

Schools of Mechanical and  
Civil Engineering

**Purdue University**

## RAY W. HERRICK LABORATORIES

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# 2014-2015 ANNUAL REPORT

FALL 2015



## THE RAY W. HERRICK LABORATORIES

The Ray W. Herrick Laboratories were founded in the mid-1950's as a research laboratory for studying the effects of climate control and for the design of improved climate control equipment. Today the research is related to a much broader range of applications including transportation, engines, and information technology. The Labs have grown and evolved into a center where graduate education and engineering research are combined in close partnership with industry in order to develop people and results of great importance. The Herrick Labs goal is to sustain a culture of excellence in an environment of partnership and shared resources.

The research programs of the Herrick Labs can be described in four general areas; electro-mechanical systems, noise and vibration control, perception based engineering, and thermal systems. It is also home to the Center for High Performance Buildings, which spans several of these areas. The community at the Herrick Labs, which includes the faculty, staff, students, and sponsors, is focused on results that are both fundamental research discoveries and of practical importance to sponsors.

The educational experience at the Herrick Labs combines the traditional training of aspiring researchers with exposure to industrial needs and culture. Students study in a strong peer education environment with active mentoring from faculty and sponsors. Over 900 Masters and PhD candidates have graduated from the Herrick Labs.

The engagement/service programs are highlighted by the well-established conference and short course activity sponsored by the Herrick Labs. In addition, technology transfer to sponsors is an integral part of a majority of the research programs. The researchers at the Herrick Labs are also widely published across the spectrum of publications from academic journals to the popular press. They are also very involved in their technical organizations taking on leadership and service roles.

### MISSION

The Ray W. Herrick Laboratories is dedicated to engineering research and knowledge transfer with an emphasis on preparing students to be leaders well qualified to develop technologies to address societal needs.

#### VISION

Recognized worldwide as the place to go when expertise is needed in thermal systems, high performance buildings, vibration and noise control, perception-based engineering, integrated powertrain engineering, and applied dynamical and electro-mechanical systems.

#### GOALS

1. Grow educational outreach activities, including fundamental, applied, and experimental short courses.
2. Build on research excellence of following research areas: Noise and vibration control, integrated thermal and power systems, and the built environment.
3. Provide the educational environment of the labs so that its graduate students are multi-disciplinary engineers who rate as the top engineering graduates in the country.
4. To recognize and promote the value of Herrick through effective brand management (internally and externally).
5. Maximize utilization of the new facilities (PBE, engine test, geothermal, etc.)
6. Continue recruiting top faculty, grad students, and staff to ensure long term stability and growth. Maintain world-class facilities.
7. Become a more multi- and inter-disciplinary laboratory by inviting researchers from additional departments across Purdue to become involved in research at Herrick.
8. Develop a testing program to support staff and infrastructure.

# 2014-2015 HIGHLIGHTS

## Research

	Last Year	This Year
Research expenditures HERL only (*academic year)	\$5,314,919	\$5,458,682
Proposals Pending	\$7,730,116	\$5,576,810
Building Expenditures (NIST & Gifts)	\$1,414,265	
Number of sponsors as of September 2015	48	39
Research assistants as of September 2015	48	60
Archival papers published (*calendar year)	75	83
Contracts in force for next academic year (July 2015-June 2016)	\$3,343,517	\$3,340,576

## Education

Graduate students as of September 2015	93	91
MS	44	37
Ph.D.	49	54
Students graduated (*calendar year)	28	25
MS	20	16
Ph.D.	8	9
Undergraduate/graduate "research experience" students	10	29
Visiting scholars, Post Doctoral Scholars		
Visiting Research Assistants	23	22
Fellowships	6	7
Grant-in-Aid	4	2
Student Paper/Poster/Thesis Awards	6	4

## Technology Transfer

Conferences/Workshops held (*academic year)	7	2
Conferences planned in the next 2 years (July 2015 - July 2017)	3	3
Short Courses held (*academic year)	3	1
Herrick Labs reports to sponsors (*academic year)	8	13
Conference and journal papers (*calendar year)	175	189

\*Academic Year - August 2014 → August 2015

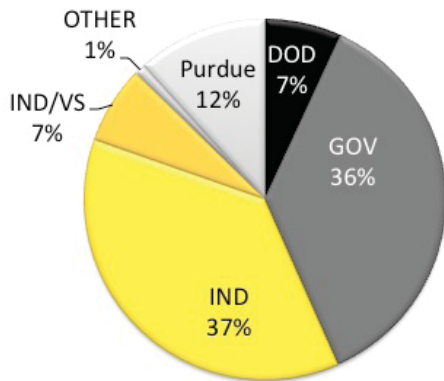
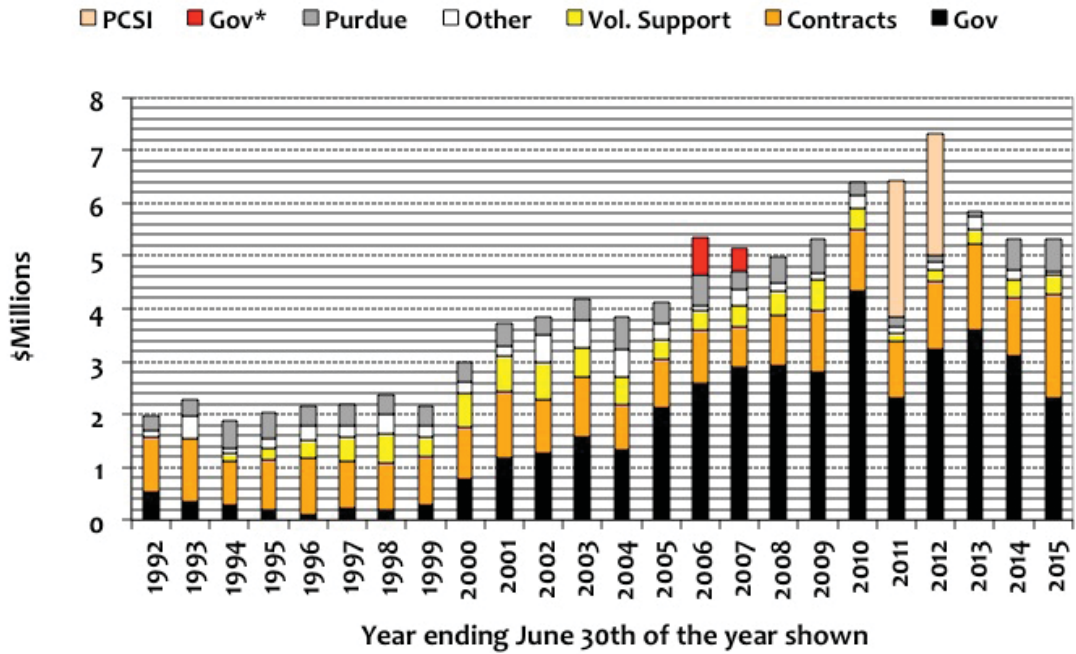
\*Calendar Year - January 2014 → December 2014

## Administrative and Support Staff

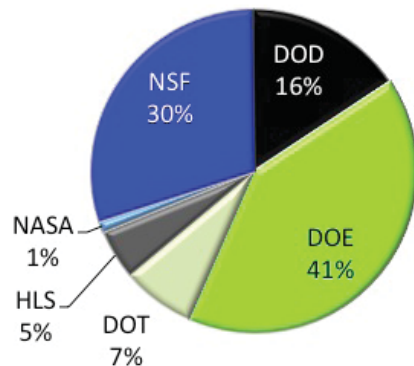
Professor Patricia Davies is the director of the Ray W. Herrick Laboratories. Donna Cackley is her administrative assistant and Cindy Cory is the Herrick secretary. Kim Stockment serves as administrative assistant for the Herrick Laboratories' conference and short course activities. Orkan Kurtulus, Research Scientist has been coordinating the new building technology, working with the construction company, commissioning agents, vendors and Herrick faculty and students on commissioning and training. The research programs are assisted by the mechanical and electronics shops: Ron Evans, technical services supervisor; Bob Brown, mechanical shop coordinator and building deputy; Frankie Lee, mechanical technician; and David Meyer, engine test cell technician. Computer support is provided by Mechanical Engineering, Mike Logan and the Engineering Computer Network, Paul Niles. Business Office support is provided by the Mechanical Engineering Business Office.

## 2014-2015 EXPENDITURES

Shown below is the distribution of research expenditures from July 1992 to June 2015

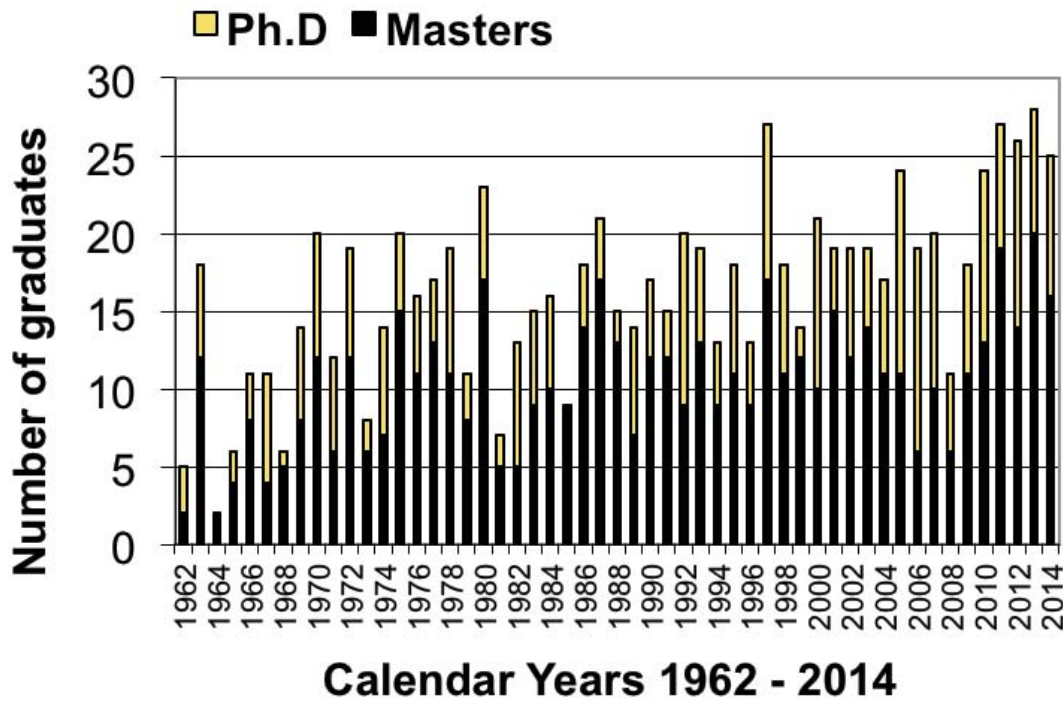


### Government & DOD Funding



# HERRICK LABS EDUCATION PROGRAMS

The primary educational program at the Herrick Labs is thesis based graduate education. We believe that the experiential learning, the open-ended and integrative nature of thesis based research is outstanding preparation for both academic and industrial careers. To complement the student/advisor relationship, the Labs offer a learning community to the student. This community includes an outstanding cohort of graduate students as well as a staff prepared to support and teach. In many cases, the student's research is sponsored. Sponsor representatives also participate in educational activities with the student. We also have programs where graduate students do internships in industry or government laboratories. In total we believe this is an outstanding educational opportunity for our graduate students.



**Fellowships**

- Cody Allen received the Perry Graduate Fellowship
- Chun Chen received the Winifred Beatrice Bilsland Dissertation Fellowship
- Dheeraj Gosala received the Ross Fellowship
- Nelson James received the Laura Winkelman Davidson Fellowship
- Daniel McArthur received the Laura Winkelman Davidson Fellowship
- Joseph Seymour received the Dr. William and Gail Cordier Graduate Fellowship
- Brandon Woodland received the James V. Stack Fellowship
- Yangfan Liu received the Lambert Fellowship

**Grants-in-Aid**

- Ruoyu You and Haojie Wang received the ASHRAE Grad Student Grant-in-Aid

**Awards**

- Nikhil Bajaj received the Estus H. & Vashti L. Magoon Award for Excellence in Teaching
- Udbhau Bhattiprolu received the Graduate School Summer Research Grant
- Nicholas Czapla received the Helen & John Lozar Graduate Assistantship
- Raghav Ramachandran received the Helen & John Lozar Graduate Assistantship
- Bao Tong and Yangfan Liu received Student Paper Awards at Noise-Con 2014
- Daniel Woods received the Classic Paper in Noise Control Engineering Award at the NoiseCon 2014
- Rui Cao received the Korean Society of Noise and Vibration Engineering/Hyundai Motor Company prize for automotive-themed paper At Internoise 2015. He also received first place award in the student paper competition at the SAE Conference.
- Amir Sadeghi received a Best Paper Award at 3rd International High Performance Buildings Conference
- Harshad Inamdar received the Magoon Award

## HERRICK LABS FACULTY RESEARCH INTERESTS

- Andres Arrieta**, Assistant Professor of Mechanical Engineering. PhD 2010, University of Bristol, United Kingdom. Adaptive structures, nonlinear vibrations, multi-stable structures, shape programmable adaptable matter, nonlinear metamaterials, dynamics of smart material systems, morphing of compliant structures, structural nonlinearity, and elastic instability.
- Anil K. Bajaj**, Head and Professor of Mechanical Engineering. PhD 1981, University of Minnesota. Nonlinear oscillations in structures, chaotic dynamics, stability analysis, flow-induced vibrations, perturbation techniques, mistuned structures, and localization of modes, drum and disk brake squeal-friction induced vibrations, modeling of carseat-occupant dynamics, and modeling/identification of polyurethane foam properties.
- J. Stuart Bolton**, Professor of Mechanical Engineering. PhD 1984, University of Southampton. Acoustics, models of porous noise control materials, optimal design of noise control materials and treatments, physical properties of noise control materials, microperforated noise control materials, analysis of tire vibration and sound radiation, fan noise control, nearfield acoustical holography, visualization of motor vehicle passby sound radiation, and machinery noise source identification.
- Brandon E. Boor**, Assistant Professor of Civil Engineering, (by courtesy) Mechanical Engineering, Herrick Labs. Indoor air quality, urban air pollution, ventilation and filtration strategies for low-energy buildings, aerosol science, bioaerosols (fungi, bacteria, pollen, viruses), airborne nanoparticles, particle resuspension, new particle formation, infiltration of outdoor air pollutants into residences, human exposure assessment, health effects of air pollution, air quality in occupational workplaces, air quality monitoring for communities with low-cost sensors, volatile organic compound (VOC) and semi-VOC (SVOC) emissions from building materials, furnishings, and consumer products.
- James E. Braun**, Herrick Professor of Mechanical Engineering. PhD 1988, University of Wisconsin. Thermal systems measurements, modeling, analysis, design optimization, and control optimization with applications to high performance building systems, advanced HVAC&R equipment and small-scale power production.
- David Cappelleri**, Assistant Professor of Mechanical Engineering. PhD 2008, University of Pennsylvania. Multi-scale robotic manipulation and assembly; mobile micro/nano robotics, micro/nano aerial vehicles, micro-bio robotics, mechatronics, MEMS/NEMS, and automation for the life sciences.
- Jun Chen**, Associate Professor of Mechanical Engineering. PhD 2004, Johns Hopkins University. Experimental fluid dynamics; development of flow diagnostic techniques; flow dynamics in stratified environment; and turbulent flow measurements and modeling.
- Qingyan (Yan) Chen**, Reilly Professor of Mechanical Engineering. PhD 1988, Delft University of Technology. Indoor and outdoor airflow modeling by computational fluid dynamics and measurements, protection of buildings from chemical/biological warfare attacks, building ventilation systems, indoor air quality, airline cabin environment.
- George T.-C. Chiu**, Professor of Mechanical Engineering. PhD 1994, University of California at Berkeley. Mechatronics, modeling/control of digital imaging and printing systems, functional printing and digital fabrication, motion and vibration control and perception, and embedded system design.
- Patricia Davies**, Professor of Mechanical Engineering, Director of the Ray W. Herrick Laboratories. PhD 1985, University of Southampton. Signal processing and data analysis applied to mechanical systems, condition monitoring, vibration measurement, sound quality and perception-based engineering, nonlinear system identification, modeling of car seat-occupant dynamics and modeling and identification of foam properties.
- James M. Gibert**, Assistant Professor of Mechanical Engineering, PHD 2009. Dynamic modeling of nonlinear systems, modeling of manufacturing systems, dynamics of closed and open cell foam packaging system, energy harvesting systems, vibrations and rolling resistance of non-pneumatic tires, ultrasonic additive manufacturing and optimization of mechanical systems.



# HERRICK LABS FACULTY RESEARCH INTERESTS

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*The Ray W. Herrick Laboratories*

**Eckhard A. Groll**, Professor of Mechanical Engineering. Director of Office of Professional Practice. PhD 1994, University of Hannover, Germany. Thermal sciences as applied to advanced HVAC&R systems, components, and working fluids: compressor research, alternative refrigeration technologies, vapor compression systems, and components, natural refrigerants, heat exchangers analysis, and Organic Rankine Cycle analysis.

**W. Travis Horton**, Assistant Professor of Civil Engineering. PhD 2002, Purdue University. Thermal sciences and energy conversion systems, including heating, air conditioning, refrigeration, and electrical systems; combined heat and power systems, and building energy modeling techniques.

**Neera Jain**, Assistant Professor of Mechanical Engineering, PhD 2013, University of Illinois at Urbana-Champaign. Dynamic modeling and optimal control of integrated energy systems (IES) for the purpose of more efficiently and effectively meeting society's energy needs. IESs typically span multiple energy domains: thermal, electrical, mechanical, and chemical. Use the thermodynamics-based approaches for designing

**Panagiota Karava**, Associate Professor of Civil Engineering. PhD 2008, Concordia University. Mixed-Mode Buildings, Building-Integrated Solar Energy Systems, Buildings Systems Modeling and Identification, Model-Predictive Control, Human-Building Interactions.

**Charles M. Krousgrill**, Professor of Mechanical Engineering. PhD 1980, California Institute of Technology. Non-linear oscillation, elastic stability, dynamics, vibrations, rotor dynamics, chaos, automotive brake squeal/vibration, and vibration in gearing systems.

**Kai Ming Li**, Professor of Mechanical Engineering. PhD 1987, University of Cambridge, UK. Environmental acoustics, sound propagation outdoors, noise control in built environments, monitoring of natural and human produced sounds in the environment, computational acoustics, physical acoustics and wave propagation in a complex medium.

**Peter H. Meckl**, Professor of Mechanical Engineering. PhD 1988, Massachusetts Institute of Technology. Motion and vibration control of high-performance machines, adaptive control, virtual sensing, and diagnostics. Applications to manufacturing devices, robotics, and automotive engines.

**Ming Qu**, Associate Professor of Civil Engineering. PhD 2008, Carnegie Mellon University. Development & application of energy efficient technologies in buildings, solar cooling & heating systems, building energy supply systems, sustainable building design & analysis.

**Jeff Rhoads**, Associate Professor of Mechanical Engineering. PhD 2007, Michigan State University. Nonlinear dynamics and vibration of macro-, micro-, and nanomechanical systems, micro- and nanoelectromechanical sensor design, mechanical and electromechanical amplifiers, parametrically-excited systems, mechanical and electromechanical radio-frequency (RF) components, system dynamics.

**Fabio Semperlotti**, Assistant Professor of Mechanical Engineering. PhD 2009, Pennsylvania State University. Structural health monitoring, structural dynamics, smart and adaptive structures, wave propagation, metamaterials, and energy harvesting.

**Gregory Shaver**, Associate Professor of Mechanical Engineering. PhD 2005, Stanford University. Modeling, design and control of advanced powertrains for the purpose of developing clean, efficient and practical approaches to utilizing conventional and alternative fuels. Coordination of conventional and advanced combustion process with variable valve actuation (VVA) aftertreatment systems and hybrid powertrains.

**Thanos (Athanasios) Tzempelikos**, Associate Professor of Civil Engineering. PhD 2005, Concordia University. Design of energy-efficient buildings, indoor environment, dynamic facades, lighting controls, integration of green and renewable technologies, solar energy applications, building energy modeling & simulation.

**Bin Yao**, Professor of Mechanical Engineering. PhD 1996, University of California at Berkeley. Coordinated control of intelligent and high performance electro-mechanical/hydraulic systems; mechatronics; robotics; automotive control; optimal adaptive/robust controls; nonlinear observer design and neural networks for virtual sensing, modeling, fault detection, diagnostics, and adaptive fault-tolerant control; data fusion.



# HERRICK FACULTY PROFESSIONAL ACTIVITIES

## **Andres Arrieta**

Member: ASME Energy Harvesting Technical Committee and ASME Active and Multi-functional Materials Technical Committee

## **Anil Bajaj**

Contributing Editor, Nonlinear Dynamics Journal

## **Stuart Bolton**

Advisory Board Member, Noise Control Engineering Journal; Institute of Noise Control Engineering – Member Board of Directors; Institute of Noise Control Engineering – InterNoise 2015 – INCE/KSNVE Liaison

## **Brandon E. Boor**

Member: American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE), 2008-Present, International Society of Indoor Air Quality & Climate (ISIAQ), 2010-Present, American Association for Aerosol Research (AAAR), 2010-Present, International Society of Exposure Science (ISES), 2012-Present, and Nordic Society for Aerosol Research (NOSA), 2014-Present

## **Jim Braun**

Editorial Board, Journal of Building Performance Simulation and Building Simulation: An International Journal; Chairman, 2016 International Refrigeration and Air Conditioning Conference, Purdue University

## **David Cappelleri**

Member, IEEE Robotics & Automation Society Technical Committee on Micro/Nano Robotics and Automation; IEEE Robotics & Automation Technical Committee on Mechanisms and Design; ASME Design Engineering Division Mechanisms and Robotics Committee; and ASME Design Engineering Division Micro and Nanosystems Technical Committee; Steering Committee, IEEE International Conference on Manipulation, Automation, and Robotics at Small Scales (MARSS) 2015-Present; Associate Editor, Journal of Micro-Bio Robotics, 2012-present; IEEE Robotics & Automation Letters (RA-L), 2015-Present; and IEEE International Conference on Robotics and Automation (ICRA), 2013, 2015 Chair, Tutorials/Workshop, ASME Inter. Design Engineering Technical Conferences & Computers and Information in Engineering Conference, 2014, 2015 Co-Organizer, IEEE RAS MNRA Mobile Microrobotics Challenge, 2013-present; Symposium Organizer, ASME International Design Engineering Technical Conferences, Micro and Nano Systems Conferences, Micro and Nano- Mechanisms and Robotics, 2010-present Special Sessions Chair, 12th IEEE Conference on Automation Science and Engineering, 2016; Program Chair, 10th Inter. Conference of Micro- and Nanosystems, ASME Inter. Design Engineering Technical Conferences, 2016.

## **Jun Chen**

Co-Chair, Forum on Fluid Measurement and Instrumentation, ASME 2014 Fluids Engineering Summer Meeting, August, 2014 and Forum on Fluid Measurement and Instrumentation, ASME 2011 Fluids Engineering Summer Meeting, August, 2011; Article Review: Applied Acoustics, Building and Environment, IEEE Transactions on Instrumentation and Measurement, International Journal for Computation Methods in Engineering Science & Mechanics, Journal of Fluid Mechanics, Journal of Fluids Engineering, Journal of Thermophysics and Heat Transfer, Journal of Applied Fluid Mechanics, Experimental Thermal and Fluid Science, Journal of Turbulence, International Journal of Multiphase Flow

## **Qingyan (Yan) Chen**

Consultant, The Canaan Company, 2012; Editor-in-Chief, Building and Environment (BAE) Journal; Member, Advisory Board, Energy and Buildings; Departmental Academic Advisor, Department of Building Services, Hong Kong Polytechnic University; Engineering Panel Member for Research Assessment Exercise, Hong Kong University Grant Council, 2014; Scientific Advisory Board Member, E.ON Engineering Research Center, RWTH Aachen University; Editorial Board Member, Journal “Sustainable Cities and Society”

## **George Chiu**

Fellow: Society for Imaging Science and Technology (IS&T); American Society of Mechanical Engineers (ASME); Editorial Board, Frontiers of Mechanical Engineering, 2008-Present; Program Chair, 2016 American Control Conference, Boston, MA, June; Editor-in-Chief Elect, IEEE/ASME Transactions on Mechatronics; 2016 Chair, Executive Committee, ASME Dynamic Systems and Control Division, 2013-2014; Member Editorial Board, Frontiers of Mechanical Engineering, 2008-Present; Executive Committee, ASME Dynamic Systems and Control Division, 2010-2015; Editor: Journal of Imaging Science and Technology, 2012-2014; Associate Editor, Journal of Control Engineering Practice, 2007-2014

## **Patricia Davies**

Fellow: Institute of Noise Control Engineering (INCE); Member: INCE Executive & Membership Committee, Acoustical Society of America (ASA); Planning Committee for InterNoise 2018, Chicago; Conference Co-General Chair, Fall 2014 Meeting of the ASA, Indianapolis, October 27-31st

## **James Gibert**

Secretary: ASME Technical Committee on Modeling, Dynamics, and Control of Adaptive Systems



**Eckhard A. Groll**

Regional Editor for the Americas: International Journal of Refrigeration; Member: Technology Council, ASHRAE, & USNC/IIR (U.S. National Committee of the Int'l Institute of Refrig.); Vice President: IIR Commission B2 "Refrigeration Equipment" and DAAD Alumni Association Board of Directors; Steering Committee Member: 17th Annual Colloquium on International Engineering Education, Providence, RI, November 7-10, 2014; General Conference Chair: 22nd Int'l Compressor Engineering Conference at Purdue, 15th Int'l Refrigeration and Air Conditioning at Purdue, and 3rd Int'l High Performance Buildings Conference at Purdue, July 14-17, 2014; Scientific Committee Member: 1st Int'l Conference on Energy and Indoor Environment for Hot Climates, Doha, Qatar, February 24-26, 2014; Inductee into 2014 Purdue Innovator Hall of Fame, 2014 DAAD Alumni Award (German Academic Exchange Service), and 2014 ASHRAE Exceptional Service Award.

**William Travis Horton**

Paper Reviewer for: International Journal of Refrigeration, Applied Energy, Energy, ASHRAE, and Renewable Energy; Secretary for TG1.Optimization, ASHRAE; Proposal Reviewer for projects related to sustainability for the USDA; Member of the United States National Commission for the International Institute of Refrigeration

**Neera Jain**

Vice Chair for Student Affairs-Operating Committee; American Control Conference 2015; Technical Program Committee, American Control Conference 2016

**Panagiota Karava**

Member: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2008-Present, International Building Performance Simulation Association (IBPSA), 2005-Present, US Building Simulation Association, 2009-Present; Organizing Committee, 2nd and 3rd Int'l High Performance Buildings Conference at Purdue University, 2012 & 2014, and ASHRAE Technical Committee 4.3, TC 6.7, and TC 4.10, 2008-present.

**Kai Ming Li**

Fellow: Acoustical Society of America and Institution of Mechanical Engineers (UK); Associate Editor: Journal of Acoustical Society of America, Applied Acoustics; Member: Membership Committee of the Acoustical Society of America; Co-Chair: American National Standards Institute (ANSI) Working Group on "Method for Determining the Acoustic Impedance of Ground Surface"

**Peter Meckl**

Finance Chair, 2013 American Control Conference; Member, ASME Dynamic Systems and Control Executive Committee, 2014; Editor, ASME Dynamic Systems and Control Magazine, 2015

**Ming Qu**

Past Chair, 2015-2016, Executive Committee, Solar Energy Division (SED) of ASME

**Jeff Rhoads**

Associate Editor: ASME Journal of Vibration and Acoustics, 2013-Present; Member: ASME Design, Materials, and Manufacturing (DMM) Segment Leadership Team, 2015-Present, ASME International Design Engineering Division Technical Committee on Sound and Vibration, 2010-Present, ASME International Design Engineering Division Micro/Nanosystems Technical Committee, 2009-Present, (Chair 2014-Present; Vice Chair & Treasurer 2013-2014; Secretary, 2012-2013); General Conference Co-Chair, 2015 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Boston, Massachusetts; Technical Program Committee, 2015 ASME Advanced Manufacturing and 3D Printing (AM3D) Conference, Boston, Massachusetts, 2015; Conference Chair, 2015 ASME International Design Engineering Technical Conferences, 27th Conference on Mechanical Vibration and Noise, Boston, Massachusetts

**Fabio Semperlotti**

Member: Program Committee of SPIE's Smart Structure/NDE Symposium, 2013-Present; ASME Technical Committee for Vibration and Sound (TCVS), 2014-2017; ASME Structural Health Monitoring Technical Committee, 2013-Present; ASCE EMI Structural Health Monitoring Technical Committee, 2014-Present

**Greg Shaver**

Associate Editor, International Journal of Engine Research and Frontiers in Engine and Automotive Research

**Thanos Tzempelikos**

Member, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); Voting Member, Vice Chair and Program Subcommittee Chair of ASHRAE Fenestration Technical committee (4.5); Member: International Building Simulation Association and International Solar Energy Society; Chairman, 1st, 2nd and 3rd International High Performance Buildings Conferences, Purdue University, 2010, 2012, 2014; Member of technical review panels for EPA, DOE, and other government-funded research proposals

**Bin Yao**

ASME Fellow, Senior Member of IEEE; Member: Editorial Board of the International Journal of Control, Automation and Systems (ICASE); Management Committee of IEEE/ASME Trans. Mechatronics, 2012-2014; Award Committee and International Advisory Committee of IEE/ASME Int. Conference on Advanced Intelligent Mechatronics, Besancon, France, July 8-11, 2014; Past Technical Editor: IEE/ASME Trans. Mechatronics

## CURRENT HERRICK LABS STUDENTS

Student	Major Professor	Thesis subject
Felipe Accorsi	Groll	ORC expander performance
Kumar Akash	Jain	Mathematical characterization of human-machine interactions
Cody Allen	Shaver	Ultra-high engine systems efficiency via flexible valve actuation
Yeonjin Bae	Horton	Optimization methodology for energy-efficient housing
Ammar Bahman	Braun/Groll/Horton	High efficiency air conditioning systems for hot climate regions
Nikhil Bajaj	Chiu	Print quality improvement
Florian (Rien) Browne	Jain	Advanced control of castrip LLC caster roll gap
Jie Cai	Braun	Development & assessment of heuristic control strategies for a multi-zone commercial building employing a direct expansion system
Rui Cao	Bolton	Predicting outdoor sound
Daniel Carr	Davies	Human response to transient environmental sounds
Stephen Caskey	Groll/Hutzel	Solar-assisted & thermally-integrated appliance system with centralized thermal storage
Ying-Chieh Chan	Tzempelikos	Analysis & optimization of intelligent & multi-functional facades for buildings
Chun Chen	Chen	Person-to-person transmission of airborne infectious disease
Weitai Chen	Chiu	SNM: Roll to roll manufacturing of films and laminates based on cellulose nanomaterials
Li Cheng	Horton	Geothermal
A.J. Covarrubias	Horton	Economical and thermal modeling of district cooling, heating, and power plants
Nick Czapla	Groll	Viper performance testing
Ameya Deshpande	Meckl	Exhaust temperature management
Mengqi Gao	Chiu/Allebach	HP printer project - toner optimization
Dheeraj Gosala	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Allison Graban	Groll	Heat pump dryer
Todd Graham	Groll	TIRA (Thermally Integrated Residential Appliances)
Rohinish Gupta	Meckl	Model calibration and validation for hybrid vehicles
Jaesik Hahn	Reid	Thermal transport in natural fiber bundles
Dong Han	Groll	Optimizing heat pump performance
Andrew Hjortland	Braun	Integrated virtual sensing & decision support for HVAC equipment
John Hollkamp	Semperlotti	Acoustic metamaterials for vibration and noise control
Vaidehi Hoshing	Shaver	Controls
Xiaodong Hou	Braun	CPS: Synergy: Plug-and plug cyber-physical systems to enable buildings
Harshad Inamdar	Groll	Analysis of air-side heat exchanger fouling
Kaushal Jain	Meckl	Selective catalytic reduction (SRC) controls of EcoCar
Nelson James	Braun/Groll	Cold climate heat pump
Rita Jaramillo	Braun	Free cooling technologies
Peter Jaron	Cappelleri	Micro aerial vehicles
Bonggil Jeon	Horton	Inverse building modeling
Xing Jin	Shaver	Heavy vehicle hybridization
Jaewan Joe	Karava	High performance buildings
Mrunal C. Joshi	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Darioush Keivan Esfahani	Li/Krousgrill	Reductions of NVH sources in automobile transmission systems
Donghun Kim	Braun	Dynamic modeling of radiant systems

# CURRENT HERRICK LABS STUDENTS (CONTINUED)

Student	Major Professor	Thesis subject
Janghyun Kim	Braun	Modeling of radiant systems
Nicholas Kim	Bolton	Microperforated materials
Iason Konstantzos	Tzempelikos	Evaluation of daylight discomfort glare in buildings
Mukta Kulkarni	Meckl	Fuel grad determination
Anurag Kumra	Meckl	Fuel grade determination
Dayi Lai	Y. Chen	Outdoor/indoor ozone transmission
Seungjae Lee	Tzempelikos	Living Laboratories experimentation
Ruoyi Li	Yao	Intelligent and high-performance control of industrial robots
Cong Liao	Li/Krousgrill	Reduction of NVH sources in automobile transmission systems
Haotian Liu	Groll	Compressor calorimeter commissioning
Yangfan Liu	Bolton	The use of equivalent source models for reduced order simulation in room acoustics
Sylvia Lu	Shaver	Ultra-high engine systems efficiency via flexible valve actuation
Domenique Lumpkin	Groll	Innovative oil-free compressor & expander technologies
Jie (Jessie) Ma	Horton	Separated sensible and latent cooling systems for residential and light commercial
Daniel McArthur	Cappelleri	Micro aerial vehicles
Yeshaswi Menghmalani	Cappelleri	Control of integrated energy systems
Jacob Miller	Rhoads	Thermomechanics of energetic materials
Tamzidul Mina	Yao	Dynamics and controls of mobile robots
Eeshan Mitra	Li/Krousgrill	Reduction of NVH sources in automobile transmission systems
Austin Nash	Jain	Modeling and control of micro-CHP system
Soumya Nayyar	Shaver	Enabling high efficiency via variable valve actuation
Whitney Novotny	Rhoads	Selective deposition of energetic materials
Chaitanya Panuganti	Shaver	Engine control development for stationary & off-highway applications
Jelena Paripovic	Davies	Identification of low frequency dynamic behavior of surrogate explosive materials
Akash Patil	Braun	Virtual sensors for roof top units
Raghav Ramachandran	Rhoads	Printable energetic materials
Sugi Ramaraj	Braun/Horton	Econometric modeling & optimization of combined operations of the Wade Power Plant
Aswin Ramesh	Shaver	Improving efficiency & emissions control through variable valve actuation on a diesel engine
Seyed Amir Sadeghi	Tzempelikos	Energy efficient buildings hub
Tridib Saha	Shaver	Design/control of advanced hybrid powertrain systems for heavy vehicles
Joseph Seymour	Cappelleri	Micro aerial vehicles
Tongyang Shi	Bolton	Acoustics and noise control
Hyun Jun Shin	Bolton	Sound transmission
Weonchan Sung	Davies	Sound quality of HVAC equipment
Alexander Taylor	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation

## CURRENT HERRICK LABS STUDENTS (CONTINUED)

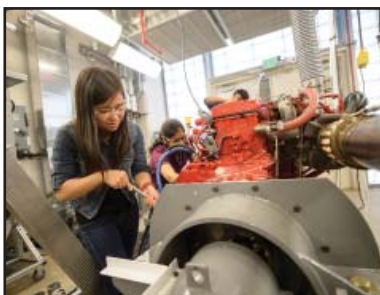
Student	Major Professor	Thesis subject
Josiah Thomas	Chiu	Bandwidth limited control systems
Matthew VanVoorhis	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Sanjeev Venkatachalam	Horton	Geothermal heat exchanger
Ashish Vora	Shaver	Model-based optimization of heavy-duty hybrid electric powertrains
Kalen Russell Vos	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Jie Wang	Chiu	SNM: Roll to roll manufacturing of films and laminates based on cellulose nanomaterials
Xiaoshen Wang	Groll	High temperature AC analysis of ECU
Yiming Wang	Li	A boundary element approach for assessing the acoustic performance of roadside noise barriers
Daniel Woods	Rhoads	The thermomechanical, near-resonant response of energetic materials
Yingying Xiao	Braun	CPS: Synergy: Plug-and plug cyber-physical systems to enable buildings
Jie Xiong	Tzempelikos	Living labs experimentation
Bin Yang	Groll	Cold climate heat pump
Jie Yang	Semperlotti	Structural health & dynamics
Ruoyu You	Chen	Energy efficient building hub
Haibin Zha	Braun	Modeling of scroll compressors
Xinye Zhang	Groll	Performance analysis of HVAC systems
Liuxian Zhao	Semperlotti	Structural health & dynamics
Zhidan Zhao	Horton	Thermal systems
Quan Zhou	J. Chen	Numerical simulations of hydrodynamic lubrication of high speed turbomachinery
Xiao Quiang Zhou	Semperlotti	CSC Fellowship

## 2014 HERRICK LABS GRADUATES

<b>Christian Bach</b>	PhD	Refrigerant side compensation for air-side maldistribution of evaporators and its effects on system performance
<b>Rui Cao</b>	MSME	Investigation of a fully coupled spinning tire-wheel model
<b>Howard Cheung</b>	PhD	Inverse modeling of vapor compression equipment to enable simulation of fault impacts
<b>Chuan Ding</b>	PhD	Thermal efficiency and emission analysis of advanced thermodynamic strategies in a multi-cylinder diesel engine utilizing valve-train flexibility
<b>David Fain</b>	MSME	Operating range characterization and expansion of premixed charge compression-ignited combustion in a multi-cylinder diesel engine with variable valve actuation, variable fuel reactivity & revised turbomachinery
<b>Adam Fogarty</b>	MSME	High voltage rear electric drivetrain design for a parallel-through-the-road plug-in hybrid electric vehicle
<b>Bilwa Jadhav</b>	MSME	Integration and implementation of high-voltage energy storage sub system for a parallel-through-the-road plug-in hybrid electric vehicle
<b>Gurneesh Jatana</b>	PhD	High-Speed Diode-Laser-Absorption Measurements of Gas Dynamics for Diesel Engines

## 2014 HERRICK LABS GRADUATES (CONTINUED)

<b>Mingang Jin</b>	PhD	Building airflow simulations with fast fluid dynamics
<b>Dat Le</b>	PhD	Physically-based modeling, estimation, and control of piezoelectric fuel injection during rate shaping operation
<b>Wei Liu</b>	MSME	Experimental and numerical study of the air distribution in an airliner cabin
<b>Mark Magee</b>	MSME	Exhaust thermal management using cylinder deactivation and late intake valve closing
<b>Andrew McMullen</b>	MSME	Assessment of noise metrics for application to rotorcraft
<b>Jacob Miller</b>	MSME	The thermomechanical responses of composite energetic materials to acoustic and ultrasonic excitation
<b>Juan Peng</b>	MSME	Propagation of wind turbine noise through wakes and turbulent atmosphere
<b>Bradley Pietrzak</b>	MSME	Algorithm development and analysis for advanced engine technologies including piezoelectric fuel injection and variable valve actuation
<b>Matthew Quock</b>	MSME	Heat exchanger performance optimization
<b>Aakash Rai</b>	Phd	Ozone-initiated chemistry in indoor environment
<b>Leighton Roberts</b>	MSME	Analysis of the impact of early exhaust valve opening and cylinder deactivation on after treatment thermal management and efficiency for compression ignition engine
<b>Nicholas Sakamoto</b>	MSME	The prediction of airborne and structure-borne noise potential for a tire
<b>Brandon Sobacki</b>	MSME	Development of sound quality metrics for gear rattle in diesel engines
<b>Nicholas Stuart</b>	MSME	Heat exchanger performance optimization
<b>Vaidyanadan Sundaram</b>	MSME	Measurement of the responses of polyurethane and Confor™ foams and the development of a system identification technique to estimate polyurethane foam parameters from experimental impulse responses
<b>Prateek Tayal</b>	MSME	Light off temperature based approach to determine diesel oxidation catalyst effectiveness level and the corresponding outlet NO and NO <sub>2</sub> characteristics
<b>Ularee Upathumchard</b>	MSME	Waste heat recovery options in a large gas-turbine combined power plant
<b>Srinivas Varanasi</b>	PhD	Sound attenuation characteristics of cellular metamaterials
<b>Daniel Woods</b>	MSME	The thermomechanical, near-resonant response of energetic materials
<b>Jinpu Yang</b>	MSME	Noise study in diesel engines
<b>David Yuill</b>	PhD	Development of methodologies for evaluating performance of fault detection and diagnostics protocols applied to unitary air-conditioning equipment
<b>Keqin Zhou</b>	MSME	NO and NO <sub>2</sub> modeling for diesel oxidation catalyst at different thermal aging levels



## MAJOR RESEARCH FACILITIES

### The Thermal Systems Laboratories



These areas are where the HVAC and Refrigeration component level and system level technology research is conducted as well as research on Air Quality. In the original building there are two psychrometric rooms (1 pair) and in the new building there are four psychrometric rooms (2 pairs) with a temperature range of  $-10^{\circ}$  to  $130^{\circ}$ F. Each psychrometric room is 7000 cu ft. The psychrometric rooms are designed to accommodate ASHRAE/ARI standard test procedures used in rating unitary air-conditioners and heat pumps up to a capacity of 5 tons of refrigeration (18 kW). There are two indoor air quality (IAQ) laboratories that can simulate indoor and outdoor conditions. Instrumentation includes ultrasonic anemometers, omnidirectional anemometers, tracer-gas sampler and analyzer, and particle generators and analyzers. Other facilities include a psychrometric wind tunnel with dust injection system; a large HVAC equipment lab with 90 ton centrifugal chiller, various computer controlled compressor load stands for small compressors.

### The Living Laboratory

The whole of the new building is a living laboratory where the building environment is being studied. It includes a 16 bore geothermal field and plug-and-play heat rejection for experiments in the engines and thermal sciences laboratories, and four nearly identical office spaces with each unit housing 20 graduate students. Each 34ft by 37ft office is reconfigurable in different ways and have separate support systems. This enables direct comparisons of alternative technologies for windows, lighting, comfort delivery, controls, and acoustic treatments. The normal temperature range is 65F to 75F but this can be extended to 55F to 85F. Relative humidity can be varied from 20% to 80%. Comfort delivery options include air supply from the ceiling, floor, or side wall along with radiant floor heating and radiant chilled beam cooling. Three of the units have double skin facades with different options for ventilation and energy recovery. All of the offices spaces have separate equipment for providing space conditioning that are well instrumented to allow direct energy comparisons.



### Engines Research Laboratory



The two engine test stands in the original building and the four test cells in the new building are home to engine and hybrid systems controls research that is focused on improving efficiency, reducing engine emissions and developing efficient and environmentally friendly systems for using alternative fuels. Currently the four new test cells and associated systems will support 670, 350, 150 and 150 HP engine testing, respectively, but space and utilities are planned so that upgrading to higher horsepower and higher levels of emissions testing are possible as research progresses. Other instrumentation includes a hydraulic variable valve actuation system capable of controlling 12 valves, a single cylinder rig for testing piezoelectric valve actuation, an AC dynamometer and several eddy-current engine dynamometers, as well as emissions sensing systems.

# MAJOR RESEARCH FACILITIES

## High-Bay Flexible Laboratory & Small-Scale Vibrations Laboratory

These house Electro-Mechanical and Vibrations research. This is comprised of two parts: an open 36 ft by 87 ft high-bay area with segmented floors for vibration isolation between experiments, and a smaller laboratory for smaller scale experiments. The high-bay area has high ceilings to accommodate large systems for testing. It can house large shakers, such as a 35 kN TIRA electrodynamic shaker that can be used to reproduce vibration profiles and has in-built hydraulic power supplies for hydraulic shakers. In this area the vibration and dynamics of larger structures can be examined such as building components, vehicle suspension systems, wind turbine blades, road vehicle and aircraft and space structures. The small-scale laboratory includes apparatus for dynamic testing of materials and small structures to investigate nonlinear dynamic behavior and to identify structural and material parameters.



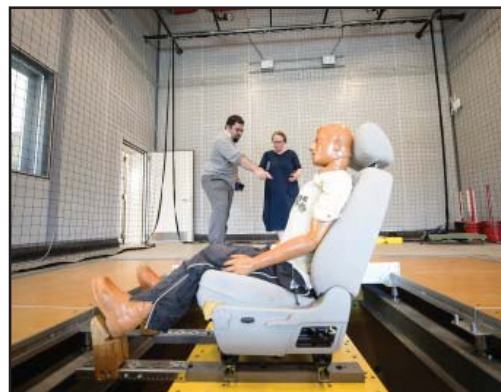
## Acoustics, Noise and Vibration Research Area

In addition to the facilities in the High-Bay Flexible Laboratory and Perception-based Engineering areas in the new building, these facilities, currently housed in the original building, include a 25 by 20 by 18 ft reverberation room, an anechoic room with useful volume of 12 by 12 by 12 ft, a hemi anechoic room with useful volume of 41 by 27 by 18 ft and an 8 by 8 ft audiometric room for sound quality testing. There is also an acoustical materials laboratory with several types of impedance tubes for standardized acoustic material testing. The reverberation room is configured for sound transmission testing of acoustical systems. Additional facilities include a tire pavement test apparatus (TPTA) for testing tires on realistic pavements at speeds up to 50 km/hr, a two wheel chassis dynamometer with 67 inch rollers, an anechoic wind tunnel with 18 by 24 inch test section and flow velocity up 120 mph, Instrumentation includes a 64 microphone acoustical holography array and 90 channel data acquisition system, various microphones, accelerometers, shakers, a laser vibrometer, and a high speed camera.



## Perception-Based Engineering Laboratory

Perception Based Engineering (PBE) researchers study people's perceptions of stimuli, their influence on satisfaction, comfort, annoyance and performance and the relationship between those outcomes and the system, design and operational parameters. PBE faculty at Purdue work on projects related to touch interfaces, sound and vibration quality, image quality and depth perception, display design and graphics optimization, effects of noise on performance, and human-computer interaction. This 43ft by 28ft laboratory houses a TEAM 6 degree-of-freedom shaker, which can be covered when not in use. Lighting, temperature (55F-85F), humidity (20% to 80%) and sound can be finely controlled, and the room can be re-configured as several small isolated rooms or one larger room, thus simulated various types of environments.



# HERRICK LABS TECHNOLOGY TRANSFER ACTIVITIES

## 2016

**July 11-14** Twenty-third International Compressor Engineering Conference  
Sixteenth International Refrigeration and Air Conditioning Conference  
Fourth International High Performance Buildings Conference

**July 10** Short Course - Oil Management in Compressors and Their Systems  
Short Course - Final Frontiers in Vapor Compression Cycle Efficiency  
Workshop - 2016 Intelligent Building Operations (IBO)

## 2015

**August 2-5** General Chair, 2015 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Boston, Massachusetts, Professor J. Rhoads

**March 16-20** Short Course - HVAC&R System Modeling and Simulation using Engineering Equation Solver, Kulthorn-Kirby, Bangkok, Thailand, Professor W. T. Horton

## 2014

**October 27-31** Co-General Chairs, 2014 Acoustical Society of America, Fall Meeting, Indianapolis, Professors P. Davies & S. Bolton

**July 14-17** Twenty-second International Compressor Engineering Conference  
Fifteenth International Refrigeration and Air Conditioning Conference  
Third International High Performance Buildings Conference  
Compressor, Refrigeration and Buildings Short Courses

## 2013

**August 26-28** General Chair and Technical Co-Chairs, Noise-Con 2013, Denver jointly held with the International Wind Turbine Noise Conference, Professor P. Davies & S. Bolton

## 2012

**July 14-19** Twenty-first International Compressor Engineering Conference  
Fourteenth International Refrigeration and Air Conditioning Conference  
Second International High Performance Buildings Conference  
Compressor, Refrigeration and Buildings Short Courses

