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RAY W. HERRICK LABORATORIES
ANNUAL REPORT
JULY 1, 2020 - JUNE 30, 2021



HOME OF THE CENTER FOR HIGH PERFORMANCE BUILDINGS



HERRICK LABORATORIES

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THE RAY W. HERRICK LABORATORIES
MESSAGE FROM
THE DIRECTOR

Jeffrey (Jeff) F. Rhoads

Members of the Ray W. Herrick Laboratories Community,

In this forum last year, I concluded my annual note by predicting that “2021 would present no fewer opportunities, or challenges, than 2020”. While the continuation of social unrest, political strife, and the global pandemic, ensured that the challenges remained, I’m happy to report that our students, faculty, and staff, consistently rose above this difficult landscape to reach new heights. To this end, I think it would be fair to characterize 2021 as the year where our common passion and commitment to a shared vision of real world impact through collaborative engineering research and education allowed us to adapt and overcome for the common good. We learned how to effectively conduct research, teach, and learn remotely (with masks, face shields, and social distancing); we learned how to collaborate with sponsors and build the Herrick community remotely; and we learned that though we may often be more than six feet apart, our common bond does not need to weaken. With this in mind, rather than spend the remainder of my note describing the many challenges that we have faced over this past year, please allow me the opportunity to focus on the positive, as the present and future of the Ray W. Herrick Laboratories is certainly bright!

As we have seen in many business sectors, the workforce has undergone, and continues to undergo, significant realignment. To this end, our Managing Director, Maralee Hayworth, and I have helped facilitate a series of systematic staff transitions and a staff modernization effort, which we hope will allow us greater agility in the face of our growing research portfolio (more on that later). Of particular note is the addition of Ashley Ancil, who will serve as the Laboratories’ Senior Safety Officer – a new role that will ensure that as we push the boundaries of what is possible in a university laboratory, we do so mindful of safety and security. In addition, in 2021, we welcomed a new faculty member, Professor Monique McClain, to our team. Monique further enhances our growing expertise in additive manufacturing and energetic materials, is a wonderful

complement to our 2020 new faculty cohort, and will also conduct research at the Maurice J. Zucrow Laboratories, further establishing a bridge with our sister facility. You can read more about Monique later in this document and will hopefully get to meet her, as well as our many new staff members soon!

Though the pandemic prevented the proper send-off that I would have liked, we also had the opportunity this year to celebrate the career of Professor Qingyan (Yan) Chen, who will retire in August after 19 years of service to the Laboratories. With his deep expertise in indoor air quality and healthy building design, Yan became a “reluctant celebrity” this past year, with his work being featured in hundreds of international media outlets as society navigated the realities of COVID-19. I hope that we can all learn from the research of Yan and his students and make buildings healthier in the years to come. Best wishes on an active retirement Yan!

On the performance metric front, I'm happy to report that research expenditures markedly increased again this year (~42%; rendering a two-year growth metric of 96%) and our student population continued to grow (~34% increase in undergraduate, graduate, and post-doctoral researchers). Managing this growth has certainly been a “good problem”, but I think it is a testament to the confidence that government and industry has in the abilities of our faculty, staff, and students.

I am also happy to report that our students, faculty, and staff continued to shine on the technical stage in 2021. Though I cannot highlight everyone in this constrained format, it was exciting to see Leon Brendel, Kwok (Frank) Lee, and Professor Eckhard Groll fly with a prototype refrigeration system in zero-g! This work, and our ongoing research activities in both the industry-supported Center for High Performance Buildings and the National Aeronautics and Space Administration (NASA)-funded Resilient Extraterrestrial Habitat Institute (RETHi), ensures that the Herrick community will not only define the future built environment on this planet, but in outer space as well!

Other highlights this year included Professors Yangfan Liu, Stuart Bolton, Patricia Davies, contributing to the National Academy of Engineering's focus work on noise control engineering (Stuart also leveraged his expertise and a collaboration with the University's Acoustical Society of America chapter to unveil the secrets of Purdue's “clapping circle”); Professor Greg Shaver and his students bringing online our first natural gas engine test cell; our thermal sciences team bringing online our first flammable-refrigerant rated psychrometric chambers; our newest faculty, Professors Rebecca Ciez, Tian Li, and Davide Ziviani, each receiving their first research awards as tenure-track faculty; and learning that the large-scale cooperative engagement with the Army Research Laboratory that was announced in this forum last year (which includes

myself, Professor George Chiu, and Professor James Gibert amongst its many participants) was fully allocated at \$24.7M by the United States Department of Defense, confirming its position as one of the largest research awards in university history.

Looking ahead, I cannot help but be excited. In 2022, we will celebrate the 50th anniversary of the Herrick Conferences, which will allow us a superb platform to highlight our amazing students, exciting research, and tangible impact of our works. We will also open our new Human/Building Interaction Laboratory, which will facilitate controlled studies investigating the complicated interdependencies of humans and buildings.

I'm happy to report that Herrick faculty, staff, and students remain poised, ready to tackle the emerging challenges tied to buildings, transportation, space exploration, the energy sector, climate change, materials and manufacturing, national security, and the human-machine interface. To this end, we continue to push toward physical, human capital, and intellectual growth, while simultaneously exploring new business models, such as contract testing, and taking time to further strengthen the Laboratories' community. All of this will be done by harnessing our common passion and commitment to positively impact the world around us.

I look forward to chatting soon, hopefully in person!

Regards,



Jeffrey (Jeff) F. Rhoads



RAY COHEN, DIRECTOR, 1972 - 1993

We are sad to announce that Raymond Cohen, professor and former director of the Ray W. Herrick Laboratories, passed away this year.

Raymond Cohen was born November 30, 1923. He served in World War II as part of the 89th Infantry Division, which was the first to liberate a concentration camp. He received his BSME in 1947, his MSME in 1950, and his PhD in 1955, all from Purdue. He had a distinguished academic career and received the highest honor bestowed by the governor of Indiana – the *Sagamore of the Wabash* award. However, Cohen didn't mention these things when asked of what career achievement he was most proud.

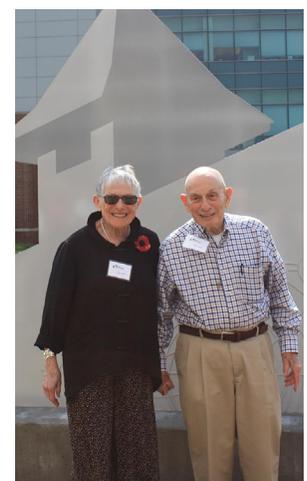
"I'm most well known for directing Herrick Laboratories, for its expansion and growth to international prominence," Cohen said. "This is my proudest accomplishment. Worldwide, everyone knows Herrick Laboratories. In Japan and China's refrigeration and air conditioning industries, for instance, Herrick Laboratories is Purdue."

The Ray W. Herrick Laboratories were founded in 1958 under the leadership of Cohen's mentor, Professor Bill Fontaine. "He got everything started," Cohen said. "I would have never wanted to start from scratch. When I took over, Herrick Laboratories already had a building and the beginnings of a good research program."

Cohen did research through the Laboratories in its early days. Not long after becoming a full professor in 1960, he and his graduate students solved a problem that was plaguing the refrigeration and air conditioning industry at the time – costly, catastrophic compressor valve failures caused by vibrations. Their published findings attracted international notice and put Herrick Laboratories on the map. He eventually became director of the Labs, and served in that capacity from 1972 to 1993.

Cohen made numerous other contributions to his field as well, such as publishing nearly 100 papers, starting two conferences that are still held biannually at Purdue and serving as the founding editor of HVAC&R Research, a scholarly journal published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

The Ray W. Herrick Laboratories and the School of Mechanical Engineering extend its deepest sympathies to Ray's wife Lila, herself a long-time contributor to Herrick Laboratories functions, and the entire Cohen family.



FY2020 - FY2021 HIGHLIGHTS

RESEARCH - FISCAL YEAR	FY2020	FY2021
Research Expenditures	\$11,643,398	\$16,577,687
Proposals Submitted	\$40,522,937	\$36,859,531
Number of Sponsors	67	53

STUDENTS

Graduate Student Researchers	133	163
MS	49	55
Ph.D.	84	108
Undergraduate Student Researchers	28	49
Post-Doctoral Researchers	3	7

STUDENTS GRADUATED

MS	15	9
Ph.D.	16	16

VISITING RESEARCHERS

Visiting Research Assistants	7	1
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EDUCATION AND OUTREACH

Conferences/Workshops Held	0*	2**
CHPB Members Meetings	2**	2**
Conferences Planned in the Next 2 Years	5	2
Short Courses Held	0*	0*

* - Due to COVID-19, many conferences and workshops were canceled or postponed.

** - Meetings Held Virtually

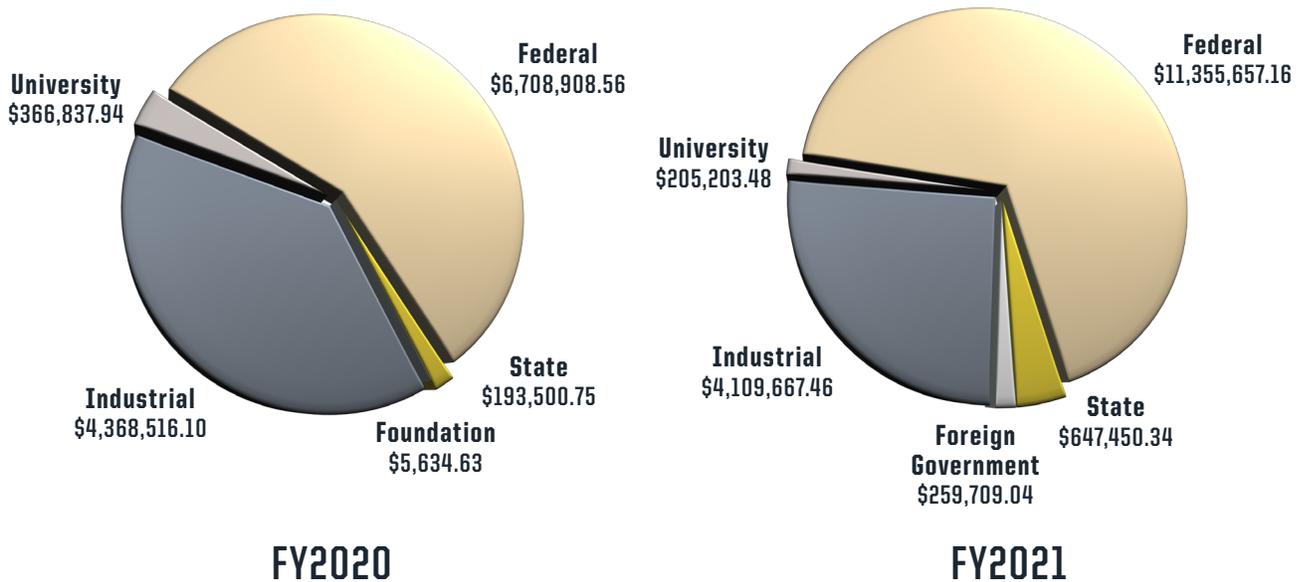
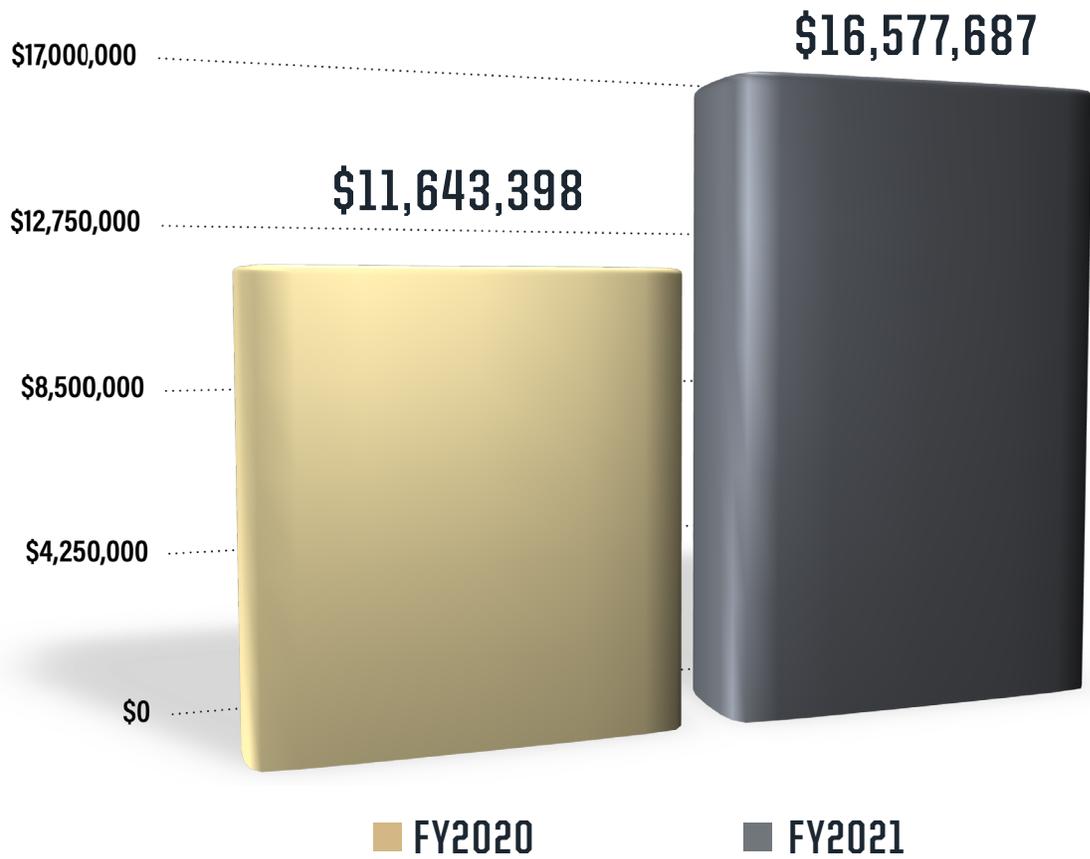
PURDUE DAY OF GIVING

Thanks to the incredible generosity of Purdue alumni, faculty, staff, retirees, students, parents, and friends, the University is positioned to help our students pursue their goals like never before. During the 2021 Day of Giving the University raised a record \$52,489,367 from over 25,000 gifts!



FY2020 - FY2021 RESEARCH EXPENDITURES

Shown below is the distribution of research expenditures for FY2020 and FY2021.



HERRICK STUDENT AWARDS

2021 - 2022 WILLIAM E. FONTAINE FELLOWSHIP

The William E. Fontaine Memorial Fellowship was established in memory of Bill Fontaine, the founding Director of the Ray W. Herrick Laboratories, to encourage the efforts of deserving graduate students.

This year we awarded two quarter-time Research Assistantships. We congratulate Shveta Dhamankar and Tyler Shelly as the William E. Fontaine Memorial Fellowship Recipients for 2021 - 2022!



DHAMANKAR



SHELLY

2021 - 2022 RAY W. HERRICK ASSISTANTSHIP

The Ray W. Herrick Assistantship was established by the Herrick Foundation in 1990 to support HVAC&R graduate research. To receive this prestigious award, a student must be doing, or intending to do, thesis-based research on a HVAC&R problem of interest to industry exclusively at the Ray W. Herrick Laboratories.

Changkuan "Steven" Liang was selected as the recipient of the 2021 - 2022 Ray W. Herrick Assistantship!

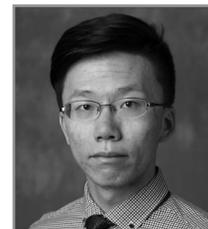


LIANG

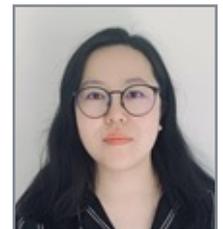
CONFERENCE AWARDS

This May, several Purdue students participated in the Student Paper Competition at the 2020ne Purdue Conferences. Winners included: **Haotian Liu**, First Place, Compressor Conference; **Jie Ma**, Third Place, Compressor Conference; and **Andrew Fix**, Second Place, Refrigeration & Air-Conditioning Conference.

Sansit Patnaik won the Elasticity Committee Student Paper Competition for a paper entitled "Fractional Order Kinematic Approach to Nonlocal Elasticity" at the 2021 ASCE Conference.



LIU



MA



FIX



PATNAIK

SELECT STUDENT SUCCESS STORIES

A team of engineers from Purdue University, Air Squared Inc., and Whirlpool Corporation is working on building a fridge for zero gravity that operates in different orientations and just as well as the one in your kitchen, giving astronauts access to longer-lasting and more nutritious food. **Leon Brendel** has helped lead the research at Herrick Labs. In May, Brendel—along with Herrick Engineering Technician Frank Lee, ME student Paige Beck and Herrick faculty member Eckhard Groll—tested the prototype fridges in microgravity. [Read the Full Story.](#)



BRENDEL

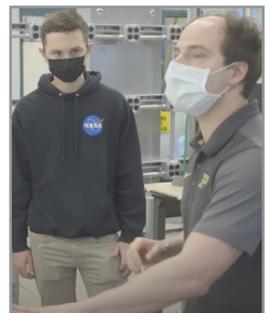
A Herrick Research team that includes Herrick student **Vatsal Shah**, former Herrick research engineer Orkan Kurtulus, and Herrick faculty members Jim Braun, Eckhard Groll and Travis Horton have developed a new autonomous sensor technology that may help businesses monitor refrigeration and heating systems in real time much faster and easier than current options. The sensor determines the oil circulation to provide data on the health and functionality of the overall system.

[Read the Full Story.](#)



SHAH

Undergraduate student research work is vital to the success of the Laboratories. Herrick faculty member **Davide Ziviani** lead a team of 17 undergraduate students as part of a project with the Resilient Extraterrestrial Habitats Institute. [Read the Full Story.](#)



ZIVIANI & STUDENT

HERRICK RESOURCE COMMITTEE

The Herrick Laboratories Student resource Committee is a student-run committee that provides Herrick students, faculty, and staff with opportunities for personal and professional growth. They organize seminars, fundraisers, IAC student events, and perform community outreach. The Herrick Resource Committee was led by Zach Siefker and Leon Brendel in 2020 - 2021.



SELECT FACULTY SUCCESS STORIES

Herrick Professor **Eckhard Groll** was a recipient of the Trask Innovation Fund for the project "In-situ Oil Circulation Ratio (OCR) Measurement Using Separation Method in Suction Lines of Systems Running Vapor Compression Cycle." The Trask Innovation Fund supports short-term projects that enhance the commercial value of Purdue's intellectual property.



GROLL



TZEMPELIKOS

Herrick Professor **Thanos Tzempelikos** was awarded the prestigious Leon Gaster Award from the Society of Light and Lighting as a co-author of the paper, "Cross-validation and robustness of daylight glare metrics", published in the esteemed journal *Lighting Research and Technology*. The award was presented at the Society's Annual Awards evening on December 3, 2020 in London.

Herrick Professor **Jim Braun**, Professor **David Warsinger**, and Herrick Student **Andrew Fix** showcased work being done at Herrick's Center for High Performance Buildings in the article *Bring the Outdoors In: The Energy-Efficient Method for Using 100% Air in Buildings*. [Read the Full Article.](#)



WARSINGER, FIX, BRAUN



BOLTON



DAVIES



LIU

Herrick Professors **Stuart Bolton**, **Patricia Davies**, and **Yangfan Liu** are featured in the Summer 2021 edition of the National Academy of Engineering's *The Bridge*, with an article on acoustic source localization. [Read the Full Article.](#)

Effective August 2021, the following faculty have received promotions. **Andres Arrieta Diaz** and **James Gibert** have been promoted to Associate Professors. **Jun Chen** and **Fabio Semperlotti** have been promoted to Full Professors.



ARRIETA



GIBERT



CHEN



SEMPERLOTTI

CENTER FOR HIGH PERFORMANCE BUILDINGS



- The CHPB Spring meeting was conducted with a virtual format on June 8 - 10, 2021. The main objectives of the meeting was to review the progress made by each regular CHPB project and assess the seed-funded projects. On the last day, faculty members presented concept projects for 2022 that will be selected during the fall meeting. A total of 13 concept papers were proposed. As part of the program, **Jerine Ahmed** from Southern California Edison and **Ed Vineyard** from the U.S. Department of Energy's Building Technologies Office gave invited plenary presentations. Over the three-day event, more than 70 members joined the CHPB activities. The 2021 CHPB Fall meeting is scheduled for October 18 - 20.
- A team led by Purdue's Center for High Performance Buildings (CHPB) has received a grant to develop a novel electrochemical heat pump technology, with the potential to outperform conventional vapor compression systems and enable the next generation of heating, ventilation, air-conditioning, and refrigeration (HVAC&R) equipment. The three-year, \$1.25-million grant from the US Department of Energy's (DOE) Building Technologies Office is entitled "NO Vapor-compression, Electrochemical Looping Heat Pump (NOVEL HP)". Initial development of the concept was funded through a grant from the CHPB, culminating in proof-of-concept experimental work and simulation assessments. [Read the Full Story.](#)

RESILIENT EXTRA-TERRESTRIAL HABITAT INSTITUTE

How to Build a Home on the Moon: A small-scale replica of a lunar habitat is taking shape at the Laboratories. The goal is to prepare for life in a hostile environment—including our own. Purdue Professor Shirley Dyke leads the Resilient Extra-Terrestrial Habitats Institute.



[Read the Wall Street Journal Article](#)

[Listen to Shirley Dyke in Apple TV's Podcast For All Mankind](#)



HERRICK CENTER STORIES

PURDUE ENERGETICS RESEARCH CENTER

In August, Purdue and the Army Research Laboratory forged a cooperative agreement focused on the development of new energetic materials, manufacturing processes, and modeling and diagnostic tools. The 3-year, \$24.7M project is one of the largest research contracts in Purdue history, and will be completed primarily at the Maurice J. Zucrow and Ray W. Herrick Laboratories.



During the summer of 2021, as part of the Advancing Army Modernization Priorities through Collaborative Energetic Materials Research (AAMP-EM) project, Purdue hosted the first summer undergraduate program called AAMP-UP!'21. This program included 25 students from Purdue and other universities during a 10-week student-centered, experiential, research program for undergraduates to help further their academic and professional goals. The program was a tremendous success with year 2 of the program already in the works.



INTERNET OF THINGS 4 PRECISION AGRICULTURE

Herrick Professor David Cappelleri will Co-PI a new five-year, \$26 million grant from the National Science Foundation with the Engineering Research Center for the Internet of Things 4 Precision Agriculture (IoT4Ag). This project was created to develop advanced agricultural technologies to address food, energy and water security challenges.

Professor Cappelleri is also featured in the Medium article "Farm to every table via precision agriculture" from November 2020. This article focuses on the efforts of IoT4Ag and its mission to create and translate to technologies for precision agriculture — as well as train and educate a diverse workforce that will address the societal grand challenge of food, energy, and water security for decades to come. [Read the Full Article.](#)



2021 HERRICK EDUCATION AND OUTREACH

Due to the COVID-19 Pandemic, scheduled events for 2020 were either canceled or postponed.

NOVEMBER 11 - 12, 2021 Annual Colloquium on International Engineering Education

JULY 10 - 14, 2022 2022 Herrick Conferences - 50th Anniversary Celebration



HERRICK CONFERENCES

JULY 10 - 14 2022

COMPRESSOR ENGINEERING
REFRIGERATION & AIR CONDITIONING
HIGH PERFORMANCE BUILDINGS

CELEBRATING 50 YEARS OF INNOVATION



Ray W. Herrick Laboratories

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