

PURDUE  
UNIVERSITY

RAY W. HERRICK  
LABORATORIES

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# 2013-2014 ANNUAL REPORT

FALL 2014



**Top Photo:** Herrick Labs 2013  
**Middle Photo:** Herrick Labs Bldg. 1980  
**Bottom Photo:** Herrick Labs Bldg. 1912\*

*\* From the J.C. Allen collection, courtesy of Purdue University Libraries, Archives & Special Collections*

## 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. Nearly 800 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.

### MISSION

An institution dedicated to graduate education and engineering research with emphasis on technology transfer to industry.

### VISION

To overcome the barriers between knowledge creation, transfer, and utilization and to become leaders of how graduate education and engineering research are done in partnership with industry.

### GOALS

1. To build upon the research excellence of the *Heating, Ventilation, Air-Conditioning, and Refrigeration Research Area* and the *Electro-Mechanical Systems* and the *Noise and Vibration Control Research Area* to enhance their national and international visibility and grow the reputation of these areas as the top research programs in the world.
2. Increase the visibility of the Center for High Performance Building.
3. To identify emerging research areas that are synergistic with laboratory focus.
4. To develop a proactive evolutionary strategy for the Laboratories to ensure its long-term stability and growth.
5. To improve the educational environment at the Labs so that its graduate students are multi-functional engineers who rate as the top engineering graduates in the country.
6. To continually monitor the technology transfer process by which research results are transferred to sponsors and the engineering community such that the labs will be recognized as the premier source of practical cutting edge research in our areas of expertise.
7. To continually grow the research environment at the Labs for the benefit of the students and faculty at the Labs.

# 2013-2014 HIGHLIGHTS

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## Research

	Last Year	This Year
Research expenditures HERL only (*academic year)	\$5,844,774	\$5,314,919
Building Expenditures (NIST & Gifts)	\$13,467,228	\$1,414,265
Number of sponsors as of September 2014	44	48
Research assistants as of September 2014	45	48
Archival papers published (*calendar year)	74	75
Contracts in force for next academic year (July 2013-June 2014)	\$2,821,276	\$3,343,517

## Education

Graduate students as of September 2014	80	93
MS	39	44
Ph.D.	41	49
Students graduated (*calendar year)	26	28
MS	14	20
Ph.D.	12	8
Undergraduate/graduate "research experience" students	11	10
Visiting scholars, Post Doctoral Scholars		
Visiting Research Assistants	17	23
Fellowships	5	6
Grant-in-Aid	5	4
Student Paper/Poster/Thesis Awards	5	6

## Technology Transfer

Conferences/Workshops held (*academic year)	4	7
Conferences planned in the next 2 years (July 2014 - July 2016)	5	3
Short Courses held (*academic year)	3	3
Herrick Labs reports to sponsors (*academic year)	15	8
Conference and journal papers (*calendar year)	189	175

\*Academic Year - August 2013 → August 2014

\*Calendar Year - January 2013 → December 2013

## 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 has been co-ordinating 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.

*The Ray W. Herrick Laboratories*

## HERRICK LABS FACULTY RESEARCH INTERESTS

- 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, analysis of tire vibration and sound radiation, nearfield acoustical holography, visualization of motor vehicle passby sound radiation, and machinery noise source identification.
- 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 air conditioning and refrigeration equipment and systems.
- 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, signature embedding for image/document security, material delivery systems for micro-fabrication, assistive devices for patient handling and movement, motion control, embedded systems/control, and perception-based engineering.
- 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.
- 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: alternative refrigeration technologies, vapor compression systems, natural refrigerants, compressor research, heat exchangers analysis, miniature refrigeration systems for electronics cooling.
- 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.
- Panagiota Karava**, Assistant Professor of Civil Engineering. PhD 2007, Concordia University. Natural/hybrid ventilation, building airflows, building-integrated photovoltaic-thermal systems, building energy modeling & simulation, design & analysis of energy efficient buildings, wind effects on buildings, indoor environment.
- 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.
- 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 combustion process with aftertreatment systems and hybrid powertrains. Novel combustion methodologies: Homogeneous Charge Compression Ignition (HCCI), clean diesel.



# HERRICK LABS FACULTY RESEARCH INTERESTS (CONTINUED)

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*The Ray W. Herrick Laboratories*

**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

### **Anil Bajaj**

Contributing Editor, Nonlinear Dynamics Journal

### **Stuart Bolton**

Advisory Board Member, Noise Control Engineering Journal  
Vice President for Publications, Institute of Noise Control Engineering, (2011 - 2013)  
Institute of Noise Control Engineering – Member Board of Directors  
Institute of Noise Control Engineering – InterNoise 2015 – INCE/KSNVE Liason  
Technical Program Committee, Noise-Con 2013

### **Jim Braun**

Editorial Board, Journal of Building Performance Simulation  
Editorial Board, Building Simulation: An International Journal  
Chairman, 2014 International Refrigeration and Air Conditioning Conference, Purdue University

### **David Cappelleri**

Member, IEEE Robotics & Automation Society Technical Committee on Micro/Nano Robotics and Automation  
Member, IEEE Robotics & Automation Technical Committee on Mechanisms and Design  
Member, ASME Design Engineering Division Mechanisms and Robotics Committee  
Member, ASME Design Engineering Division Micro and Nanosystems Technical Committee  
Associate Editor, Journal of Micro-Bio Robotics, 2012-present  
Associate Editor, 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.

### **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 of the Society for Imaging Science and Technology (IS&T)  
Fellow, American Society of Mechanical Engineers (ASME)  
Member, Institute of Electrical and Electronic Engineers (IEEE)  
Chair, Executive Committee, ASME Dynamic Systems & Control Division, 2012-present  
Member, International Federation of Automatic Control (IFAC) Technical Committee on Mechatronic Systems, 2005-present  
Member, Executive Committee, ASME Dynamic Systems and Control Division, 2010-2012  
Editor, Journal of Imaging Science and Technology, 2012-present  
Member, Editorial Board, Frontiers of Mechanical Engineering, 2008-present  
Associate Editor, Journal of Control Engineering Practice, 2007-present  
Program Chair, the 2016 American Control Conference, Boston, MA, June 2016

# HERRICK FACULTY PROFESSIONAL ACTIVITIES (CONTINUED)

## Patricia Davies

Member of the Institute of Noise Control Engineering (INCE) Executive Committee, Business Office Search Committee, Long Range Planning, and Nominations committees.  
General Chair, NoiseCon 2013 Conference, Denver, Colorado (Aug. 16-28, 2013)  
Planning (Conference co-Chair) for the Fall 2014 Meeting of the Acoustical Society of America, Indianapolis, IN (Oct. 27-31, 2014)

## Eckhard Groll

Regional Editor for the Americas, International Journal of Refrigeration  
Guest Editor, "Making the Odd Couple Work: Combining Engineering and Language Education," Festschrift in honor of John Grandin, Online Journal for Global Engineering Education (2011 – 2012)  
Advisory Board Member, Karlsruhe House of Young Scientists, Karlsruhe Institute of Technology  
Member, Technology Council, ASHRAE  
Chair, ASHRAE Data Center Working Group  
Chair, USNC/IIR (U.S. National Committee of the Int'l Institute of Refrig.), 2007-2011  
ASHRAE Advisory and Scientific Committee member: 11th CLIMA 2013 Congress, Prague Czech Republic, June 16-19, 2013  
Steering Committee Member: 15th Annual Colloquium on Int'l Eng. Education, Newport, Rhode Island, Nov. 2-4, 2012  
Steering Committee member: ASHRAE/NIST Refrigerants Conference, NIST, Gaithersburg, MD, October 29-30, 2012  
General Conference Chair: 21st Int'l Compressor Engineering Conference at Purdue, 14th Int'l Refrigeration & Air Conditioning Conference at Purdue, and 2nd Int'l High Performance Buildings Conference at Purdue, July 15-19, 2012  
International Scientific Committee Member: 8th Int'l Conf. on Compressors and Coolants, Smolenice, Slovakia, September 2-4, 2013  
Purdue University Global Council Member

## Panagiota Karava

Member, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2008-present  
Member, International Building Performance Simulation Association (IBPSA), 2005-present  
Member, American Wind Engineering Association, 2008-present  
Member, US Building Simulation Association, 2009-present  
Member of Organizing Committee, 2nd and 3rd Int'l High Performance Buildings Conference at Purdue University, 2012, 2014  
Member, ASHRAE Technical Committee 4.3, TC 6.7, and TC 4.10, 2008-present  
Member, ASCE Technical Committee on Environmental Wind Engineering, 2009-2013

## 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

Chair, 2014-2015, Executive Committee, Solar Energy Division (SED) of ASME

## Jeff Rhoads

Associate Editor of the ASME Journal of Vibration and Acoustics (2013-present)  
Member of the ASME International Design Engineering Division Technical Committee on Sound and Vibration (2010-present)  
Member of the ASME International Design Engineering Division Micro/Nanosystems Technical Committee (2009-present)  
Chair and Treasurer (2013-present)  
Secretary (2012-2013)  
Member of the ASME International Student Design Committee (2008-present)

## Greg Shaver

Chair, ASME Automotive and Transportation Systems Technical Committee  
Associate Editor, International Journal of Engine Research  
Associate Editor, ASME Journal of Dynamic Systems and Control

## Thanos Tzempelikos

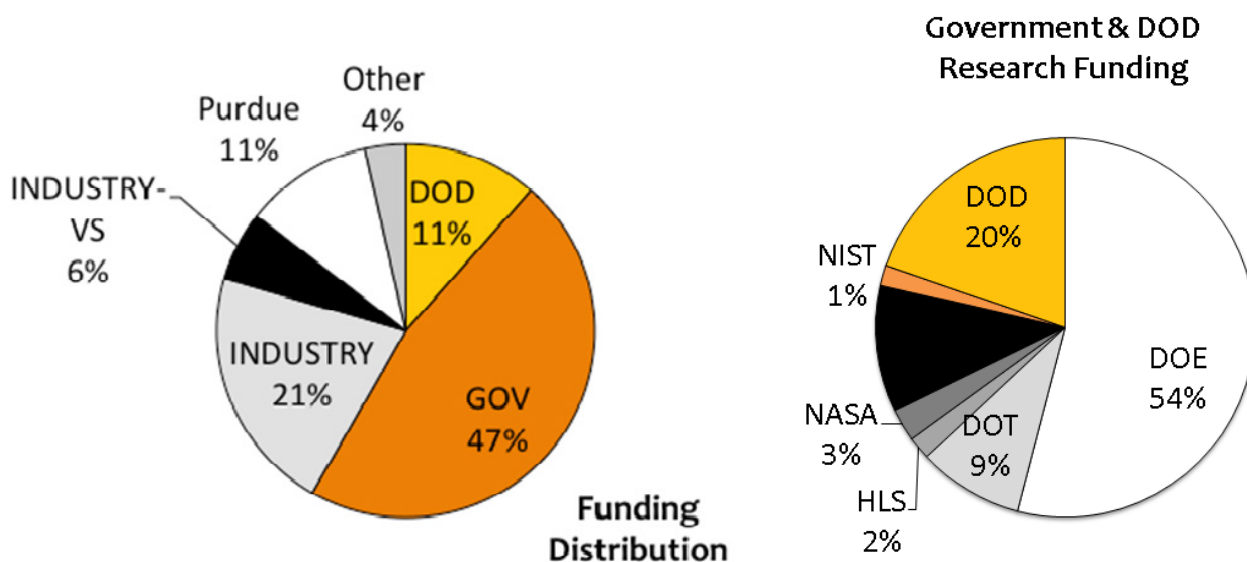
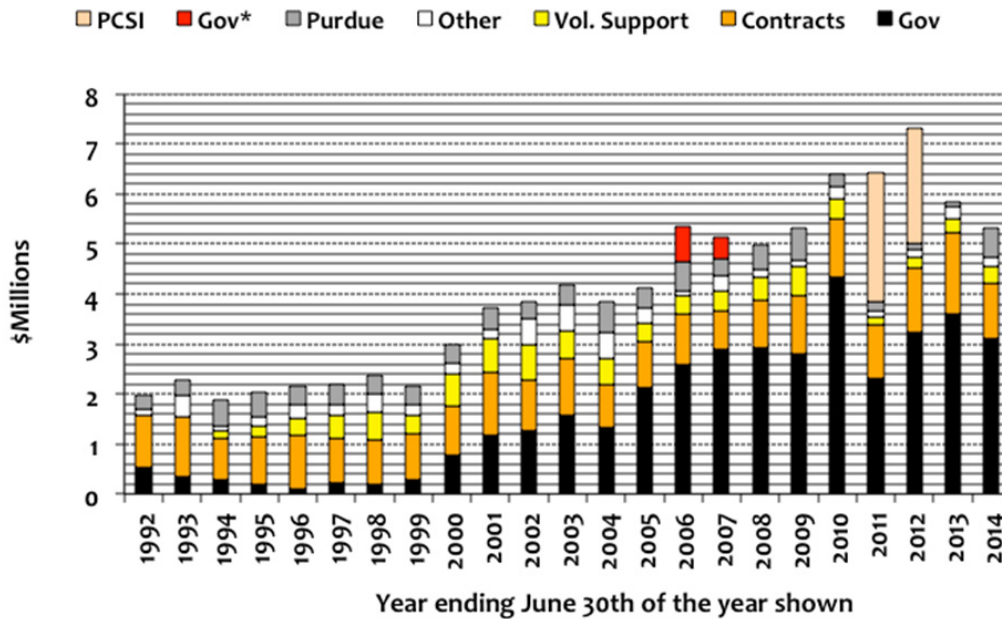
Member, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)  
Voting Member, Vice Chair and Program Subcommittee Chair of ASHRAE Fenestration Technical committee (4.5)  
Member, International Building Simulation Association  
Member, International Solar Energy Society  
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

# 2013-2014 EXPENDITURES

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Shown below is the distribution of research expenditures from July 1992 to June 2014

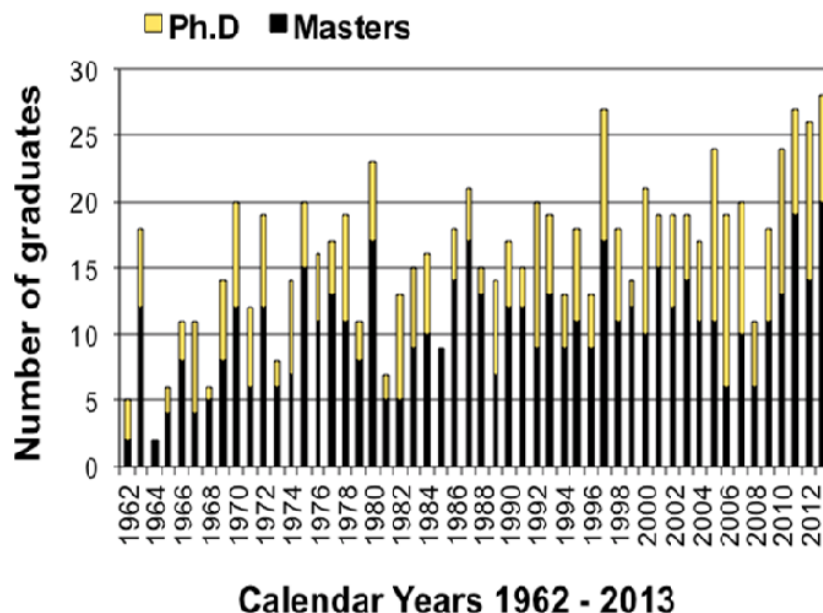
Total Herrick Laboratories Research Expenditures \$5,314,919-2014; \$5,844,774-2013  
Additional Building Expenditures: \$13,467,228-2013; \$10,882,857-2012



The Ray W. Herrick Laboratories

## 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

**Howard Cheung** received a Ward Lambert Teaching Fellowship  
**Chuan Ding** received a Ward Lambert Teaching Fellowship  
**Dayi Lai** received the Ross Fellowship  
**Domenique Lumpkin** received GEM-Graduate Degrees for Minorities in Engineering and Science Fellowship  
**Jelena Paripovic** received an Ingersoll-Rand Fellowship  
**Brandon Woodland** received a Ward Lambert Teaching Fellowship  
**Brandon Woodland** received the Gerald I. Gilbert Scholarship

### Grants-in-Aid

**Jie Cai** received an ASHRAE Grant-in-Aid  
**Chun Chen** received an ASHRAE Grant-in-Aid  
**Aakash Rai** received an ASHRAE Grant-in-Aid  
**Haojie Wang** received an ASHRAE Grant-in-Aid

### Awards

**Udbhau Bhattacharya** received the Best Presentation Award at the 2013 International Conference on Recent Advances in Structural Dynamics  
**Rui Cao** received an INCE/USA Student Paper Competition Award  
**Nelson James** won first place in the Technical Presentation Competition at the 37th Annual Board Meeting and Conference for the GEM National Consortium  
**Dat Le** received a Best Presentation Award at the 2013 American Control Conference  
**Lu Lu** received the CETA - committee for the Education of Teaching Assistants Teaching Award  
**Astitva Tripathi** received second place in the VIB Conference Student Paper Competition



# CURRENT HERRICK LABS STUDENTS

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Student	Major Professor	Thesis subject
Allen, Cody	Shaver	Ultra-high engine systems efficiency via flexible valve actuation
Yousof Azizi	Davies/Bajaj	Improvements to models of flexible polyurethane foam to enhance predictions of seat-occupant dynamics
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
Shambhavi Balasubramanian	Meckl	Estimation & compensation of fuel quantity variation in multipulse injections
Kunal Bansal	Groll	Liquid-flooded Ericsson power cyclers expansion
Udbhau Bhattiprolu	Davies/Bajaj	Modeling & system identification of structural systems incorporating nonlinear viscoelastic materials
Jie Cai	Braun	Development & assessment of heuristic control strategies for a multi-zone commercial building employing a direct expansion system
Jiajun Cao	Meckl	Noise reduction in small diesel genset engine
Rui Cao	Bolton	Experimental testing of coupled structural-acoustic modes of tires
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	Predicting transient particle transport in enclosed environments with the combined CFD & Markov chain method
Yi-Ting Chen	Chiu	Analysis and optimization of intelligent and multi-functional facades for building
Nick Czaplá	Groll	Viper performance testing
Supriya Dharkar	Groll	High COP heat pumps for commercial energy applications
Joonyup Eun	Chiu	Print quality improvement
Michelle Flachs	Rhoads	Whirlpool top-load washing machine vibrations
Adam Fogarty	Shaver/Meckl	EcoCar2 – rear drivetrain design
Mengqi Gao	Chiu/Allebach	HP printing
Dheeraj Gosala	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Rohinish Gupta	Meckl	Model calibration and validation for hybrid vehicles
Mayura Halbe	Shaver	Operating range expansion of premixed charge compression-ignited combustion in a multi-cylinder diesel engine with flexible valve actuation & variable fuel reactivity
Dong Han	Groll	Optimizing heat pump performance
Jagdish Hiremath	Meckl	SCR dosing strategy/EcoCar2
Andrew Hjortland	Braun	Virtual sensor based RTU FDD for multiple simultaneous fault diagnoses
Vaidehi Hoshing	Shaver	Model-based heavy hybrid design optimization & control
Yu-Wei Hung	Horton	Radiant heating/cooling systems
Harshad Inamdar	Groll/Garimella	Performance of heat exchangers & heat sinks after air-side fouling & cleaning
Nelson James	Braun/Groll/Horton	Liquid flooded Ericsson power cycle
Rita Jaramillo	Braun/Horton	Optimizing the control of free cooling & thermal energy storage options at Purdue
Peter Jaron	Cappelleri	Micro aerial vehicles
Bonggil Jeon	Horton	Annual HVAC equipment performance comparison for existing commercial buildings
Xing Jin	Shaver	Model-based optimization of heavy-duty hybrid electric powertrains

*The Ray W. Herrick Laboratories*

## CURRENT HERRICK LABS STUDENTS (CONTINUED)

Student	Major Professor	Thesis subject
Jaewan Joe	Karava	Multi-agent system modeling, identification, and control to enable intelligent buildings
Yanling Ju	Chiu	Print quality improvement and sustainability
Darioush Keivan Esfahani	Li/Krousgrill	Elimination of NVH sources
Donghun Kim	Braun	Development of plug&plug optimal control algorithms for small commercial buildings
Janghyun Kim	Braun/Horton/ Tzempelikos	Modeling & experimental analysis of passive chilled beams
Nicholas Kim	Bolton	Optimization of multiple-layer microperforated panels as functional absorbers & duct liners
Iason Konstantzos	Tzempelikos	Evaluation of daylight discomfort glare in buildings
Abhinav Krishna	Groll	Analysis of a rotating spool expander for organic rankine cycles in heat recovery applications
Mukta Kulkarni	Meckl	Fuel grade determination
Yi-shu Kung	Qu	An integrated system of vapor-compression chiller & absorption heat pump for efficiency improvement
Dayi Lai	Y. Chen	Outdoor/indoor ozone transmission
Seungjae Lee	Tzempelikos	Living Laboratories experimentation
Seungkyu Lee	Bolton	Fan noise control
Cong Liao	Li/Krousgrill	NVH sources
Yangfan Liu	Bolton	The use of equivalent source models for reduced order simulation in room acoustics
Huizhi Lu	Chiu	Print quality improvement and sustainability
Sylvia Lu	Shaver	Ultra-high engine systems efficiency via flexible valve actuation
Domenique Lumpkin	Groll	Innovative oil-free compressor & expander technologies
Daniel McArthur	Cappelleri	Micro aerial vehicles
Jacob Miller	Rhoads	Thermal & mechanical response of particulate composite plates under inertial excitation
Soumya Nayyar	Shaver	Enabling high efficiency via variable valve actuation
Chaitanya Panuganti	Shaver	Engine control development for stationary & off-highway applications
Jelena Paripovic	Davies	Identification of low frequency dynamic behavior of surrogate explosive materials
Maryam Parsa	Karava	CPS Synergy: Plug and play cyber-physical systems to enable intelligent buildings
Yuan Peng	Li	Sound propagation through turbulent atmosphere
Sugi Ramaraj	Braun/Horton	Econometric modeling & optimization of CHP operations of the waste power plant
Aswin Ramesh	Shaver	Improving efficiency & emissions control through variable valve actuation on a diesel engine
Lalitya Reddy	Tzempelikos	Living Laboratories experimentation
Nicholas Righetti	Groll	Thermally integrated appliances
Seyed Amir Sadeghi	Tzempelikos	Energy efficient buildings hub

# CURRENT HERRICK LABS STUDENTS (CONTINUED)

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*The Ray W. Herrick Laboratories*

Student	Major Professor	Thesis subject
Jason Schneemann	Groll	Sustainable water systems
Joseph Seymour	Cappelleri	Micro aerial vehicles
Tongyang Shi	Bolton	Acoustics & noise control
Zhu Shi	Y. Chen/J. Chen	Numerical study of entrainment in a jet flow with weak stratification
Hyun Jun Shin	Bolton	Sound transmission
Brandon Sobecki	Bolton/Davies	Development of sound quality metrics for diesel engine component specification
Yuanpei Song	Qu	Energy efficient integrated frp-confined sandwich roof system
Vaidy Sundaram	Davies/Bajaj	Seat-occupant dynamics
Bao Tong	Li	Acoustical modeling of the sound field within a rigid porous layer: theory & experiments
Astitva Tripathi	Bajaj/Rhoads	Vibrations of plates
Jebaraj Vasudevan	Horton	Geothermal heat exchange modeling/validation
Ashish Vora	Shaver	Model-based optimization of heavy-duty hybrid electric powertrains
Haojie Wang	Chen	A semi-empirical model for studying the impact of thermal mass & cost-return analysis on mixed-mode ventilation in office buildings
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
Yuntian Wang	Shaver	Operating range expansion of premixed charge compression-ignited combustion in a multi-cylinder diesel engine with flexible valve actuation & variable fuel reactivity
Chaitanya Wani	Groll	Organic rankine cycle analysis
Josh (J.T.) Whitman	Groll	Food chilling systems
Brandon Woodland	Braun/Groll/Horton	Methods of increasing net work output of organic rankine cycles for low-grade waste-heat recovery
Daniel Woods	Rhoads	Thermal & mechanical response of particulate composite plates under inertial excitation
Jie Xiong	Tzempelikos	Living Laboratories experimentation
Bin Yang	Braun/Groll/Horton	Application of oil flooded compression with regeneration to a packaged heat pump system
Mingda Yang	Yao	Modeling and control of hydraulic arm
Ruoyu You	Chen	Energy efficient building hub
Xinye Zhang	Groll	Performance analysis of HVAC systems
Weikang Zhao	Yao	Energy saving control of electro-hydraulic systems
Zhidan Zhao	Horton	DOE energy hub

## 2013 HERRICK LABS GRADUATES

<b>David Berdy</b>	PhD	Kinetic Energy Harvesting from Low Frequency Sources
<b>Stephen Caskey</b>	MSME	Cold Climate Field Test Analysis of an Air-Source Heat Pump with Two-Stage Compression and Economizing
<b>Steffen Ebling</b>	MSME	Carbon Dioxide Compressor Load Stand
<b>Scott Flueckiger</b>	PhD	Multiscale Simulation of Thermocline Energy Storage for Concentrating Solar Power
<b>Kevin Foertsch</b>	MSME	The Number-of-Events as a Predictor Variable in Aircraft Noise Annoyance Models
<b>Akash Garg</b>	MSME	Exhaust Thermal Management Using Intake Valve Closing Timing Modulation
<b>Michael Hayward</b>	MSME	Identification and Modification of Dominant Noise Sources in Diesel Engines
<b>Seth Holloway</b>	MSME	An Annual Performance Comparison of Various Heat Pumps in Residential Applications
<b>Andrew Jessop</b>	PhD	Near-Field Pressure Distributions to Enhance Sound Transmission Through Multi-Layer Materials
<b>Woo Hyun Kim</b>	PhD	Fault Detection and Diagnosis for Air Conditioners and Heat Pumps Based on Virtual Sensors
<b>Derek Kultgen</b>	MSME	Assessing the Energy Reduction Potential of a Cold Climate Heat Pump
<b>Lu Lu</b>	PhD	A Performance-Oriented Multi-Loop Control of Systems with Constraints and Uncertainties
<b>Simbarashe Nyika</b>	MSME	Development, Validation and Application of General Gray-Box Models for Ductless and Ducted Residential Heat Pumps
<b>Jelena Paripovic</b>	MSME	Characterization and Modeling of Materials Used in Improvised Explosive Devices
<b>Nishigandha Railkar</b>	MSME	Investigation of Operating Range Capability of Gasoline Fueled Compression Ignition
<b>Akhil Salunke</b>	MSME	Control of Impacting Dynamical Systems
<b>Sai Shirsikar</b>	MSME	Estimation of Fueling Variation in Multipulse Injection
<b>Yuanpei Song</b>	MSME	Modeling and Experimental Validation of a Multi-Port Vapor Injected Scroll Compressor
<b>Raymond Sutjiono</b>	MSME	Real-Time On-Board Indirect Light-Off Temperature Estimation as a Detection Technique of Diesel Oxidation Catalyst Effectiveness Level
<b>Hongdan Tao</b>	PhD	Propagation of Sound in the Vicinity of Rigid Porous Interfaces
<b>Aniket Vagha</b>	MSME	Strategy for Health Monitoring and Fault Detection in Heavy Duty Diesel Engines
<b>Dan Van Alstine</b>	PhD	Control-Oriented Modeling and Operating Range Expansion of Premixed Charge Compression-Ignited Combustion in a Multi-Cylinder Diesel Engine with Flexible Valve Actuation and Variable Fuel Reactivity
<b>Yan Xue</b>	MSME	Determination of Heat Transfer in Under-Floor Plenums in Buildings with Under-Floor Air Distribution Systems



# HERRICK LABS TECHNOLOGY TRANSFER PROGRAMS

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*The Ray W. Herrick Laboratories*

## 2014

**October 27-31** Acoustical Society of America, Fall Meeting, Indianapolis

## 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** Noise-Con 2013, Denver  
International Wind Turbine Noise Conference, Denver

## 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

## 2010

## July 10-15

Twentieth International Compressor Engineering Conference  
Thirteenth International Refrigeration and Air Conditioning Conference  
First International High Performance Buildings Conference  
Introduction to Compressors (Compressors 101) Short Courses  
Supermarket Refrigeration Systems Simulation Tools—Status and Recent High Performance Building Technologies Short Course

## May

Short Course for Delphi Company, Kokomo, IN  
CLIMA World Congress, Antalya, Turkey

## 2009

## July

Los Alamos National Laboratory Dynamics Summer School, Lectures on Nonlinear Vibration  
Marie Curie Action SICON, Stability, Identification, and Control in Structural Dynamics  
University of Liege, Belgium, Master Series on Identification and Prognosis in Structural Systems

## August

INTER-NOISE 2009, Ottawa, Ontario, Canada,  
Tutorial for Integrated Systems Health Management Workshop, AFRL

## September

9th Healthy Buildings Conference, Syracuse, NY



## 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  $130^{\circ}\text{F}$ . 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, omni-directional 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.



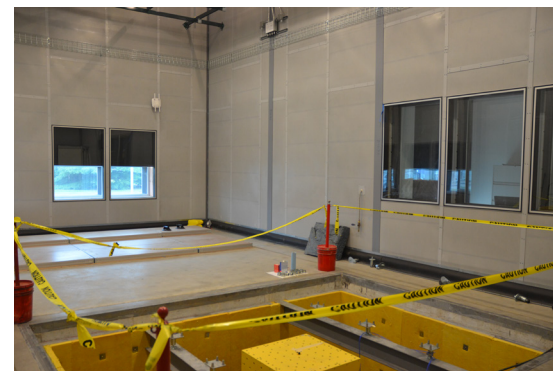
### Engines Research Laboratory



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.

### 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.





# MAJOR RESEARCH FACILITIES (CONTINUED)

## 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 to 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.



