

**PURDUE
UNIVERSITY**

2007-2008

ANNUAL REPORT

Fall 2008



**RAY W. HERRICK
LABORATORIES**

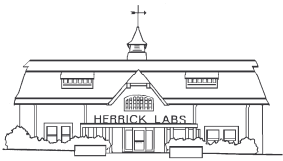
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THE RAY W. HERRICK LABORATORIES

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. 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. 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. Almost 700 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.

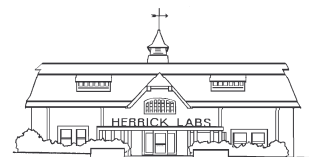
VISION

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 *Noise and Vibration Control Research Area*, the *Heating, Ventilation, Air-Conditioning, and Refrigeration Research Area* and the *Electro-Mechanical Systems* to enhance their national and international visibility and grow the reputation of these areas as the top research programs in the world.
2. To identify emerging research areas that are synergistic with laboratory focus.
3. To develop a proactive evolutionary strategy for the Laboratories to ensure its long-term stability and growth.
4. 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.
5. 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.
6. To continually grow the research environment at the Labs for the benefit of the students and faculty at the Labs.

2007-2008 HIGHLIGHTS



Research

	<i>Last Year</i>	<i>This year</i>
Research expenditures (*academic year)	\$5,143,374	\$4,985,054
Number of sponsors as of September 2008	31	33
Research assistants as of September 2008	57	56
Archival papers published (*calendar year)	28	56
Contracts in force for next academic year (July 2008-June 2009)	\$1,498,820	\$1,605,942
Proposals pending in September (HL share)	\$1,063,160	\$3,236,411
Large multi-person proposals		\$11,867,756

Education

Graduate students as of September (now)	68	66 (73)
MS	21	23
Ph.D.	47	43
Students graduated (*calendar year)	19	20
MS	6	10
Ph.D.	13	10
Undergraduate/graduate “research experience” students	30	19
Visiting scholars, Post Doctoral Students, Visiting Research Assistants	15	16
Fellowships	8	9
Grant-in-Aid	2	2
Student Paper/Poster/Thesis Awards	1	3

Technology Transfer

Conferences/Workshops held (*academic year)	2	1
Conferences planned in the next 2 years	3	4
Short Courses held (*academic year)	5	7
Herrick Labs reports to sponsors (*academic year)	21	13
Conference and journal papers (*calendar year)	113	139

Americas Co-Editors and Americas Editorial Office, **Journal of Sound and Vibration**
(Patricia Davies and J. Stuart Bolton)

Associate Editor of the **International Journal of HVAC&R Research**
(Jim Braun)

Advisory Board Member, **International Journal of Refrigeration**
(Eckhard Groll)

Editor-in-Chief, **Building and Environment (BAE) Journal**
(Yan Chen)

President, **Institute of Noise Control Engineering**, April 1, 2008 – 2010
(Patricia Davies)

* Academic Year - July 2007 → June 2008 and Calendar Year - January 2007 → December 2007

Administrative and Support Staff

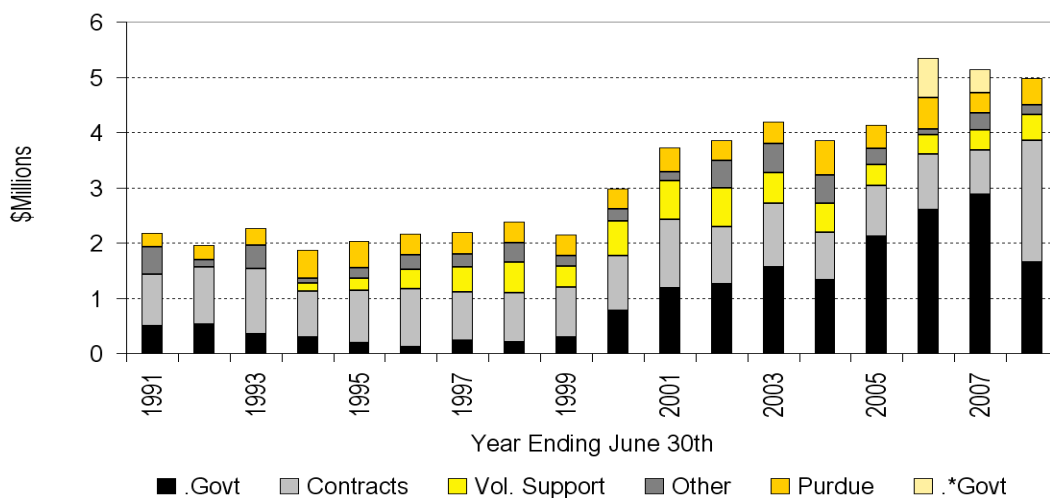
Professor Patricia Davies serves as director of the Ray W. Herrick Laboratories. Judy Hanks is her administrative assistant. The research programs are assisted by the mechanical and electronics shops headed by Fritz Peacock, supervisor of technical services. Ginny Freeman serves as administrative assistant for the Herrick Laboratories’ conferences and short courses. Donna Miller serves as editorial assistant for the *Journal of Sound and Vibration*. Additional support staff includes Donna Cackley, secretary; Gilbert Gordon, electronic shop coordinator; Bob Brown, mechanical shop coordinator and building deputy; and Frankie Lee, mechanical technician.

The Ray W. Herrick Laboratories



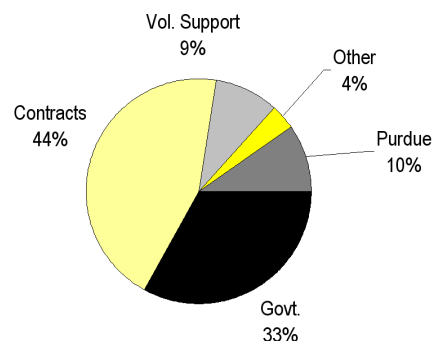
2007-2008 EXPENDITURES

The Ray W. Herrick Laboratories

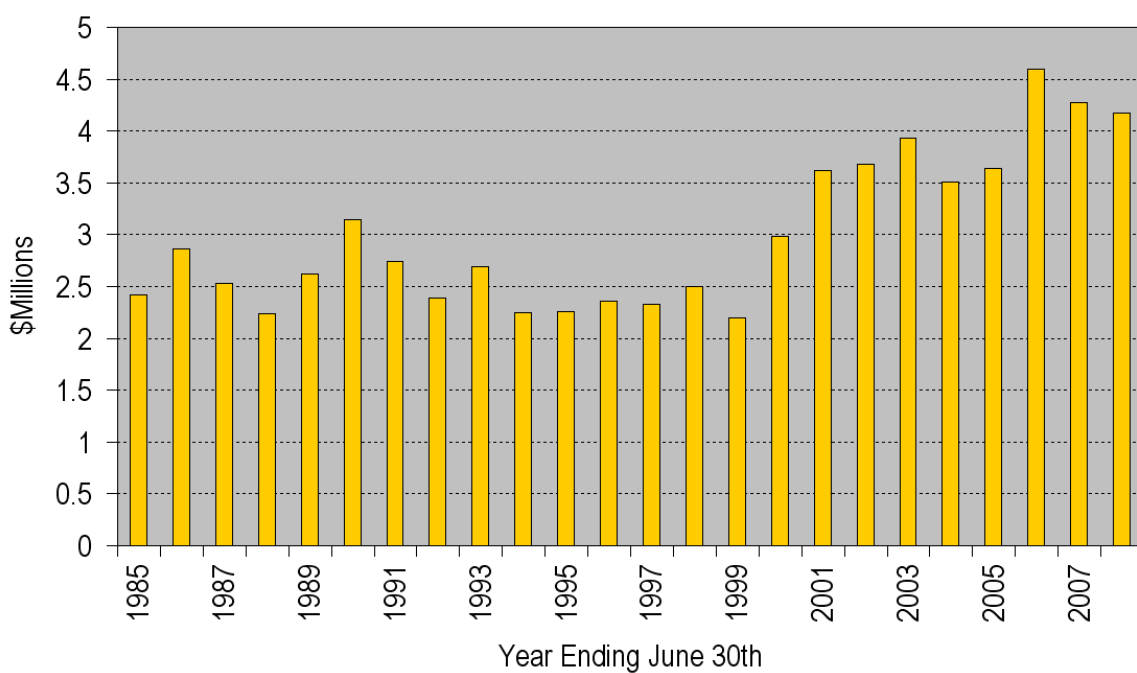


Expenditures for the 2007-2008 academic year are just below last year. These expenditures reflect a large amount of effort from our faculty, students and staff. Shown is an increase in industry funding over last year, but just under half of the contract funding is from the companies who primarily do work for DOD entities.

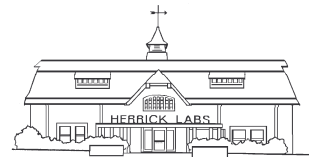
Sources of 2007-2008 Research Expenditures



Expenditures in 2000 dollars

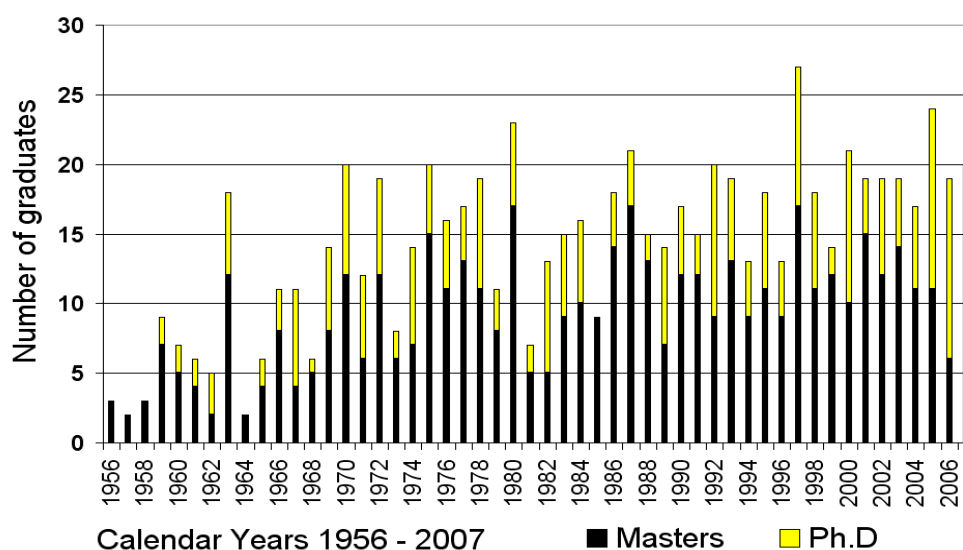


HERRICK LABS EDUCATION PROGRAMS



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.

Annual Graduation Numbers



The Ray W. Herrick Laboratories

Fellowships

Doug Cook received the Bilsland Strategic Initiatives Fellowship
Josh Cummins received the Ingersoll-Rand Fellowship
Janette Meyer received the Arvin Calspan/Gene Anderson Fellowship
Rick Meyer received the National Defense Science and Engineering Graduate Fellowship
Yury Pensky received the Laura Winkelman Davidson Supplemental Scholarship
Janene Silvers received the Laura Winkelman Davidson Fellowship
Jon White received the Adelberg Fellowship
Zhao Zhang received the Bilsland Dissertation Fellowship

Grants-in-Aid

Ian Bell received an ASHRAE Grant-in-Aid
Zhao Zhang received an ASHRAE Grant-in-Aid

Awards

Alok Joshi received an Outstanding Dissertation award presented by the College of Engineering
Sarah McGuire received the Federal Aircraft Administration Centers of Excellence Outstanding Student of the Year award
Matias Zanartu received an award for best poster presentation at the Latino Scholars Forum, sponsored by the College of Engineering and the "Qualcomm Q Award of Excellence" from Qualcomm Inc.
Tengfei Zhang received the Dimitris N. Chorafas Foundation Doctoral Dissertation Award, presented by the Chorafas Foundation
Wangda Zuo received a Travel Award for Doctoral Student, sponsored by School of Mechanical Engineering

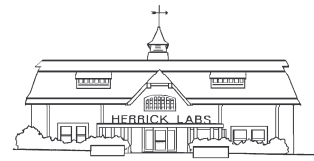


HERRICK LABS FACULTY RESEARCH INTERESTS

The Ray W. Herrick Laboratories

- Douglas E. Adams**, associate professor of mechanical engineering. PhD 2000, University of Cincinnati. Experimental nonlinear dynamics and system identification, diagnostics and prognostics, health monitoring, system-level modeling (compressors, suspensions, exhausts, mounts).
- Anil K. Bajaj**, 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.
- Robert J. Bernhard**, currently vice president for research at Notre Dame University, but continues his road-tire research at Herrick Laboratories. PhD 1982, Iowa State University. Tire/Pavement noise, acoustics, noise and vibration control, and validation of numerical methods.
- 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**, 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.
- Qingyan (Yan) Chen**, 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. 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, miniatur refrigeration systems for electronics cooling.
- Monika Ivantysynova**, MAHA Professor of Fluid Power Systems. PhD 1983, Slovak Technical University of Bratislava. Fluid power systems and components measurements, modeling, analysis, design optimization, and control optimization with applications to off-road vehicles, airplanes, cars, robots and other drive systems.
- Kristofer Jennings**, assistant professor of statistics. PhD 2003, Stanford University. Bootstrap resampling, applied statistics, engine dynamics and fault detection.
- 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.
- Jeff Rhoads**, assistant 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**, assistant 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.
- 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.

MAJOR RESEARCH FACILITIES



Thermal Systems Research Area

- Two 7000 ft³ psychrometric rooms with -10° to 130°F temperature range
- Two room indoor air quality (IAQ) laboratory
- Psychrometric wind tunnel with dust injection system
- Large HVAC equipment lab with 90 ton centrifugal chiller
- Two computer controlled compressor load stands for small compressors
- Many bench test facilities and special experimental setups

Noise and Vibration Research Area

- 25 by 20 by 18 ft reverberation room
- Anechoic room with useful volume 12 by 12 by 12 ft
- Hemi anechoic room with useful volume 41 by 27 by 18 ft
- 8 by 8 ft audiometric room
- Acoustical materials laboratory
- Two wheel chassis dynamometer with 67 inch rollers
- Anechoic wind tunnel with 18 by 24 inch test section and flow velocity up to 120 mph
- Three 1000 lb_f hydraulic shakers with 4 inch stroke
- Two 400 lb_f electromagnetic shakers
- 64 microphone acoustical holography array and 90 channel data acquisition system

Perception Based Engineering

- 8 by 8 ft audiometric room
- Printer image quality facilities
- Binaural measurement system and sound quality estimation software
- Steering wheel vibration perception facility
- Two room indoor air quality (IAQ) laboratory
- Perception Based Engineering Lab (*future*) (combined thermal, acoustic, motion, and visual perceptions)

Electro-mechanical Systems Research Area

- 1500 psi 3-axis electro-hydraulic robot
- Four post experimental electro-hydraulic lift system
- Diesel engine control load stand with eddy current dynamometer, EGR, and exhaust after-treatment with transient emissions analyzers
- Gasoline engine control load stand with eddy current dynamometer and transient emissions analyzer
- Prognostics modeling and simulation facility
- Thermal/acoustic test facility
- Environmetrics material conditioning chamber
- MTS static/dynamic/fatigue test apparatus
- Large inventory of vibration and acoustics sensors and actuators

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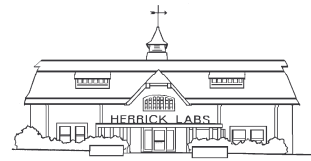


CURRENT HERRICK LABS STUDENTS

The Ray W. Herrick Laboratories

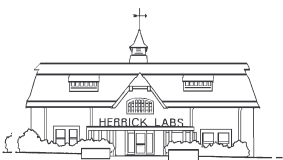
Student	Major Professor	Thesis Subject
Gayatri Adi	Shaver	Modeling, design and control of advanced power train
Varun Agrawal	Yao	Adaptive robust control of flexible cable driven surgical robotic devices
Michelle Bash	Groll	Smart Compressors
Ian Bell	Groll/Braun/King	Ericsson cycle cooler
Chaitanya Bhat	Meckl	Multi-objective optimization of small electric power units
Nasir Bilal	Adams	Prediction uncertainty in compressor modeling and simulation
Craig Bradshaw	Groll	Analysis of miniature-scale linear compressors for electronics cooling
Ethan Brush	Adams	Health monitoring of missile casing
Carson Budde	Adams	Load identification in composite rotors
Mike Bunce	Shaver	Biodiesel combustion in modern diesel engines
Neha Chandrachud	Meckl	On-Board diagnostics of diesel engines
Hoyt Yu Chang	Li	Acoustics
Li-Jen Chen	Mongeau	Fluid structure interactions within the human larynx
Douglas Cook	Mongeau/Nauman	Fluid structure interactions
Josh Cummins	Adams	Tire diagnostic testing
Tyler Dare	Bernhard	Investigation of tire/pavement noise generation mechanisms
Yash Deshmukh	Davies	Nonlinear dynamics of seat-occupant systems
Tiffany Di Petta	Adams	Health monitoring of military vehicles
Frank Eberhardt	Davies/Bolton	Diesel Engine Noise
Shreekant Gayaka	Yao/Meckl	Diagnosis and emission control of engines
Kamran Ahmed Gul	Adams	Engine cold-test driveline modeling and simulation
Jitendra Gupta	Chen	Infectious disease transmissions in airliner cabins
Thanh Huy Ha	Chiu/Allebach	Electromechanical systems
Carrie Hall	Shaver	Fuel flexible combustion control
Derek Hengeveld	Braun/Groll	Development of a system design methodology or robust thermal control systems to support operationally responsive space
Julio Ho	Bolton/Wodicka	Speech acoustics
Kwan Woo Hong	Bolton	Numerical methods in acoustics
Kang Hou	Bolton	Acoustics of small enclosures
Matt Houtteman	Adams	Nondestructive testing
Scott James	Meckl/King	Engine diagnostics
Andy Jessop	Li	Prediction and reduction of low frequency ground-borne noise
Gauri Joshi	Davies	Nonlinear dynamics of seat-occupant systems
Raymond Joshua	Adams	Nonlinear methods and testing of morphing aircraft
Ravindra Kakade	Meckl	Engine Diagnostics
Woohyun Kim	Braun	Methods for evaluating diagnostic protocols for packaged air conditioning equipment
Yan Fu Kuo	Chiu	Tone curve stabilization for color electrophotography
Robin Kusmanto	Adams	System of systems modeling
Ki Sup Lee	Chen	Air distribution effectiveness with stratified flows in rooms

CURRENT HERRICK LABS STUDENTS (CONTINUED)



Feng Liu	Chiu	Xerographic process control
Sheng Liu	Li	Transmission of low frequency sound above a poro-elastic ground
Lu Lu	Yao	Integrated direct/indirect adaptive robust control with quantitative parameter estimation
Vishal Mahulkar	Adams	System of systems modeling and optimization in Navy ships
Andrew Marshall	Davies	Human response to supersonic aircraft noise
Margaret Mathison	Braun/Groll	Modeling of a two-stage rotary compressor
Sagnik Mazumdar	Chen	Airliner cabin environment research
Sarah McGuire	Davies	Feasibility of constructing a survey and measurement database for validating environmental noise metrics
Shawn McKay	Adams	System of systems reliability analysis in Navy ships
Janette Meyer	Adams	Modeling and simulation of rattle vibrations in car seats
Rick Meyer	Yao	Modeling and adaptive robust control of fuel cell power systems
Rajani Modiyani	Shaver	Modeling and control of HCCI
Amit Mohanty	Yao	Coordinated control of electro-hydraulic robot manipulators
Shashi More	Davies	Aircraft noise characteristics and metrics
James Mynderse	Chiu	Motion and vibration control
Joe Poland	Groll	Acoustically enhanced heat transfer in microchannels
Tyler Robbins	Adams	Acoustic leak detection in engine blocks
Ryan Schultz	Meckl	Diesel particulate filter diagnostics
Chintan Shah	Meckl	Diesel particulate filtering
Hyunjun Shin	Bolton	Acoustical materials
Yoon Shik Shin	Bolton	Electronic cooling fan noise
Janene Silvers	Adams	Active vibration control of fuselage structure
David Snyder	Shaver	Modeling, design and control of advanced powertrain
Karla Stricker	Shaver	Advanced combustion control with variable valve actuation
Hales Swift	Davies	Health effects of noise
Sara Underwood	Adams	Composite damage detection using laser vibrometry
Dan Van Alstine	Shaver	Advanced mode combustion control with variable valve actuation
Miao Wang	Chen	Modeling low velocity large scale fluctuating flows in ventilated spaces at transitional Reynolds numbers
Jonathan White	Adams	Structural diagnostics in thermal protection systems
Tanya Wulf	Bernhard	Texture effects on tire/pavement noise
Guangqing Xue	Chen	Infectious disease transmissions in airliner cabin
Nate Yoder	Adams	Diagnostics and prognostics for rolling tires
Matias Zanartu	Mongeau/Wodicka	Voice synthesis
Wangda Zuo	Chen	Rapid simulation of contaminant transport in buildings
Brandon Zwink	Adams	Damage detection in a composite rotor blade using

The Ray W. Herrick Laboratories



HERRICK LABS TECHNOLOGY TRANSFER PROGRAMS

The Ray W. Herrick Laboratories

2010

July 10-15, Twentieth International Compressor Engineering Conference
Thirteenth International Refrigeration and Air Conditioning Conference
Compressor and Refrigeration Short Courses

2008

July 12-17, Nineteenth International Compressor Engineering Conference
Twelfth International Refrigeration and Air Conditioning Conference
Compressor and Refrigeration Short Courses

2007

October 17-19, Short Course: Nonlinear Vibration:
Theory & Practice, Indianapolis
Aviation Technology Center

November 1-4, 10th Annual Colloquium on
International Engineering Education



2006

July 17-20, Eighteenth International Compressor
Engineering Conference
Eleventh International Refrigeration and
Air Conditioning Conference

July 15-16, Short Course: Noise Control Methods
for HVAC&R Applications

July 15-16, Short Course: Latest Developments with Respect
to the Transcritical CO₂ Cycle Technology

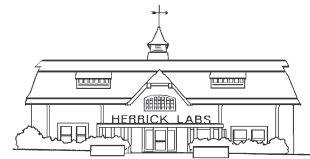
July 24-28, Short Course: Nonlinear Vibrations, Los Alamos
Dynamics Summer School

September 21, Short Course: Measurements of
Acoustic Materials, Brüel & Kjaer, Novi, MI

October 16-18, Short Course: Health Monitoring,
Palmdale, CA



2007 HERRICK LABS GRADUATES



Spencer C. Ackers	MSME	<i>A Method for Crack Detection in a Wheel End Spindle Using Broadband Modal Excitation</i>
Gazi Naser Ali	PhD	<i>Image Quality Analysis of Electrophotographic Printers for Banding Measurement and Forensic Application</i>
Adam Andruska	MSME	<i>The Design, Analysis, and Control of a Two Dimensional Hyper-Redundant Robot Interacting with an Elastic Environment</i>
Arthur Blanc	PhD	<i>Validation of Vibro-Acoustic Numerical Models</i>
Chen, Xi	MSME	<i>A Numerical Study on Decontaminating Unoccupied Airliner Cabins</i>
Muhammad Haroon	PhD	<i>A Methodology for Mechanical Diagnostics and Prognostics to Assess Durability of Ground Vehicle Suspension Systems</i>
Ali Israr	PhD	<i>Tactual Transmission of Phonetic Features</i>
Scott James	MSME	<i>Diesel Engine Diagnostics Using Singular Spectrum Analysis</i>
Alok A. Joshi	PhD	<i>Strategies for Data-Based Diesel Engine Fault Diagnostics</i>
Miguel E. Jovane	PhD	<i>Modeling and Analysis of a Novel Rotary Compressor</i>
Andrew J. Marshall	MSME	<i>A Preliminary Investigation into the Perceptual Characteristics of Low Level Sonic Booms Heard Outdoors</i>
Paloma Y. Mejia	MSME	<i>Experimental and Numerical Investigation of Separated-Reattached Flows Behind Uniform and Notched Spoilers</i>
Daniel H. Robinson	MSME	<i>Effect of Low Frequency Sound on Resonant Sound Insulation and Rattle Systems</i>
Mychal Spencer	MSME	<i>Indirect Determination of the Strain and Stress in Physical Models of the Vocal Folds Using Digital Image Correlation</i>
Nick Stites	MSME	<i>Minimal-Sensing, Passive and Semi-Active Load and Damage Identification Techniques for Structural Components</i>
Shankar Sundararaman	PhD	<i>Numerical and Experimental Investigations of Practical Issues in the Use of Wave Propagation for Damage Identification</i>
Liangzhu Wang	PhD	<i>Coupling of Multizone and CFD Programs for Building Airflow Distribution and Contaminant Transport Simulations</i>
Adam J. Wichman	MSME	<i>Evaluation of Fault Detection and Diagnosis Methods for Refrigeration Equipment and Air-Side Economizers</i>
Anthony (Tony) Wright	MSME	<i>Rapid-fire Combustion Engine (non-thesis)</i>
Tengfei Zhang	PhD	<i>Detection and Mitigation of Contaminant Transport in Commercial Aircraft Cabins</i>
Zhao Zhang	PhD	<i>Modeling of Airflow and Contaminant Transport in Enclosed Environments</i>

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