Schools of Mechanical and Civil Engineering Purdue University

2015-2016 ANNUAL REPORT
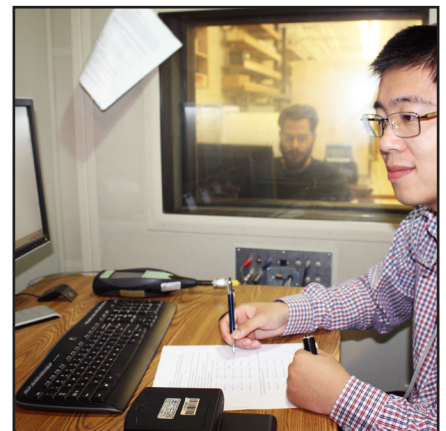
FALL 2016

RAY W. HERRICK LABORATORIES

home of the
Center for High Performance Buildings

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THE RAY W. HERRICK LABORATORIES

The Ray W. Herrick Laboratories turned 50 years old in 2008. Today we are part of the School of Mechanical Engineering, but the 25 Mechanical Engineering and Architectural Engineering faculty who do research here collaborate on interdisciplinary research projects with faculty in the other Schools of Engineering and also with the faculty in the College of Science and College of Health and Human Sciences and the College of Technology. There are four main technical areas of research with some overarching themes related to energy utilization and efficiency, reduction of pollutants in the environment, quality of life, and sustainability and safety.

The main technical areas are:

1. High Performance Buildings, Thermal Systems and Air Quality
2. Noise and Vibration Control, which includes research on Acoustics, Dynamics, and Materials
3. Electromechanical Systems & Advanced Engines: Controls, Signal Processing, Sensing, Estimation, Diagnostics and Prognostics
4. Perception-Based Engineering: Modeling of Human Response for Machine and System Optimization

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.

MISSION

An institution dedicated to graduate education through engineering research with emphasis on technology transfer

VISION

To overcoming barriers between knowledge creation, transfer, and utilization for the advancement of society

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.) 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.

The Ray W. Herrick Laboratories

2015-2016 HIGHLIGHTS

Research	**Last Year**	**This Year**
Research expenditures HLAB August 2015-August 2016	$5,458,682	**$7,375,042**
Proposals Pending	$5,576,810	**$7,920,100**
Number of sponsors as of September 2016	39	**83**
Research assistants as of September 2016	60	**68**
Archival papers published-January 2015-December 2015	83	**102**
Contracts in force for July 2015-June 2016	$3,340,576	**$4,661,793**
Education		
Graduate students as of September 2015	91	**115**
MS	37	**44**
Ph.D.	54	**71**
Students graduated-January 2015-December 2015	25	**20**
MS	16	**10**
Ph.D.	6	**10**
Undergraduate/graduate "research experience" students	29	**38**
Visiting scholars, Post Doctoral Scholars		
Visiting Research Assistants	22	**14**
Fellowships	7	**3**
Grant-in-Aid	2	**7**
Student Paper/Poster/Thesis Awards	4	**6**
Technology Transfer		
Conferences/Workshops held -August 2015-August 2016	2	**6**
Conferences planned in the next 2 years (July 2016-July 2018)	3	**4**
Short Courses held August 2015-August 2016	1	**4**
Herrick Lab reports to sponsors August 2015-August 2016	13	**12**
Conference and Journal Papers January 2015-December 2015	189	**185**

ADMINSTRATIVE AND SUPPORT STAFF

Professor Patricia Davies is the Director of Ray W. Herrick Laboratories. Donna Cackley is her administrative assistant with Cindy Cory being the Herrick secretary. Kim Stockment serves as administrative assistant for the Herrick Laboratories' conference and short course. Orkan Kurtulus serves as the Senior Research Associate helping support the setup of operation of projects that utilize experimental facilities within the thermal system laboratory. The various research programs are assisted by: Ron Evans, Technical Services Supervisor and Research Engineer; 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

The Ray W. Herrick Laboratories

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.

Shirley Dyke, Professor of Mechanical and Civil Engineering, Ph.D. 1996, University of Notre Dame. Structural dynamics and controls, damage detection and structural condition monitoring, cyber-physical systems, real-time hybrid simulation, cyberinfrastructure development, and machine vision.

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.
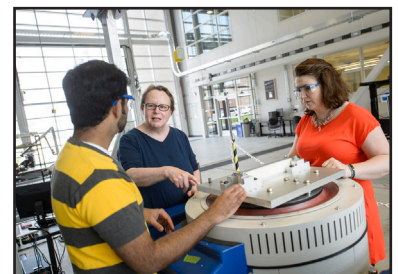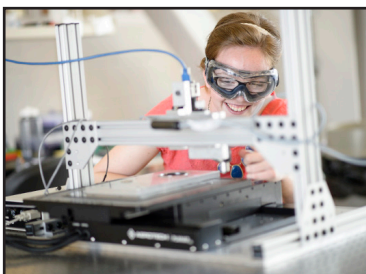
HERRICK LABS FACULTY RESEARCH INTERESTS

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, Associate 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, 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, 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.

The Ray W. Herrick Laboratories
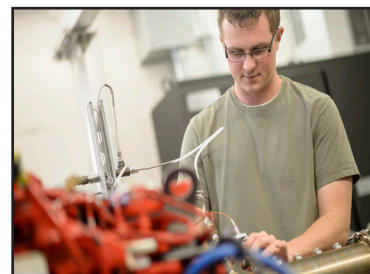
HERRICK FACULTY PROFESSIONAL ACTIVITIES

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, 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

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

HERRICK FACULTY PROFESSIONAL ACTIVITIES

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 Steering Committee Member: 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: 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

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, General Conference Co-Chair, 2015 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Boston, Massachusetts; 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
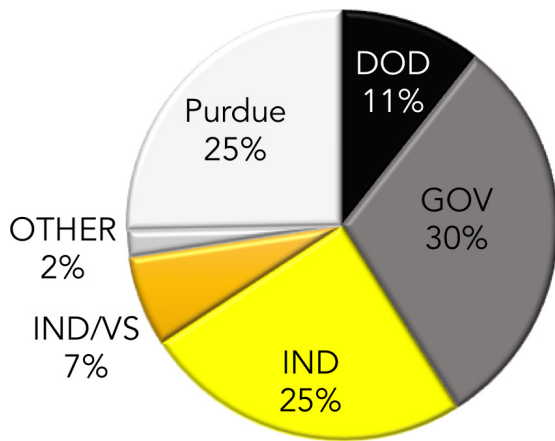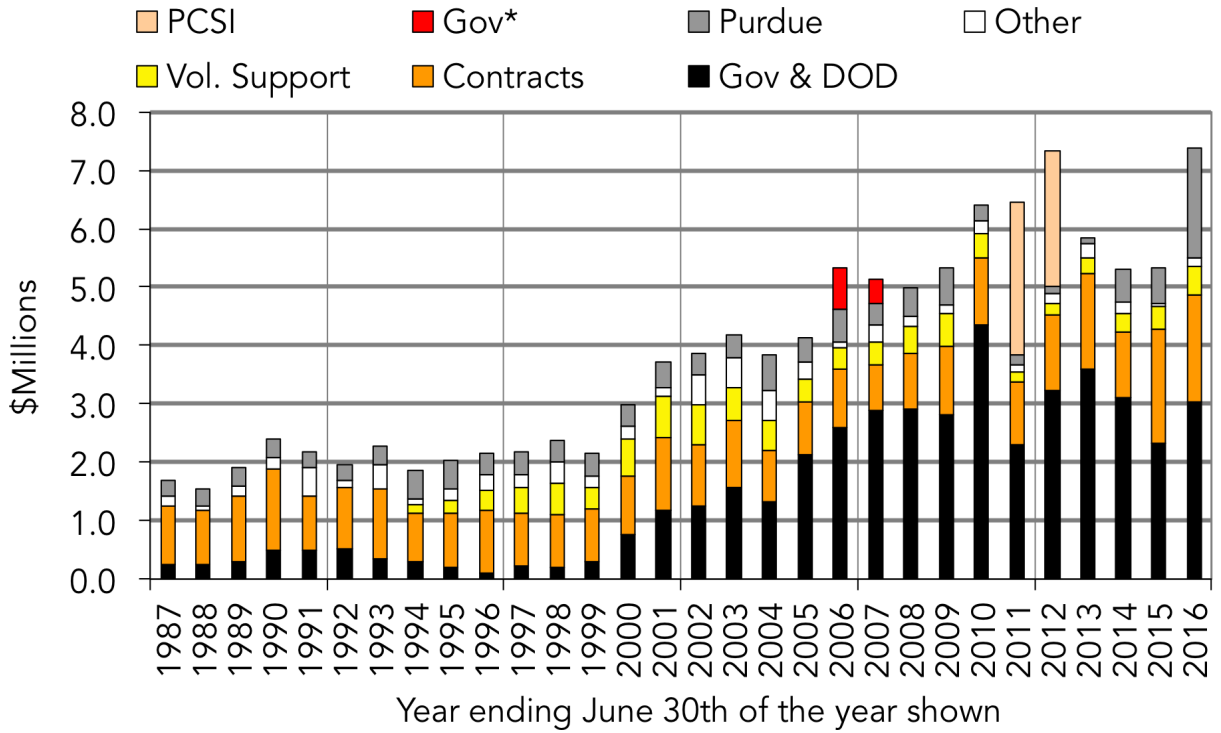
Thanos Tzempelikos
Member, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); Voting Member, Vice Chair and Program Subcommittee Chair of ASHRAE Fenestration Technical committee (4.5); Member: International Building Simulation Association and International Solar Energy 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
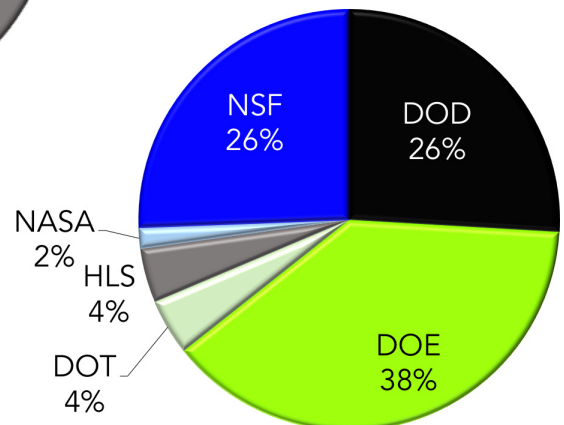ASME Fellow, Senior Member of IEEE; Member: Editorial Board of the International Journal of Control, Automation and Systems (ICASE); Management Committee of IEEE/ASME Trans. Mechatronics, 2012-2014; Award Committee and International Advisory Committee of IEE/ASME Int. Conference on Advanced Intelligent Mechatronics, Besancon, France, July 8-11, 2014; Past Technical Editor: IEE/ASME Trans. Mechatronics

2015-2016 RESEARCH EXPENDITURES

Shown below is the distribution of research expenditures from July 1987 - June 2016
Total Herrick Laboratories research expenditures **$7,375,042**

Legend:
- PCSI
- Gov*
- Purdue
- Other
- Vol. Support
- Contracts
- Gov & DOD

Y-axis: $Millions (0.0 to 8.0)

X-axis: Year ending June 30th of the year shown (1987–2016)

Pie chart:
- DOD 11%
- GOV 30%
- IND 25%
- IND/VS 7%
- OTHER 2%
- Purdue 25%

Government & DOD Funding

Pie chart:
- DOD 26%
- DOE 38%
- NSF 26%
- NASA 2%
- HLS 4%
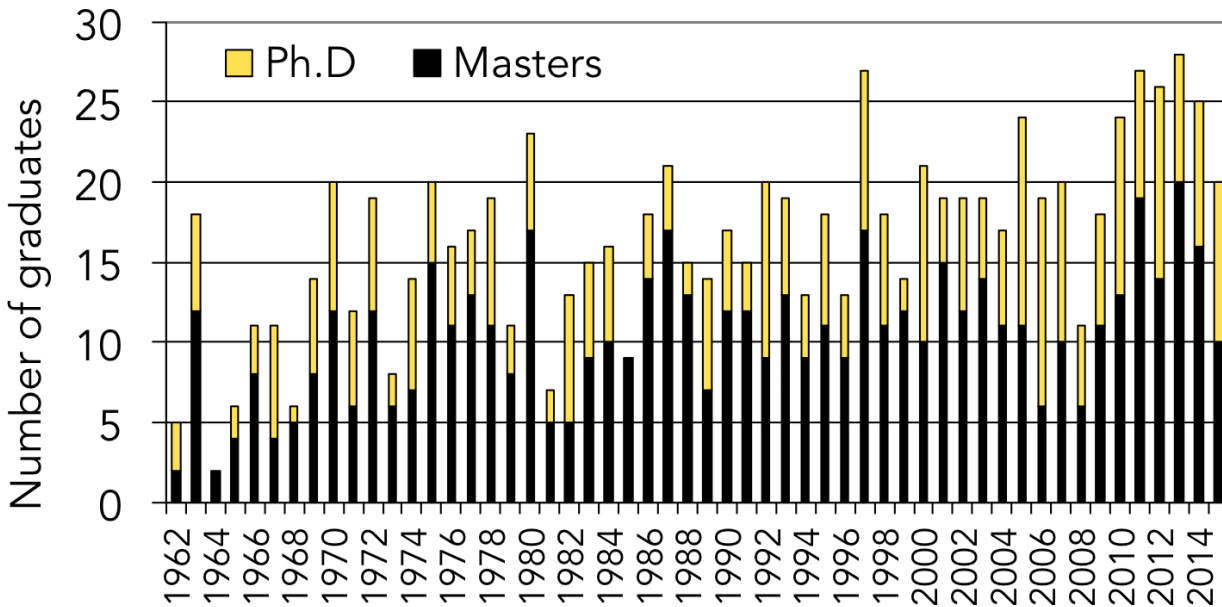- DOT 4%

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
Youyi Bi received the Lambert Teaching Fellowship
Caleb Heitkamp received the Arrasmith Fellowship
Dennis Lyle received the Arrasmith Fellowship

Assistantships
Katie Riley received the Lozar Assistantship
Trevor Kyle received the Lozar Assistantship

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

Awards
Daniel Carr received the Classic Papers in Noise Control Engineering, Noise-Con 2016
Jiawei Liu & Tongyang Shi each received an award for their paper at Noise-Con 2016
Andy Hjortland & Nelson James each received an award for their papaer at the Purdue
    Internation Refrigeration and Air Conditioning Conference
David Ziviani received a 3rd place, Student Paper at Purdue's Compressor Conference
Yangfan Liu received the Teaching Academy Graduate Teaching Award
Wei Liu received the Bilsland Dissertation
Harshad Inamdar received the Summer Res Grant
Hyunjun Shin received the Hallberg Foundation Travel Award (Noise-Con 2016)

The Ray W. Herrick Laboratories

CURRENT HERRICK LABS STUDENTS

| Student	Major Professor	Thesis subject
Kumar Akash	Jain	Mathematical characterization of human-machne interactions
Cody Allen	Shaver	Ultra-high engine systems efficiency via flexible valve actuation
Vishal Anand	Chen, Y.	Experimental evaluation of the thermal and ventilation performance of Stratified air distribution systems coupled with passive beams
Aaron Anderson	Arrieta	Design of a twisting multi-stable morphing structure
Ammar Bahman	Groll	High efficiency A/C systems for hot climate zones
Nikhil Bajaj	Chiu	Print quality improvement
Riley Barta	Groll	Multii-temperature refrigerated continer system (MIRCS)
Suyash Bhangale	Groll	Performance testing of unitary split-system heat pump
Youyi Bi	Davies	Characterization of next generation vehicle sounds
Nicholas Brenn	Groll	Greywater system of efficient homes
Florian (Rien) Browne	Jain	Advanced control of Castrip LLC caster roll gap
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
Weitai Chen	Chiu	SNM
Li Cheng	Horton	Geothermal
Jongseong (Brad) Choi	Dyke	Active citizen science for lifecycle assessment
Arindam Bhanja Chowdhury	Cappelleri	Embedded intelligence for robotics and assistive devices
A.J. Covarrubias	Horton	Economical and thermal modeling of district cooling, heating, and power plants
Nick Czapla	Groll	Viper performance testing
Zhipeng (Steven) Deng	Chen, Y.	Recognition of building occupant behaviors from indoor environment parameters by a data mining approach
Trevor Fleck	Rhoads	Selective deposition of energetic materials
Dheeraj Gosala	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Jaesik Hahn	Reid	Thermal transport in natural fiber bundles
David Halbrooks	Braun/Groll	Load-based testing of HVAC equipment
Sang Woo Ham	Karava	Cyber-sees - smart buildings
Dong Han	Groll	Optiziming heat pump performance
Haitian Hao	Semperlotti	Thermoacoustics
Caleb Heitkamp	Rhoads	Acoustics-based IED detection and defeat
Ashwin Clement Henry	Arrieta	Aero-structural optimization of distributed Piezoelectri actuation in smart morphing wing
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
Myungwon Hwang	Arrieta	Nonlinear dynamics of bi-stable unit cell lattices
Harshad Inamdar	Groll	Analysis of air-side heat exchanger fouling
Kaushal Jain	Meckl	SCR Controls of EcoCAR
Nelson James	Braun/Groll	Cold climate heat pump
Rita Jaramillo	Braun	Free cooling technologies

CURRENT HERRICK LABS STUDENTS (CONTINUED)

Student	Major Professor	Thesis subject
Bonggil Jeon	Horton	Inverse building modeling
Xing Jin	Shaver	Heavy vehicle hybridization
Jaewan Joe	Karava	High performance buildings
Amin Joodaky	Gibert	Transient & random packing dynamics
Mrunal C. Joshi	Shaver	Enabling ultra-high engine system efficiency via flexible vale actuation
Darioush Keivan Esfahani	Li/Krousgrill	Eliminiation of NVH Sources
Janghyun Kim	Braun	Modeling of radiant systems
Nicholas Kim	Bolt	Microperforated materials
Iason Konstantzos	Tzempelikos	Evaluation of daylight discomfort glare in buildings
Anurag Kumra	Meckl	Fuel grade determination
Trevor Kyle	Rhoads	Acoustics-based IED detection and neutralization
Dayi Lai	Y. Chen	Outdoor/indoor ozone transmission
Alejandro Lavernia	Groll	Organic rankine cycle as a bottoming cycle for wste heat recovery from internal combustion engine
Seungjae Lee	Tzempelikos	Living Laboratories experimentation
Ruoyi Li	Yao	Intelllignet and high-performance control of industrial robots
Haotian Liu	Groll	Compressor calorimeter commissioning
Ting-Wei Liu	Semperlotti	Design and testing of topological acoustic metamaterials
Wei Liu	Chen, Y.	Experimental and numerical study of the air distribution in an airliner cabin
Xiaoqi (Claire) Liu	Karava	Uncertainty impact on predictive control of buildings
Domenique Lumpkin	Groll	Innovative oil-free compressor & expander technologies
Lyle, Dennis	Gibert	Macroscopic modeling and control of UAM
Jie (Jessie) Ma	Horton	Separated sensible and latent cooling systems for residential and light commercial
Ningyu Ma	Chen, Y.	Using thermal
Daniel McArthur	Cappelleri	Micro aerial vehicles
Yeshaswi Menghmalani	Cappelleri	Control of integrated energy systems
Tamzidul Mina	Yao	Dynamics and controls of mobile robots
Eeshan Mitra	Krousgrill	VIB analysis and Characterization
Allison Murray	Rhoads	Portable integrated microscale sensors
Austin Nash	Jain	Modeling and control of microCHP system
Whitney Novotny	Rhoads	Selective deposition of energetic materials
Troy Odstrcil	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Malavika Panicker	Meckl	Fuel system diagnostics
Jelena Paripovic	Davies	Identification of low frequency dynamic behavior of surrogate explosive materials
Akash Patil	Braun	Virtual Sensors for RTU's
Raghav Ramachandran	Rhoads	Defense threat reduction agency
Sugi Ramaraj	Braun/Horton	Econometric modeling & optimization of CHP operations of the wade power plant

CURRENT HERRICK LABS STUDENTS (CONTINUED)

| Student	Major Professor	Thesis subject
Aswin Ramesh	Shaver	Improving efficiency & emissions control through variable valve actuation on a diesel engine
Allison Rose Range	Rhoads	Thermomechanics of energetic materials
Katie Riley	Arrieta	Programmable structures with spatially distributed mechanical properties
Seyed Amir Sadeghi	Tzempelikos	Energy efficient buildings hub
Tridbid Saha	Shaver	Cummins: Design/control of advanced hybrid powertrain systems for heavy vehicles
Nick Salts	Groll	Optimizing heat pump system performance
Vatsal Manilal Shah	Groll	Next generation unitary AC & HP equipment
Tongyang Shi	Bolton	Acoustics and noise control
Hyun Jun Shin	Bolton	Sound Transmission
Sarah Small	Groll	Thermally integrated residential appliances
Robert St. Claire	Bolton	Prediction of aircraft noise
Mingyu Sun	Meckl	EcoCAR2-power management of plug-In hybrid vehicle
Weonchan Sung	Davies	Sound quality of HVAC equipment
Aaron Tam	Braun	
Alexander Taylor	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Josiah Thomas	Chiu	Bandwidth limited control systems
Janav Parag Udani	Arrieta	Control of bi-stable structures
Matthew VanVoorhis	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Kalen Russell Vos	Shaver	Enabling ultra-high engine system efficiency via flexible valve actuation
Danielle Wagner	Boor	Nandi clean kitchen study
Jie Wang	Chiu	SNM
Wenxin (Wendy) Wang	Boor	Indoors aerosols
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
Rih-Teng Wu	Boor	UAV project
Tianren Wu	Boor	Indoor aerosol research
Yingying Xiao	Braun	CPS: Synergy: Plug-and plug cyber-physical systems to enable buildings
Jie Xiong	Tzempelikos	Living labs experimentation
Yutong Xue	Bolton	Structural damping
Bin Yang	Groll	Cold climate heat pump
Jie Yang	Semperlotti	Structural health & dynamics
Chul Min Yeum	Dyke	Active citizen for lifecycle assessment
Ruoyu You	Chen	Energy efficient building hub
Xinye Zhang	Groll	Performance analysis of HVAC systems
Xu Zhang	Shaver	Natural gas engine control
Liuxian Zhao	Semperlotti	Structural health & dynamics
Zhidan Zhao	Horton	Thermal systems
Hongfei Zhu	Semperlotti	Metamaterials for vibration control

2015 HERRICK LABS GRADUATES

Yousof Azizi	PhD	Development of a multi-body nonlinear model for a seat occupant system
Shambhavi Balasubramanian	MSME	Fuel Type Estimation Using Fuel System
Kunal Bansal	MSME	Modeling and evaluation of scroll expanders for a liquid-flooded Ericsson power cycle
Udbhau Bhattiprolu	PhD	Modeling and measurement of the response of a beam interacting with a polyurethane foam foundation
Jiajun Cao	MSME	Analysis and simulation of nonlinearities in noise attenuation model for a diesel engine
Daniel Carr	MSME	Two laboratory studies of people's responses to sonic booms and other transient sounds as heard indoor
Chun Chen	PhD	Modeling person-to-person contaminant transport in enclosed environments
Supriya Dharkar	MSME	CO_2 eat pumps in commercial building applications with simultaneous heating and cooling demand
Mengqi Gao	MSME	Toner usage prediction for laser electro-photographic printers
Soumya Nayyar	MSME	Implementation and analysis of reverse breathing, rebreathing and cylinder deactivation for aftertreatment thermal
Mayura Halbe	MSME	Analysis and algorithm development for diesel engine systems utilizing variable valve actuation to enable premixed charge compression ignition and cylinder deactivation
Jagdish Hiremath	MSME	Development of UREA-SCR dosing control strategies for a diesel electric hybrid car
Donghun Kim	PhD	Development and applications of models and algorithms for model-predictive control in buildings
Abhinav Krishna	PhD	Analysis of a rotating spool expander for organic rankine cycle application
Yi-Shu Kung	PhD	An integrated system of vapor-compression chiller and absorption heat pump: Experiment, modeling, and energy and economic evaluation
Seungkyu Lee	PhD	Application of microperforated elements in axial fan noise control and silencer design
Zhu Shi	MSME	Numerical simulation and characterization of jet flows in indoor
Bao Tong	PhD	Prediction and reduction of aircraft noise in outdoor environments
Astitva Tripathi	PhD	On computational synthesis and dynamic analysis of nonlinear resonant systems with internal resonances
Jebaraj Vasudevan	MSME	Training and evaluation of virtual sensors for rooftop units
Haojie Wang	MSME	Modeling on single-sided wind driven natural ventilation
Yuntian (Lucius)	MSME	Increasing the high load limit of effective premixed charge compression ignition via intake valve closure modulation and late injection
Brandon Woodland	PhD	Methods of increasing network output of organic rankine cycles for low-grade waste heat recovery with a detailed analysis using a zeotropic working fluid mixture and scroll expandeer

MAJOR RESEARCH FACILITIES
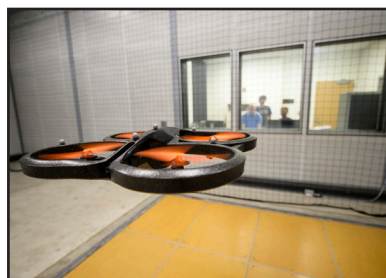
The Ray W. Herrick Laboratories

The Thermal Systems Laboratories
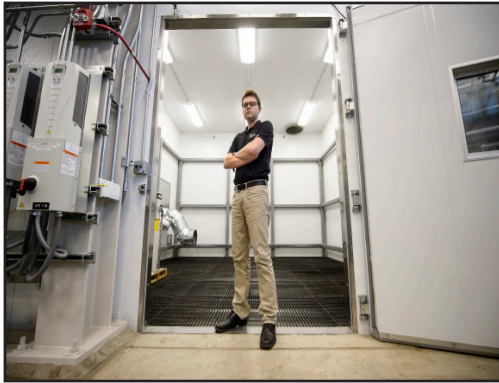
These areas are where the HVAC and Refrigeration component level and system level technology research is conducted as well as research on Air Quality. In the original building there are two psychrometric rooms (1 pair) and in the new building there are four psychrometric rooms (2 pairs) with a temperature range of −10° to 130°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 psychometric 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
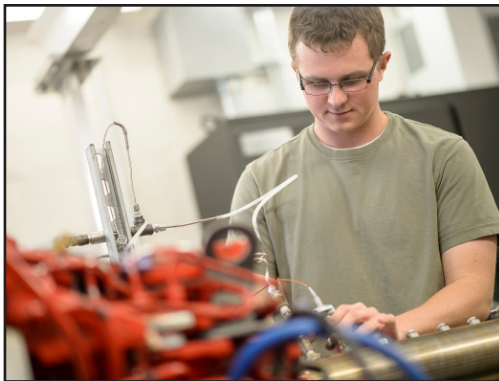
The two engine test stands in the original building and the four test cells in the new building are home to engine and hybrid systems controls research that is focused on improving efficiency, reducing engine emissions and developing efficient and environmentally friendly systems for using alternative 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.

The Ray W. Herrick Laboratories

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HERRICK LABS TECHNOLOGY TRANSFER ACTIVITIES

2018

July 16-19   Twenty-fourth International Compressor Engineering Conference

Seventeenth International Refrigeration and Air Conditioning Conference

Fifth International High Performance Buildings Conference

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