Ph.D. candidate,, Matt Krott, M,S. candidate

Title: Fundamental Physics of Active Rotor Concepts for Acoustics and Performance Enhancement
Sponsor: NRTC VLRCOE
PI(s): Ken Brentner, Mark Maughmer, Sven Schmitz
Students: Frank Kody, Tenzin Choephel, Tianxiao Yang, Ph.D. candidates

Title: Rotorcraft Airfoil Design for Unsteady Aerodynamics
Sponsor: NRTC VLRCOE
PI(s): Mark Maughmer
Student: Bernardo Vieira, Ph.D. candidate

Title: Tailored Wing Extensions and Winglets for Large Civil Tiltrotors
Sponsor: NRTC VLRCOE
PI(s): Ed Smith, Mark Maughmer
Students: Same Johnson, M.S. 2014, Willie Costa, Sandilya Kambampati, Julia Cole, Ph.D. candidates

Title: Innovative Method for Real-Time Damage Alleviation
Sponsor: US Navy NAVY SBIR—subcontract to Technical Data Analysis, Inc.
PI(s): Joe Horn

Title: Advanced Response Types and Cueing Systems for Naval Operations
Sponsor: NRTC VLRCOE
PI: Joe Horn

Title: Autonomous Multi-Lift Systems
Sponsor: NRTC VLRCOE
PI(s): Joe Horn, Jack Langelaan

Title: Flight Test Measurement of Airwake Disturbances for Validation of Virtual Dynamic Interface Simulations
Sponsor: ONR
PI: Joe Horn

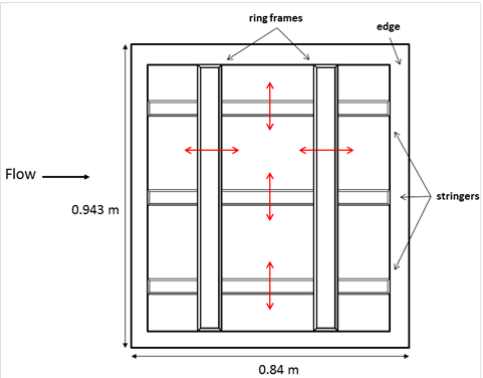
Title: Pilot-in-the-Loop
Sponsor: ONR
PI: Joe Horn

Structural Vibration and Acoustics

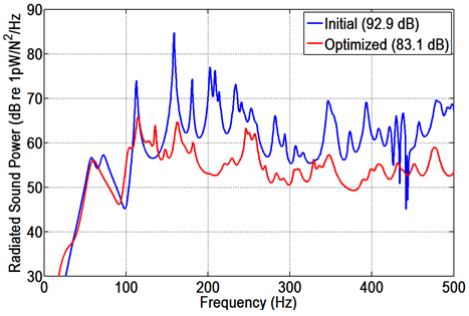
Steve Hambric, - Group Leader
sah19@psu.edu

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.

One of our students, Micah Shepherd, just completed his Ph.D. in Acoustics with a thesis on optimizing TBL– excited structures to minimize vibration and radiated sound. In the example below, Micah used a global optimization procedure to shift a stiffened aircraft panel's ring



Technical Group Research Highlights



frames and stringers, as well as choose from several cross-section possibilities, to reduce radiated sound by nearly 10 dB.

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

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

Title: High speed structural-acoustics computing
Sponsor: ONR
PI(s): Dean Capone, Rob Campbell, John Fahnline

Title: Large journal bearing modeling and measurements
Sponsor: NAVSEA PMS 397
PI(s): Rob Campbell

Title: Offshore wind turbine flow-induced vibration and structural integrity
Sponsor: DoE
PI(s): Rob Campbell (part of interdisciplinary PSU team)
Student: Javier Motta-Mena, M.S. candidate

Title: Fluid Structure Interaction Modeling of Blood Clot Migration and Entrapment in the Inferior Vena Cava
Sponsor: ARL Walker Fellowship
PI(s): Robe Campbell, Brent Craven
Student: Ken Aycock, Ph.D. candidate

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

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

Title: Acoustics Black Holes
Sponsor: ARL Walker Fellowship
PI(s): Steve Conlon
Student: Phil Feurtado, Ph.D. candidate

Title: Airframe Active Vibration-Based Damage Detection and Localization
Sponsor: PSU Aerospace Engineering/VLRCOE
PI(s): Steve Conlon
Student: Justin Long, M.S. candidate

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

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

Title: Development of Acoustically Tailored Composite Rotorcraft Fuselage Panels
Sponsor: NASA
PI(s): Steve Hambric, Kevin Koudela, Ed Smith

Title: Advanced Material Propulsor
Sponsor: ONR
PI(s): Kevin Koudela

Title: Hybrid Multi Material Propulsor
Sponsor: DARPA
PI(s): Keven Koudela

Title: Optimization of TBL-Excited Ribbed Aircraft panels to minimize sound radiation
Sponsor: NASA
PI(s): Steve Hambric
Student: Micah Shepherd, Ph.D. May 2014

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

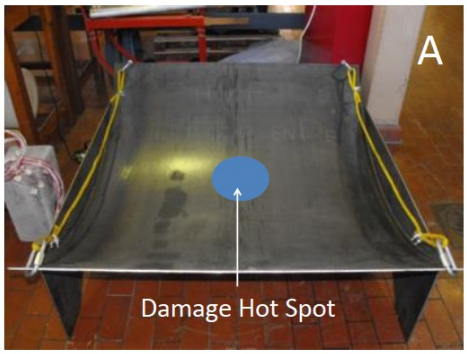
Title: Acoustic scattering and target physics of multi-layered finite cylindrical shells in water
Sponsor: NUWC/ONR
PI(s): Sabih Hayek, J.E. Boisvert

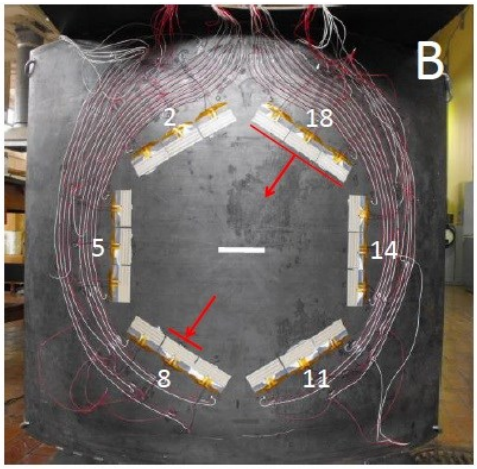
Systems and Structures Health Management Technical Group

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.

Ultrasonic Guided Waves for Structural Health Monitoring
Sponsors: Nuclear Energy University Program (DoE), National Science Foundation (CNNI), Vertical Lift Research Center of Excellence (Army, Navy, NASA)
PI(s): Cliff Lissenden, Lissenden@psu.edu; Joseph Rose, jlr9@psu.edu
Graduate Students: Yang Liu, Vamshi chillara, Baiyang Ren, Gloria Choi, Xiachu, Frank Yao, Aaron Lesky, Hwanjeong Cho, Mostafa Hasanian, Devren Yener
Undergraduate Students: Stephen Williamson,

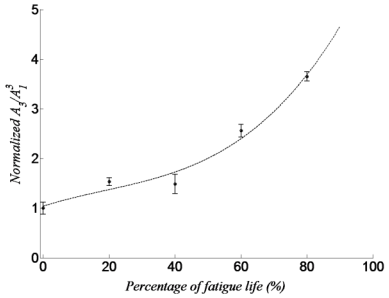




Kyle Salitrik, Clayton Dickerson

A project entitled, **"Continuous piezoelectric health monitoring systems based on ultrasonic guided waves,"** sponsored by the Sensors and Sensing Systems program of NSF has been completed. Strip transducers were developed and

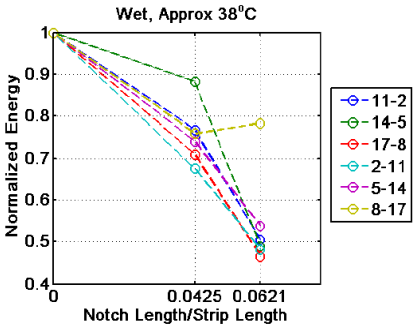
Technical Group Research Highlights



shown to detect damage in a steel shell structures. See Figure 1.

Figure 1. (above and top of next page) Instrumented steel mockup structure in which damage was artificially induced. The through-transmission signals exhibited a decrease in normalized energy that was related to the damage accumulation.

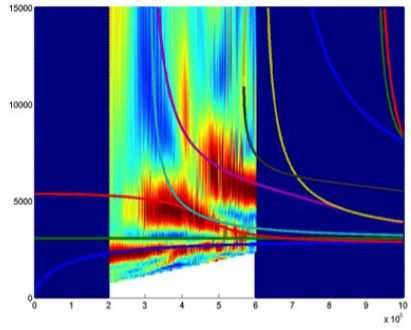
Projects entitled "**Monitoring microstructural evolution of Alloy 617 with nonlinear acoustics for remaining useful life prediction: multi-axial creep-fatigue and creep-ratcheting, "** and **"High temperature transducers for online monitoring of microstructure evolution,"** sponsored by the Nuclear Energy University Program are ongoing. Both of these projects are aimed at condition monitoring of stationary components in nuclear power plants and focus on the earliest characterization of damage. In the second project on-line monitoring in high-temperature environments is investi-

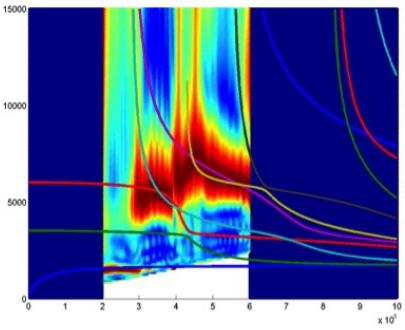


gated. Higher harmonic generation is being correlated with the early stages of material degradation to provide a basis for condition based maintenance. Figure 2 shows the increase in the third harmonic shear horizontal wave mode due to increasing fatigue cycles in an aluminum plate. Note that no cracks are visible prior to failure in these load-controlled experiments.

Figure 2. Third harmonic amplitude increases in aluminum plated due to unseen fatigue damage.

The project **"Health monitoring methods for joints in rotorcraft composite structures,"** is sponsored by the Vertical Lift Research Center of Excellence. In this project we are researching and developing stay-in-place phased array transducers for monitoring the structural integ-





rity of bonded joints. We have researched, designed, and fabricated transducers 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 as shown in Figure 3. The transducers provide capabilities to identify modes and mode conversion that did not exist previously.

Figure 3. Comparison between theoretically predicted and blindly scanned dispersion curves for 5-mm aluminum (above) and 3.2 mm CFRP (below) plates.

"**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 we can have harmonics generated by mode mixing (mutual interaction between two primary modes). Preliminary results indicate that harmonics occur at sum and difference frequencies of carefully selected guided wave modes.

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

Lissenden, C.J., Y. Liu, G. Choi, X. Yao, 2014 "Effect of localized microstructure evolution on higher harmonic generation of guided waves," *J. NDE*, DOI 10.1007/s10921-014-0226-z.

Liu, Y., V.K. Chillara, C.J. Lissenden, J.L. Rose, 2013, "Cubic nonlinear shear horizontal and Rayleigh Lamb waves in weakly nonlinear plates," *J. Appli. Phys.* Vol. 114:114908.

Kannajosyula, H., C.J. Lissenden, and J.L. Rose, 2013, "Analysis of annular phased array transducers for ultrasonic guided wave mode control," *Smart Materials and Structures*, Vol. 22, 085019 (44pp).

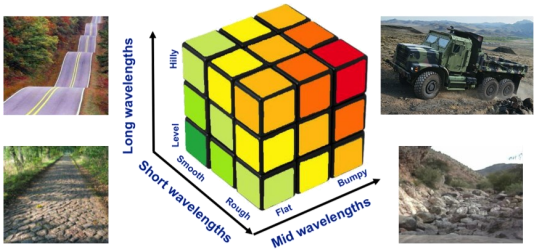
Soorgee, M.H., C.J. Lissenden, J.L. Rose, A. Yousefi-Koma, 2014, "Defect sensitivity of piezoelectric strip transducers based on planar Lamb waves," *J. Intell. Mat. Struct. Sys.*, Vol. 25(4), pp. 472-483.

Ren, B., C.J. Lissenden, 2013, "Ultrasonic guided wave inspection of adhesive bonds between composite laminates," *Int., J. Adhesives and Adherends,* Vol. 45:59-68.

Puthillath, P., B. Ren, J.M. Galan, C.J. Lissenden, and J.L. Rose, 2013 "Ultrasonic guided wave propagation across waveguide transitions: energy transfer and mode conversion," *J. Acoustic Soc. Am.* 133(5):2624-2633

Title: Terrain classification for condition based maintenance
Sponsor: US Army TACOM
PI(s): Karl Reichard, Jeffrey Banks
Student: R. Tory Taylor

This research addresses techniques to assess fuel use and operational loads on vehicles used over varying types of terrain. Reducing the total cost of owning and operating equipment are increasing fuel efficiency and reducing maintenance costs. The United State Army Material Systems Analysis Activity (AMSAA) has developed an algorithm for terrain classification called Terrain Regime Identification and Classification, or the TRIC for short. The algorithm classifies the harshness of the vehicle's operating conditions based on the roughness (z-axis motion), bumpiness (magnitudes of vehicle pitch and roll), steepness of the terrain and vehicle's speed as illustrated in Figure 4. This will contribute to maintenance prediction algorithms, as rates of damage to the various sub-

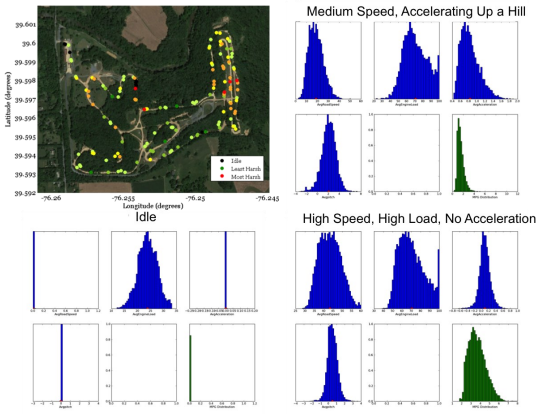


systems of the vehicle are correlated to the harshness of terrain traversed. The spectra from a z-axis accelerometer mounted in the body of the vehicle has been compared to the spectra from a z-axis accelerometer mounted on the axle of the vehicle to see if the same information regarding the roughness can be extracted in both cases, or if a translation model can be devel-

Technical Group Research Highlights

oped to produce comparable results.

Figure 4. Concept of terrain classification based on feature wavelengths.



The TRIC algorithm has been reproduced in MATLAB to see what additional information and uses can be obtained. The classifications from TRIC were compared to mode classifications previously developed by the Applied Research Laboratory (ARL) at Penn State based on vehicle operating data such as engine speed, vehicle speed and accelerator position. Color-coded classifications overlaid on maps of the test course show operating modes as a function of the vehicle's path. This overlay technique is also useful for comparing vehicle mode classification to terrain classification.

Figure 5. Terrain classification based on vehicle operating parameters.

It is also being examined how vehicle size affects the TRIC algorithm—current algorithms have been tailored or calibrated for particular vehicles. A process is being developed to convert the data recorded in the time domain into the distance domain to obtain the wavenumber spectra. Once the wavenumber spectrum is obtained for the data of vehicles of different wheelbase sizes on the same courses, it can be determined how the vehicles experience bumpiness differently.

Title: Update on Development of an Optical Fiber Pressure Sensor for Nuclear Power Plant Monitoring Applications
Sponsor: EPRI
PI(s): Mark Turner, Karl Reichard

The goal of this project is the development of a pressure sensor for nuclear power plant applications based on optical fiber Bragg grating sensors as reported in last year's CAV Review. An average nuclear power plant 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. During the past year, this sensor underwent environmental, vibration, and radiation exposure testing to validate performance under normal operating range and accident conditions. Sensor performance proved satisfactory. The next phase of the project will see the temporary installations of the sensor in one of two working power plants.

Underwater Acoustics and Instrumentation Technical Group

Dave Bradley, - Group Leader
dlb25@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 and radiated noise often involve large scale multi-vessel ocean acoustic experiments or measurements on instrumented acoustic ranges, while projects in Marine Bioacoustics may involve measurements of marine mammals and fish habitats using a few hydrophones over periods of weeks or months. Date acquired during field measurements are analyzed and incorporated into theoretical investigations, parametric studies and computational models. Acoustical Oceanography studies use acoustic data to determine physical propertied of the ocean environment. Applied research efforts include characterizing the performance of underwater acoustic systems, design and development of transducers and application of signal processing techniques.

Current Project:

Title: Wind-Dependence of Very Low Frequency Ambient Noise in the Deep Ocean Sound Channel
Sponsor: ONR
Summary: Nonlinear interactions of wind generated surface waves produce high amplitude noise at very low frequencies (below 5 Hz) which propagate to great depths with little attenuation. According to theory, the noise produced by this mechanism exhibits a characteristic frequency (or

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MARK YOUR CALENDARS

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

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

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

Penn State CAV members are helping to organize next year's Noise and Vibration Emerging Methods (NOVEM) conference, to be held 12-15 April 2015 in Dubrovnik, Croatia. Dubrovnik is a medieval resort town on the Adriatic Sea. Held every three or four years, this will be the fifth NOVEM. The conferences focus on the latest measurement and simulation methodologies, have no more than two parallel sessions, and include interactive discussion forums with expert speakers and the conference attendees. Abstracts are due 17 October 2014. Papers are due 17 January 2015.

For more information please visit novem2015.sciencesconf.org send your questions to novem-2015@sciencesconf.org.

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