AEROGRAM

2024/2025

PURDUE UNIVERSITY SCHOOL OF AERONAUTICS AND ASTRONAUTICS

DUCK, DUCK, BOOM

Tackling the impact of bird strikes on jet engines

PAGE 22

DAVE MASON

GRAND OPENING OF ZUCROW LAB 9

On October 4, 2024, a ceremonial ribbon-cutting marked the opening of the new $73 million High-Speed Propulsion Lab, otherwise known as ZL9. Eckhard Groll, the William E. and Florence E. Perry Head and Reilly Professor of Mechanical Engineering; Arvind Raman, the John A. Edwardson Dean of the College of Engineering and the Robert V. Adams Professor in Mechanical Engineering; and Bill Crossley, the Uhrig and Vournas Head of Aeronautics and Astronautics, held the oversized scissors at the event.

The scale of ZL9 dwarfs the facilities in ZL8 and features a new, high-pressure air plant that represents an order-of-magnitude increase in capabilities compared to the old air compressor system. ZL9 features new testing capabilities for innovative research in rocket combustion and gas turbine engines, continuing Purdue's history of world-class research and development in those areas at a scale only found in government or large defense contractor facilities. The new lab will augment Purdue's advanced propulsion testing and research prowess.

Read about Zucrow's 75th anniversary on page 44.

AEROGRAM is an annual publication for alumni and friends of the Purdue University School of Aeronautics and Astronautics. Unless otherwise noted, articles in *Aerogram* may be reprinted without permission. Appropriate credit is appreciated.

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ON THE COVER: Alumnus Zherui Martinez-Guo, assistant professor of AAE, leads the Impact Science Lab.

PURDUE UNIVERSITY | School of Aeronautics and Astronautics

IN THIS ISSUE:

LETTER FROM THE HEAD

Dear alumni, friends, students, staff and faculty,

We often hear that aerospace engineering is the ultimate team sport. No one launches to the Moon alone. As a reflection of that, a collaborative culture is thriving within the School of Aeronautics and Astronautics. A strong community is a pillar in our strategic plan, and I'm proud of what our faculty and staff continue to accomplish.

Our school reached two record highs recently: Our undergraduate program is now ranked No. 3 by U.S. News and World Report, and our Gambaro Graduate Program in Aeronautics and Astronautics is No. 2 in the U.S. — in a tie for the best program at a public institution.

It's a remarkable achievement for our program that had a total student enrollment around 300 when I joined Purdue, and now graduates more aerospace engineers than any other institution in the US. That growth comes with challenges, but we persist through grit, determination, and togetherness.

When our student clubs were outgrowing Armstrong Hall, we leased 5,000 square feet of space off campus. With the tools and equipment there, they can design and build better vehicles for collegiate engineering competitions. Working with the college, we are now securing an on-campus location to make this "maker space" more accessible.

New professor-of-practice and lecturer positions are becoming a core part of how we address our record enrollment and continue to provide a top-tier education. They reduce the strain on tenured faculty who are still engaged in research, and I'm heartened to see that they are being integrated as part of the team. We are also rewarding our outstanding tenure-track faculty through two more named professorships, made possible by a loyal donor.

Like many other schools our size, we are also adding postdocs to expand our research reach. The new Apollo 11 Postdoctoral Fellowship is funded through the success of the patented ALITEC solid rocket fuel, developed by Adranos founder Brielle Terry during her PhD studies here.

You'll find stories on many more developments within this publication: from new facilities to patented technologies; from fundamental research producing more resilient jet engines to a structural fatigue training partnership with a national defense organization.

With these successes and more, I'm grateful to have received and accepted an offer continuing my role as the Uhrig and Vournas Head of Aeronautics and Astronautics. The coming years will bring many more challenges, to be sure. But if we work together, they will yield successes too.

Boiler up!

Bill

WILLIAM A. CROSSLEY
Uhrig & Vournas Head of Aeronautics and Astronautics

PHOTO: JOHN UNDERWOOD

AERONAUTICS AND ASTRONAUTICS BY THE

NUMBERS

RANKED **3RD**

BEST UNDERGRADUATE AEROSPACE/ AERONAUTICAL/ ASTRONAUTICAL ENGINEERING

U.S. News and World Report (2024)

RANKED **2ND**

BEST GRADUATE AEROSPACE/ AERONAUTICAL/ ASTRONAUTICAL ENGINEERING

U.S. News and World Report (2024)

THE FACULTY (FALL 2024)

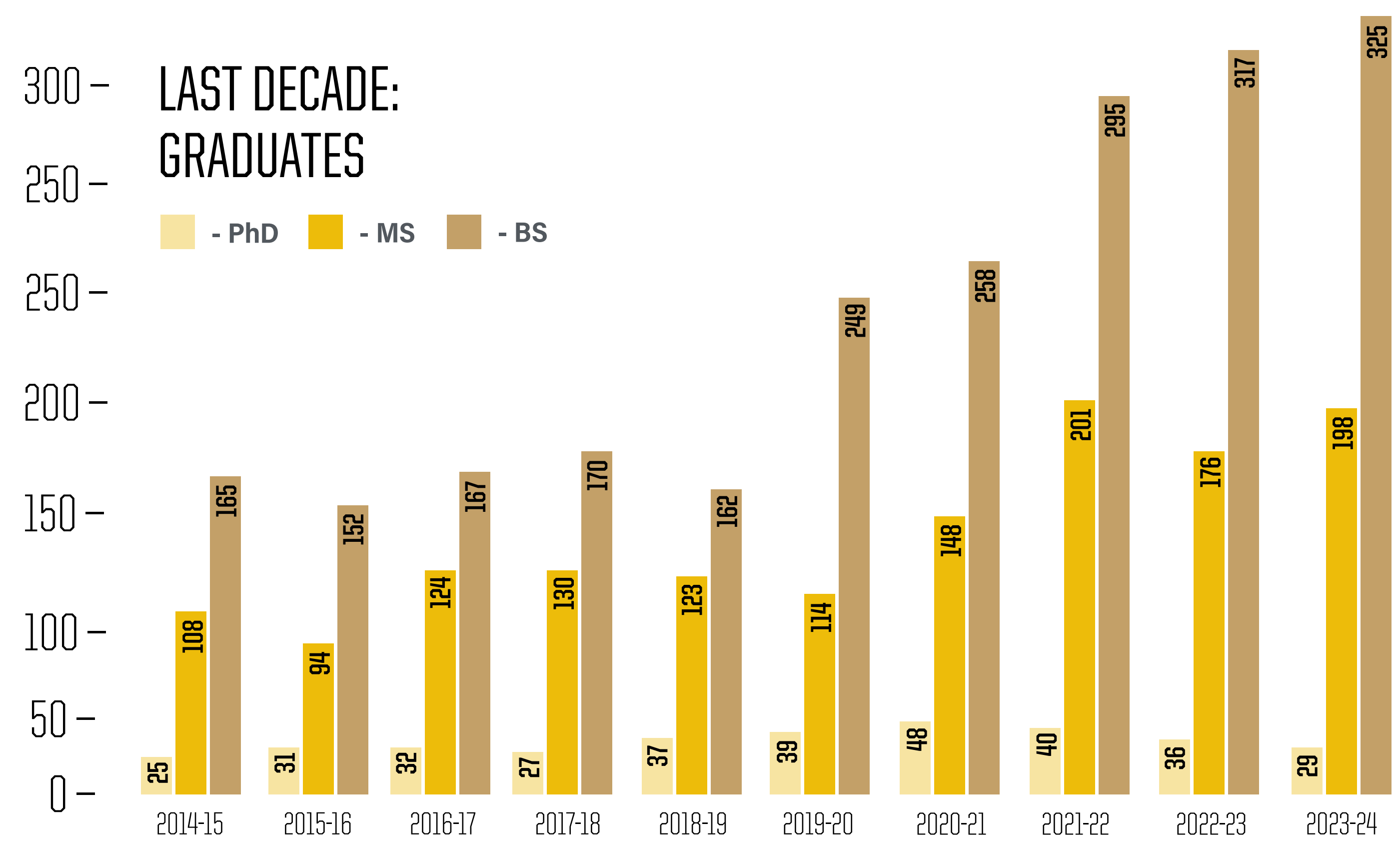
**includes joint appointments*

- **44** TENURED/TENURE-TRACK FACULTY*
- **26** FULL PROFESSORS
- **13** ASSOCIATE PROFESSORS
- **5** ASSISTANT PROFESSORS
- **3** PROFESSORS OF PRACTICE
- **2** LECTURERS
- **3** RESEARCH FACULTY
- **4** VISITING FACULTY
- **16** COURTESY FACULTY

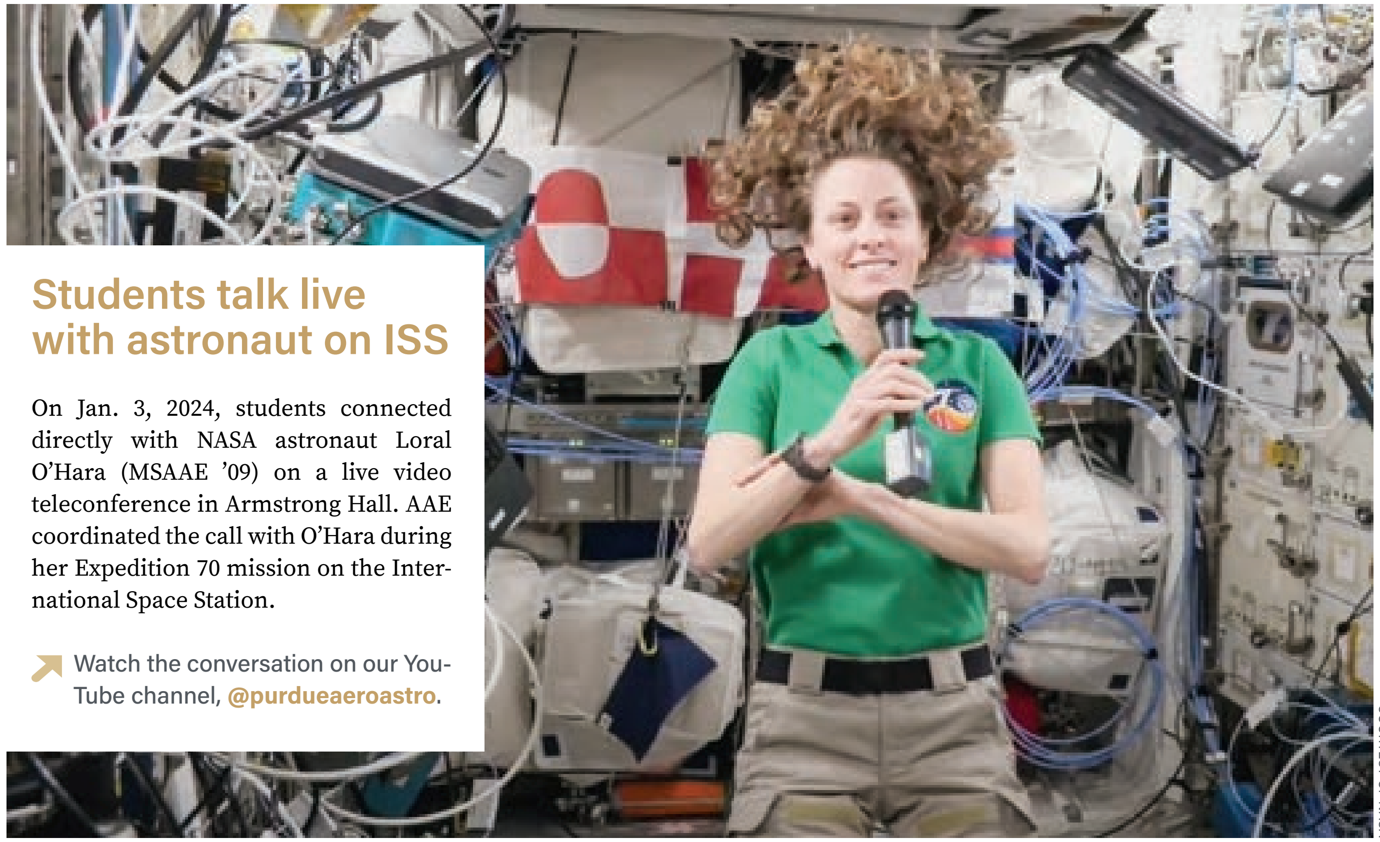
THE STUDENTS (2024 FALL ENROLLMENT)

1240 UNDERGRADUATE
19% FEMALE
11% INTERNATIONAL
10% UNDERREPRESENTED MINORITIES

640 GRADUATE (227 PhD)
17% FEMALE
27% INTERNATIONAL
9% UNDERREPRESENTED MINORITIES



STUDENT NEWS



Students talk live with astronaut on ISS

On Jan. 3, 2024, students connected directly with NASA astronaut Loral O'Hara (MSAAE '09) on a live video teleconference in Armstrong Hall. AAE coordinated the call with O'Hara during her Expedition 70 mission on the International Space Station.

Watch the conversation on our YouTube channel, **@purdueaeroastro**.

COURTESY OF NASA

PHOTOS: ALAN CESAR

Two first-time Purdue teams place at NSBE flight competition

Boilermakers competed for the first time in the flight competition at the 2024 convention of the National Society of Black Engineers. AAE professor and department head Bill Crossley served as advisor to all three Purdue teams. Two of the teams earned awards for their technical presentations.

The Boiler Wings, with members Olan Sodunke (ME), Patrick Thompson (AAE), Andrew Cuello (AAE) and Muyi Arowolo (AAE), earned a $600 prize for a second-place technical presentation.

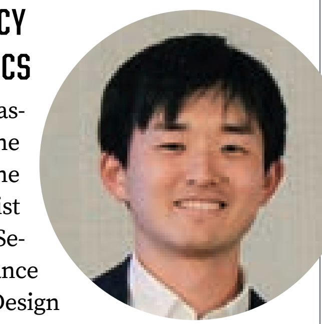
The Purdue Skywalkers placed third in the technical presentation, earning $400 for team members Mozen Mertami (BME), Kaleia Maxey (IE), Yasar Dambo (ChemE) and Nic Konoma (AAE).

GARCIA WINS NASA PROPOSAL WRITING COMPETITION

Incoming master's student Chelsea Garcia arrived on campus fresh from a major success: She led a team to a winning proposal in the NASA Proposal Writing and Evaluation Experience Academy. The team earned $10,000 in funding to continue exploring her idea of using regolith for constructive in situ engineering.

With that project in her back pocket, the first-generation college student was ready to embark on her aeronautics and astronautics degree under distinguished professor R. Byron Pipes, a legend in the world of aerospace composites.

Read a Q&A with Garcia on the AAE website — visit: bit.ly/aae-garcia



KUMAGAI CONTINUES OGURI LEGACY OF BEST PAPERS IN ASTRODYNAMICS

Naoya Kumagai, a PhD student under assistant professor Ken Oguri, received the John V. Breakwell Student award at the 2024 AAS/AIAA Astrodynamics Specialist Conference. Kumagai's paper is titled, "Sequential Chance-Constrained Covariance Steering for Robust Cislunar Trajectory Design under Uncertainties."

Another of Oguri's students, Yanis Sidhoum, received this award in 2023. Oguri himself earned the same award in 2018.

ZHOU AND LU EARN BEST PAPER AWARD ON CYBER-PHYSICAL SYSTEMS

PhD students Tianyu Zhou and Zehui Lu, advised by associate professor Shaoshuai Mou, received the Best Student Paper Award at the IEEE International Conference on Cyber-Physical Systems. Their paper was titled, "Multi-Robot Formation Control with Human-on-the-Loop."

SUPERCOMPUTER ALLOCATION ENABLES PURDUE HYPERSONICS RESEARCH

The U.S. Department of Energy has awarded time on its leadership-class supercomputers to Purdue researchers. Carlo Scalo, associate professor of mechanical engineering (AAE by courtesy), and Matteo Ruggeri, a PhD student in AAE, will use this computing power to run large-scale numerical simulations on aerodynamic properties of hypersonic vehicles. Their research supports current and future hypersonic experiments at the Air Force Research Laboratory.

ALUMNI PROFILE

ACHIEVING THE IMPOSSIBLE DREAM

ALAN CESAR

Joule Foundation empowers African girls to seek STEAM careers

As Alinda Mashiku (MSAAE ’09, PhDAAE ’13) walks the halls of Goddard Space Flight Center outside of Washington, D.C., she reflects on her journey to NASA and a job she describes as a dream come true.

Mashiku, the conjunction assessment risk analysis program manager at Goddard, leads a team of 50 people who are charged with assuring the safety of NASA satellites and of our ability to use space for science — from monitoring Earth’s changing climate, to orbiting observatories, communications systems and experimental devices that help identify new technologies for space exploration.

In her daily life, she draws inspiration from a quote by American physicist Robert Goddard, known as the father of modern rocket propulsion — “It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.”

As a young girl growing up in Tanzania with a fascination with astronauts and big aspirations for a career in aerospace, some might have thought Mashiku’s dreams were impossible. She attended an all-girls school and was surrounded by fellow high achievers, but opportunities for women in engineering weren’t prevalent in Africa where young women make up only 10% of engineering students.

Searching for a way to spark an interest in STEAM fields among high school girls in Africa, Mashiku partnered with two friends she met at Purdue, Mopelola Akande (PhD ECE ’13) and Oluwaseyi Ogebule (PhD ChemE ’13), to establish the Joule Foundation in 2015.

“At the time, we didn’t know anything about starting a nonprofit foundation,” Mashiku says. “We just wanted to inspire girls to pursue their dreams. We trusted that if we put one step in front of the other, the rest would follow.”

The trio started offering virtual workshops to introduce girls to engineering. The Joule Foundation now offers curricula that pair classroom learning with hands-on activities to foster STEAM education in three African countries — Nigeria, Tanzania and Zimbabwe. Teams of local volunteers facilitate the academic programs.

“We have an amazing group of volunteers,” Mashiku says. “They’ve empowered girls to calculate rover trajectories on the moon or build rockets using locally available resources. Seeing those students express excitement while achieving a project objective is a seed that will keep on growing. It’s been an amazing journey.”

Along the path of her amazing journey, Mashiku and her husband are raising two sons. She affectionately refers to their first son as a “quals baby” because he was born while she was preparing for her PhD qualifying exam. While earning her PhD and tending to a newborn, she also worked as a NASA graduate student research program fellow.

ABOUT THE JOULE FOUNDATION

The SI unit of energy is the Joule, which is equivalent to kg.m2/s2. The Joule Foundation believes that by giving a person (kg) a platform (m2) over time (s2) their energy can be used to transform and change our world for the better.

Learn more at **www.joulefoundation.org**.

The couple's second son was born during the COVID-19 pandemic, at a time when the future of the Joule Foundation was uncertain. After global school closings, Mashiku wasn't sure the foundation could rebound.

"As soon as the schools reopened, they were ready for us and asking when we were coming back," she says. "The foundation has evolved so much. We're continually learning how to be sustainable, to manage our growth and expand our future capacities and capabilities."

Mashiku has achieved the life and career her 13-year-old self could only imagine. It hasn't been without its challenges and she'll be the first to say that she didn't accomplish it all on her own. Through a graduate student mentoring program, she was paired with Maria Kuczmarski who worked in the Materials and Structures Division at NASA's Glenn Research Center in Cleveland, Ohio.

"I met with Maria every month to talk about my dissertation progress and challenges," Mashiku says. "She gave me insight on how to manage my work and graduate on time. She also advised me on how to secure funding. She helped me stay on track to complete my PhD in three years."

Mashiku has also received support from friends and colleagues who build each other up. Now, through the Joule Foundation and in her role as a program manager at NASA, Mashiku is empowered to create environments that nuture talents and encourage others to dream of the impossible.

"I believe there is space for everyone to thrive," she says. "And thriving despite adversity is what makes us stronger."

FOUNDATIONAL VALUES

The Joule Foundation shows support of education for young African women by providing access to STEAM educational programs and initiatives. The foundation is driven by these values:

Integrity
The foundation's vision is to bridge the gender gap in African STEAM education.

Excellence
The foundation's mission is to promote STEAM education among young African women through academic programs.

Transparency
The leadership of the Joule Foundation is composed of young women and men with a passion and a heart for the people of Africa.

Fairness
Young women represent 7% to 12% of engineering students in Africa. The Joule Foundation seeks to change that.

Giving Back
The foundation creates mentoring and networking relationships among students and program alumni.

Innovation
The foundation provides a platform for networking with other companies worldwide.

Empowerment
Giving young women an education in STEAM empowers them to seek careers in these fields.

FLYING SOLO

In 2024, Anh-Thu Nguyen (BS Math '13, MSAAE '15) became the 10th woman to fly solo around the world, a voyage that included 25 stops.

Growing up in Vietnam, Nguyen was fascinated by the airplanes that soared above her remote village. "I longed to have that experience of flying and controlling a plane, of feeling small and vulnerable yet at the same time so powerful," says the pilot and flight instructor.

Nguyen arrived in the United States at age 12, a move that ultimately brought her to Purdue to pursue studies in mathematics and aerospace engineering. "I learned the power of intellectual curiosity in college," she says. "I'm also thankful for the recreational classes I took, including wine tasting and salsa dancing. Purdue helped me become a well-rounded individual."

Hoping to encourage and engage aspiring women pilots and engineers, Nguyen founded the nonprofit Asian Women in Aerospace and Aviation in 2018. Through its outreach efforts, the organization provides discounted flight training and mentorship while shining a light on Asian women who are thriving in related careers.

"As an Asian woman, I faced many obstacles and challenges to get to where I am today, especially adapting to a new culture, language and life in the United States. I wanted to give back and inspire the next generation."

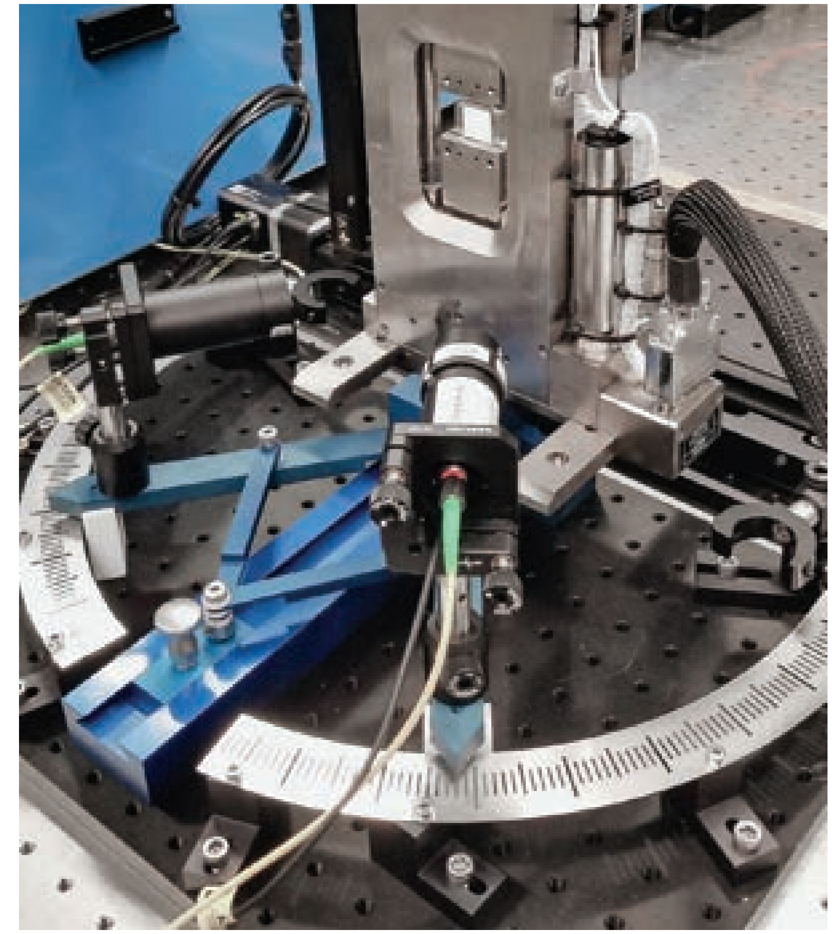
In 2020, Nguyen opened Dragon Flight Training Academy at North Perry Airport in Pembroke Pines, Florida. There, students learn how to fly in addition to developing skills in risk assessment and safety-oriented decision-making. "I love being a flight instructor because I'm able to share my knowledge while at the same time learning more about aviation myself," she says.

"As an Asian woman, I faced many obstacles and challenges to get to where I am today, especially adapting to a new culture, language, and life in the United States. I wanted to give back and inspire the next generation."

FROM CHILDHOOD DREAMS TO CERN COLLABORATION

Sushrut Karmarkar contributes to structures and materials research

PHOTOS COURTESY OF SUSHRUT KARMARKAR



Left: Sushrut at the P5 CMS assembly area at CERN, France.

Above: Bi-material interface strain measurement setup using THz-TDS.

Sushrut Karmarkar (MSAAE '18, PhD AAE '24) is an associate research engineer in AAE at Purdue whose research focuses on structures and materials. In professor Vikas Tomar's Interfacial Multiphysics Lab, he studies the development of terahertz time domain spectroscopy for interface strain-stress mapping within composite materials and coatings.

He also works with associate professor Andreas Jung on the High-Luminosity Large Hadron Collider (HL-LHC) upgrade project for the CMS collaboration with CERN where Karmarkar is a composite engineer working to design, manufacture, validate and install carbon fiber composite structures for the Phase-II Tracker Detector.

"As a kid growing up in a small city in India, I remember visiting science centers and labs and always being awed by people in white lab coats," Karmarkar says. "I had the opportunity to visit, on multiple occasions, the research center where my mom used to work and also 'play' in the HVAC manufacturing plant, courtesy of my dad. I also remember that Sundays were spent watching a show on DD India (a TV channel) called 'Turning Point' which predominantly talked about space exploration and technological advancements."

He aspired to be part of the Indian space program, as he grew up during a decade when it was picking up steam, ultimately finding his motivation to study science-related topics in school after being fascinated by the engineering of cars and airplanes. Karmarkar credits his father for getting him interested in mechanical engineering, saying his dad hopes Karmarkar can come work for his company and replace him in HVAC design and manufacturing, but Karmarkar says he "keeps disappointing him in this regard!"

Karmarkar offers nothing but praise for Tomar and Jung, who let him explore a great deal in the field of composite design and remote sensing.

"The best part is that I get to go to CERN and work in one of the largest technical collaborations in the world," Karmarkar says. "As a part of my research, I am developing terahertz time domain spectroscopy techniques to evaluate the degradation and cracking in the interface materials between silicon detector modules and base composite support structures for the Tracker Forward Pixel Detector for CMS collaboration. We are also designing and building large composite structures for sustaining the high radiation environment of the particle collider."

Karmarkar says one of the main challenges for grad students in AAE is that the field is changing at a rapid pace and the quality of research papers is degrading.

"When compared to papers from 10 years ago, there are certainly more papers that have been published where the claims made or experiments shown are almost impossible to replicate," Karmarkar says. "Hence grad students, including me, need to be very, very critical of the work being cited as a part of the literature review that guides your contribution to the field."

Now that he's earned his PhD, Karmarkar plans to remain as a research engineer on the CERN project and hopes to install the detector in the CERN tunnel, which is anticipated to happen in 2027.

In five to 10 years, Sushrut aspires to be a design engineering lead on particle accelerator projects like EPIC at Brookhaven National Labs and FCC at CERN. He was introduced to these projects at the Seattle Snowmass Summer Meeting 2022 and hopes to see how this research can be applied to outer space missions but is excited that his degree will allow him to work on structures 500 feet underground.

A version of this story was originally published on May 19, 2023, on Labroots.com by Laurence Tognetti, MSc. Reprinted with permission from Labroots Inc. It has been edited for style, space and clarity.

PICTURE PERFECTION

Boeing-funded research project produces a testbed for a cubesat-based, fully autonomous satellite characterization and inspection system

Spotting and identifying satellites from Earth is difficult. Not only are they far away and very small, but getting a meaningful amount of detail requires a high-end telescope with a large opening (aperture). Never mind the pesky problems of atmospheric blurring, light pollution and — the bane of every amateur astronomer — clouds. Spotting smaller pieces of orbital debris is even harder.

But what if you could send up a satellite to take pictures up close? And, rather than sending back just those pictures — which takes a lot of bandwidth — could it be smart enough to generate a 3D model of what it saw, calculate how it is oriented in space, and beam that information down to Earth for people to study? Complete with their trajectories?

In Purdue's Space Information Dynamics Lab, a detailed model of NASA's TESS satellite is being used to refine lightweight software that can identify objects in low Earth orbit.

PHOTOS: ALAN CESAR

ALAN CESAR

Graduate student Daigo Kobayashi monitors the calculated ground truth based on their lab's webcam output.

That's the goal of the Boeing-funded Relative Navigation Project that Associate Professor Carolin Frueh has tackled for the past two years. Together with PhD student Daigo Kobayashi, Frueh worked to design a hardware-in-the-loop testbed that can calculate the shape, orientation (attitude motion) and trajectory of another space object — be it a live satellite, a derelict satellite or just space junk.

Their technique is a variation of Simultaneous Localization and Mapping (SLAM) — which is how autonomous vehicles figure out where they are and where they're going. But space missions have strict power, size and weight requirements, meaning Frueh couldn't rely on advanced sensors like LiDAR, infrared or multiple color cameras that capture depth information.

Frueh and Kobayashi would have to get by with just one monochrome camera. The kicker was to design the software to be simple enough to run on a low-power microcomputer. The kind that might fit on a cubesat.

"The true application here is to check out satellites and get independent information about their operational state and operational health," Frueh says. But she also envisions broader applications for a system like this.

"There is a lot of interest in collecting debris in space. This could be used to help identify what that debris is and if it's worth collecting. One can tell a non-responsive satellite by whether its solar panels are deployed or pointed towards the sun, or if it's tumbling."

Simulating Space Snapshots

Frueh had a head start in designing the software: She specializes in orbital dynamics and debris tracking. Her previous work includes programs that identify and characterize objects in orbit based on their reflections as seen from Earth.

That kind of expertise is what brings partners like Boeing to work with Purdue, says Joe Krok, executive director of at the Office of Industry Partnerships.

"Boeing comes to Purdue because together we have built a long-term, mutually beneficial, productive partnership. Purdue has a deep bench of talent among students and faculty, we have a business friendly approach to contracting, and we bring world-class capability in a broad range of disciplines," Krok says.

Frueh's novel challenge in this project was to develop her previous work into a similar, but scaled-down image analysis tool for resolved images. In the first phase of this project, their software design was tested with simulated pictures. Phase 2 took her work into the realm of real-world experiments, making use of her Space Information Dynamics Lab.

The SID Lab space is a windowless room inside Armstrong Hall. With the door shut, it's pitch black inside. Frueh and Kobayashi have precise control of all light sources in that room, making it the perfect place to simulate the depth of space — and a great photo studio.

A hyper-realistic satellite model would serve to test the system's capabilities. Frueh reached out to Dailey Productions, experts in additive manufacturing, to 3D-print a scale model of NASA's Transiting Exoplanet Survey Satellite (TESS).

Giving themselves no advantages, Frueh got one of the cheapest webcam models they could find and connected it to a Raspberry Pi — an extremely low-cost, single-board computer about the size of a credit card.

Frueh's Earth-bound webcam would take grainy, grayscale pictures of an extremely detailed satellite model.

Additional complicating factors were added to test the strength of the algorithm. Frueh's program had to contend with hot and cold pixels, perspective projection errors, stray light from the sun and moon and more.

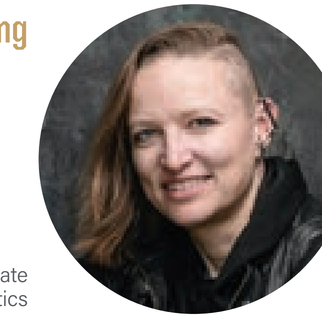
They attached helper shapes, called ArUco markers, on the model's rotating platform to train and improve the software model and fuse it with a gyro unit measurements. ArUco markers are common in augmented reality systems to correctly overlay renderings into the real world, correcting for effects like camera position and lens distortion. Gyros are traditionally used in the on-board attitude estimation. The attitude solution provides feedback to train their image analysis model against the ArUco-based "ground truth."

Putting their computations to work, Frueh and Kobayashi's software was successful in finding the satellite's calculated key points and tracking the satellite's major shapes through multiple rotations about vertical and tilted axes.

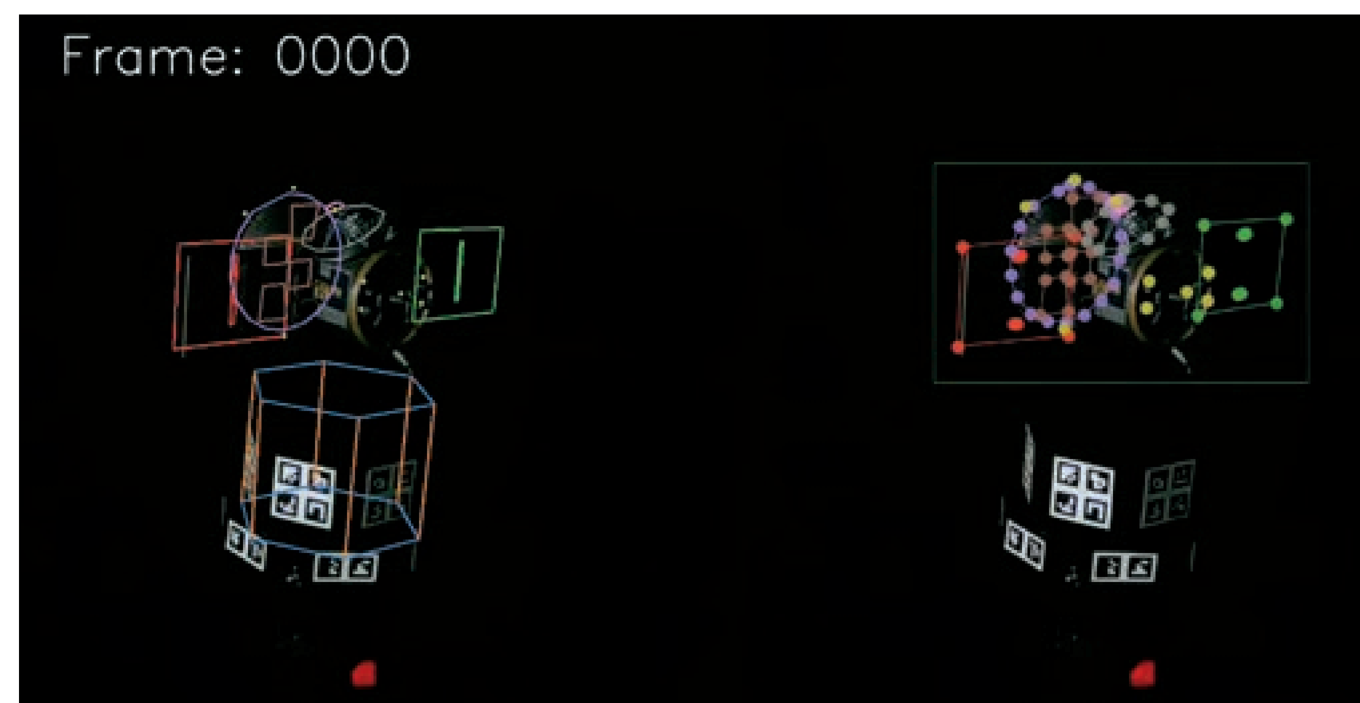
"We're very pleased with these results," Frueh says, noting that Boeing has renewed the project to continue into 2025.

"We have succeeded in producing a light and effective program that can estimate the shape, orientation, position and trajectory of space objects using very limited information and computational power. I'm excited to see how we can put this to use in our future research."

> **"There is a lot of interest in collecting debris in space. This could be used to help identify what that debris is and if it's worth collecting."**
>
> —**CAROLIN FREUH**, the Harold DeGroff Associate Professor of Aeronautics and Astronautics



In lab experiments, the software devised by Frueh and Kobayashi was able to identify and follow the major shapes in the TESS satellite model as it rotated about a tilted vertical axis. ArUco markers attached to the model's rotating support were used for a "ground truth" comparison. In some frames, the solution calculated from images alone appear more accurate than the ground truth solution.



A Purdue-designed experiment, funded through NASA's Flight Opportunities program, experienced three minutes of weightlessness aboard the final flight of Virgin Galactic's VSS Unity suborbital spacecraft.

A SCIENCE LAB IN SPACE

'Rotational Slosh' experiment flies aboard final commercial launch of VSS Unity

A Purdue-designed and -built experiment has taken a trip to space on the last commercial flight of Virgin Galactic's VSS Unity spacecraft. It is one of just nine experiments that the ship carried to space, along with its human crew, on this historic flight.

This Rotational Slosh Experiment, funded through NASA's Flight Opportunities program, was spearheaded by Professor Steven Collicott as its principal investigator. Collicott has had dozens of his students work on this project since 2019 — with 10 students involved in the Spring 2024 semester alone — through his Zero Gravity Flight Experiments course, AAE 418.

"My funded research program incorporates the 418 course, so students are getting real-world microgravity experience as undergrads," Collicott says.

Four students accompanied Collicott to New Mexico to see the experiment off on its flight test: Trey Hackman, Jack Martin, Alex Edwards and Ryan Williams.

The type of research this automated experiment conducted is impossible on Earth, Collicott says. You need to get the test into microgravity, and the Unity is one of very few ways to accomplish that. The contents aboard VSS Unity experience about three minutes of weightlessness, perfect for this experiment.

"These are excellent laboratories," Collicott says. "The research you can do there is unique. Volcanologists go to volcanoes — to do our research, we have to go to space."

The experiment box is fully automated. Accelerometers detect when the spaceship's rocket fires up, initiating a countdown to begin the experiment that rotates the small, transparent fuel tanks. They're filled with two liquids, one that wets the solid surfaces poorly (hydrophobic) and one that wets the solid surfaces well (hydrophilic). Dyes help to visualize the differences in how they interact. A camera pointed at these tanks records the results.

Studying this footage will yield a better understanding of how these liquids behave in microgravity. This will give important insight into how fuel tanks for satellites can be better designed to reduce the effect of fuel slosh on a craft's maneuverability.

The experiment summary published by Virgin Galactic provides additional details:

"When spacecraft are accelerating in space, such as during a pointing maneuver, re-orientation burns for docking or to transfer to a new trajectory, it sets the liquid in propellant tanks in motion. After the thruster firing ends, the liquid motion slows down in the zero-gravity environment. This experiment will study the rate of damping of liquid motion after a rotational maneuver. The results will use this additional understanding of low-g propellant slosh to improve spacecraft pointing and mission operations. With the ongoing small satellite revolution, this experiment can use actual propulsion tank sizes for small satellites, rather than sub-scale mock-ups of tanks for larger satellites. The research can be furthered by studying how green propellants movements may differ from traditional propellants, like hydrazine, in zero-g."

Pictured, left to right: AAE students Trey Hackman, Ryan Williams and Alexander Edwards; Virgin Galactic vice president Sirisha Bandla (BSAAE '11, OAE '22); AAE professor Steven Collicott; AAE student Jack Martin; VG director of research operations Kathleen Karika; and VG program manager of research operations Issa Mukhar.

ALAN CESAR

Flight Lieutenant Gaurav Gandhi and Squadron Leader Niti Prasad are the most recent alumni of AAE's four-decade partnership with the RAAF.

ADVANCING SAFETY IN FLIGHT

40-year partnership with Royal Australian Air Force trains aviators in structural fatigue

RAAF Squadron Leader Janet Thompson (Executive Officer, Office of the Air & Space Attaché, Embassy of Australia), center, visited Purdue from the Australian embassy in fall 2024. She met with, from left, Professor Michael Sangid, Professor Emeritus Alten Grandt, Flight Lieutenant James Carr (31st participant in the program), and Flight Lieutenant Gaurav Gandhi.

Squadron Leader Nitilaksh Prasad, keys in hand, had to steel himself. Years of study, training and work in the Royal Australian Air Force couldn't prepare him for this challenge: Driving a rental car out of an airport terminal onto a busy interstate highway — on the wrong side of the road.

"I think I left my handprints on the steering wheel," he says, laughing.

He was headed to Purdue, invited to participate in a rare opportunity among RAAF officers to study structural fatigue in the School of Aeronautics and Astronautics. Leaving finger-shaped impressions in his rental car was not officially part of his forthcoming research and education.

Prasad would be only the 29th — and Flight Lieutenant Gaurav Gandhi the 30th — RAAF officer to embark on some version of that trip since 1984, when Alten "Skip" Grandt, the Raisbeck Distinguished Professor Emeritus, initiated the partnership. The RAAF wanted to bring structural integrity expertise into their ranks to address fatigue issues with the General Dynamics F-111 Aardvark supersonic combat aircraft.

"I was privileged to be faculty advisor for the first 15 RAAF graduates. Two of those officers [Steve Drury (MSAAE '89) and Terry Saunder MSAAE '94)] achieved the rank of air commodore, making extremely substantial contributions to the RAAF," Grandt says.

In 2010, the F-111 was retired from service. Grandt received a letter of appreciation from Air Commodore D.E. Tindal, thanking him for the "sustained contribution in post-graduate education you have made over the past 25 years to the Royal Australian Air Force."

"The fact that the RAAF/Purdue program continues today is one of the most memorable achievements of my Purdue career," Grandt says. "Indeed, the opportunity to witness so many graduates make important contributions to the RAAF is extremely gratifying."

But the RAAF saw the value of this partnership beyond that specific vehicle. Though Grandt was retiring, they continued sending officers annually to study structural fatigue — advised first by Professor Tom Farris, then Professor Byron Pipes, and now Michael Sangid, the Reilly Professor of Aeronautics and Astronautics.

"The Australian air force is keen to continue this relationship with Purdue," Prasad says. "Even though the problem we first started off with, which was the F-111 fatigue issue, has long gone and we've retired that aircraft, fatigue will always be relevant in our aircraft. And having subject matter expertise is always relevant and necessary."

Forty years after its inception, Gandhi successfully defended his master's thesis and became the 30th graduate from this program.

ALAN CESAR

Professor Mike Sangid fosters a collaborative and supportive culture in his research group. Students help each other out academically, professionally and socially. Left to right: Gaurav Gandhi, Taylor Hodes, Capt. John Ferguson (USAF), Brandon Mackey and Niti Prasad.

He is returning to serve his country as a subject matter specialist in materials fatigue having studied under Sangid — a professor as well-known for his expertise as for the high standards he keeps for his students.

"The RAAF students have added tremendously to the academic, research and collegial culture in my group and within the School of Aeronautics and Astronautics," says Sangid. "They leave Purdue with valuable experience in structural integrity and durability and are well-positioned to solve critical issues that arise in maintaining the RAAF fleet of aircrafts. I've been delighted to work with so many bright and professional RAAF students and look forward to continuing this partnership."

Good Vibes and High Expectations

Gandhi and Prasad viewed the Purdue program as a proud opportunity that offered more than career advancement. It was a chance to conduct meaningful work at a globally renowned research institution.

"The intent of the program is to learn and understand the state-of-the-art research in the area of structural fatigue, and hopefully contribute to the field of research," Gandhi says. "To work under the guidance of Dr. Sangid as a leader in his field, and publishing meaningful research, is the main output of this program."

After arriving on campus, Gandhi and Prasad credited the positive atmosphere in their lab group for helping them feel welcome. The positive culture within Sangid's lab created an environment where students were eager to help each other out academically, professionally and socially.

Prasad and Gandhi both cherished their time at the Australian Defence Force Academy, where they completed their undergraduate engineering degrees concurrently with military training. However, years away from academia alongside the rigor of the AAE master's program provided them with a challenge — a challenge made easier by the support they received.

"In the defense academy, we learned a lot of engineering fundamentals and graduated as officers in the Australian air force." Prasad says. "At Purdue, I appreciated working with students and academic staff of such a high caliber. The students here graduate with an excellent level of subject matter knowledge, which is necessary because the consequence of failure in our field of aerospace materials can be catastrophic."

Both Prasad and Gandhi commenced postings at Australia's military aviation authority, the Defence Aviation Safety Authority, at the completion of their studies.

"We look forward to bringing the technical skills and expertise gained here back to the air force, with the aim of continually enhancing aviation safety," Gandhi says.

They also join a strong network of program graduates who stay connected through an alumni group led by Kevin Walker (MSAAE '87) that fosters a supportive community for both current and past students.

SQUADRON LEADER NITI PRASAD (MSAAE '24)

At Purdue, Niti Prasad studied the properties of carbon-carbon composites common in high-speed and high-temperature applications. "Australia has the ability to manufacture this, and we worked with Dr. Sangid to characterize how this material works in terms of its load-handling abilities after being exposed to a high-temperature environment," Prasad says.

Upon completing his military training at the Australian Defence Force Academy, with a bachelor's degree in aeronautical engineering, Prasad posted to Newcastle, New South Wales, working with the F/A-18 Classic Hornets. Over the following years, he worked in structures for the PC-9/A training aircraft, later overseeing disposal of the platform; with the KC-30A air-to-air refueling tanker squadron, deploying to the Middle East and Guam; and supporting airworthiness for the KC-30A, C-17A, BBJ and Falcon F7X. Prasad has also completed a master's in project management.

FLIGHT LIEUTENANT GAURAV GANDHI (MSAAE '24)

In December 2024, Gaurav Gandhi became the 30th student to complete a master's at Purdue through the RAAF partnership. His research involves analyzing the fatigue behavior of cooling channels in additively manufactured specimens of GRCop-42, a NASA-designed material for rocket combustors. The material is becoming popular for its ability to be additively manufactured, and its beneficial properties at elevated temperatures. It was used in a recent Purdue test of a liquid-cooled rotating detonation engine.

After completing military training and a bachelor's degree in engineering, and a few postings on various Royal Australian Air Force platforms, he commenced a posting at the Defence Aviation Safety Authority, Australia's military aviation authority, in the Aircraft Structural Integrity section. Gandhi has also earned a master's degree in project management. He is returning to his role at DASA.

FORMER AIR COMMODORE STEVE DRURY (MSAAE '89, OAE '07)

Steven Drury served for three decades in the RAAF, completing his Purdue studies during that time and enabling him to provide aircraft structural integrity support to the RAAF fleet on his return.

Drury left the air force to join BAE Systems Australia in 2010 as general manager weapons systems, leading the Nulka anti-ship missile decoy design and manufacture business, as well as contributions to the international ESSM product, hypersonics and autonomous systems.

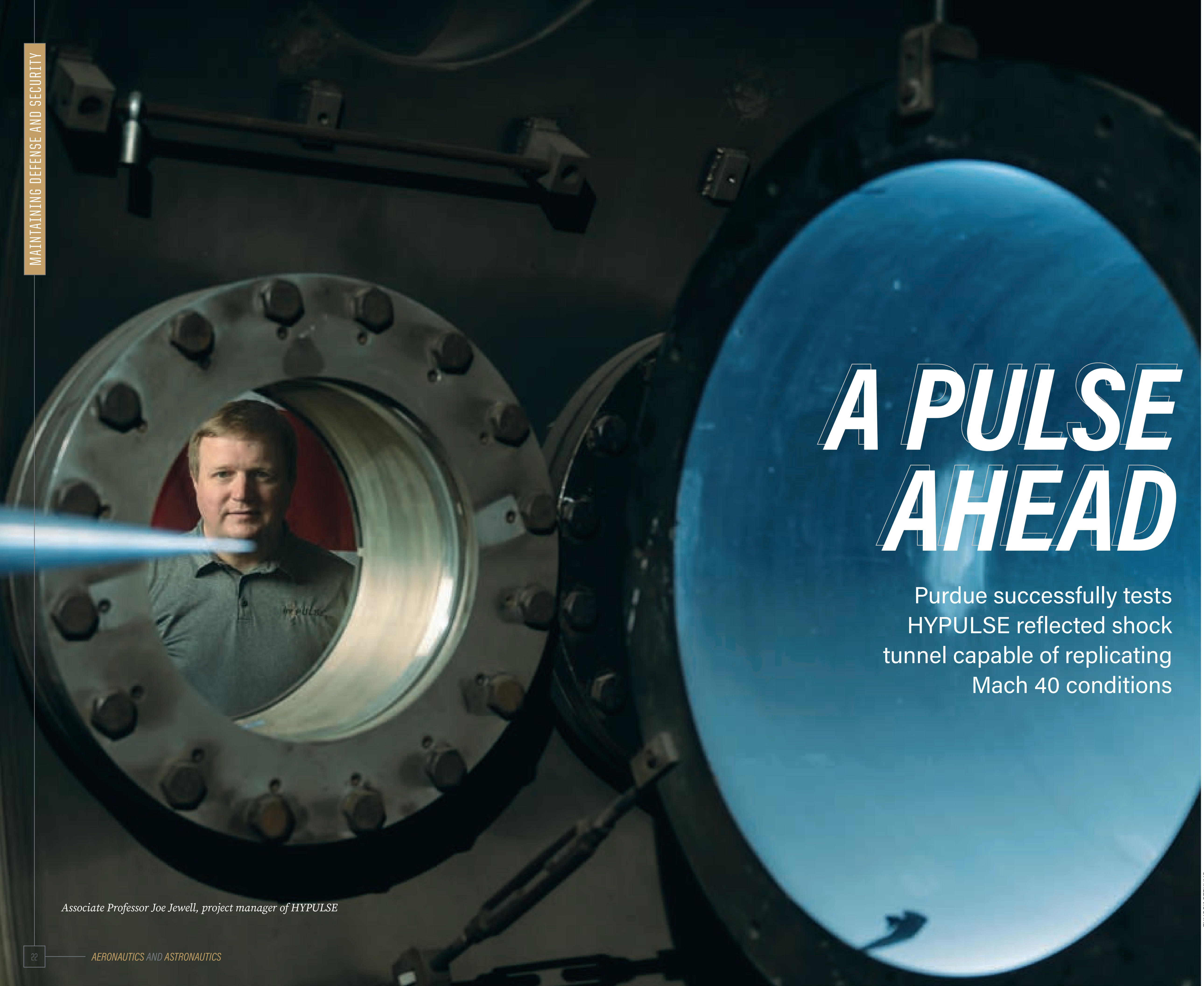
In 2013, he became director aerospace supporting aircraft, helicopter and civil airline maintenance, including the Hawk lead-in fighter as well as pilot and technician training, and weapons systems. During this time, the U.S. Government awarded BAE's Aerospace business the F-35 Joint Strike Fighter support contract for the Southern Hemisphere. Drury has worked as a defense and industry consultant since 2019.

FORMER AIR COMMODORE TERRY SAUNDER (MSAAE '91, OAE '12)

Terry Saunder spent decades in the Royal Australian Air Force and Defence Australia, in appointments including chief engineer in the Defence Force's flight test establishment, to staff officer to the chief of the Defence Force. Saunder served as senior engineering officer of 77 Squadron's fleet of F/A-18 Hornets.

In 2015, Saunder became director general of Joint Strike Fighter acquisition and sustainment, leading the team chartered to deliver the F-35A, including the aircraft, training and support system, for Australia. The Joint Strike Fighter was the largest acquisition in the history of the RAAF.

In 2019, he joined Northrop Grumman Australia as director of its capture team. He is now first assistant secretary of engineering, technology and materiel logistics at Defence Australia.



Associate Professor Joe Jewell, project manager of HYPULSE

CHARLES JISCHKE

A PULSE AHEAD

Purdue successfully tests HYPULSE reflected shock tunnel capable of replicating Mach 40 conditions

It's nearing 3 p.m. on April 1, 2024, and six graduate students, a research assistant and an associate professor have been watching pressure graphs closely for most of the afternoon. Since the previous summer, they've been working to fire up a new test tunnel in Purdue's super-secure Hypersonics and Applied Research Facility (HARF), dealing with impossibly tight tolerances even for a so-called "low-pressure" test.

The qualifiers for this are baffling: Building up the driver reservoir to "just" 1,900 psi, a far cry from its 20,000 psi maximum. A high-speed camera slowed down to "only" 20,000 frames per second, so it can be run continuously. They're expecting "merely" Mach 7 flow, just a start on the way to its Mach 40 limit.

Even when operating so far from maximum, the 6-inch-diameter steel shock tube must be perfectly straight — deflecting no more than an eighth of an inch every 30 feet.

As the first test, they don't expect everything to go perfectly. But it does, nearly. In the final minutes pre-test, they must program a workaround to the filling routine to compensate for a minor leak. Everything else is going exactly to plan.

The team — consisting of grad students Kyle York, Jared Slack, Adrian Flores, Connor Hennessy, Samant Mahipathi and Grant Dilley, and senior research engineer David Tibbo — double-check everything on their nine-page startup procedure.

It's time. They pass around ear plugs. Hennessy hovers the mouse cursor over the "go" button.

He clicks.

A deep hissing emanates through the brick wall. There's a subtle pop, and then a few seconds of a whistling sound. A black-and-white output display from the high-speed camera shows something that resembles the driving rain during a hurricane.

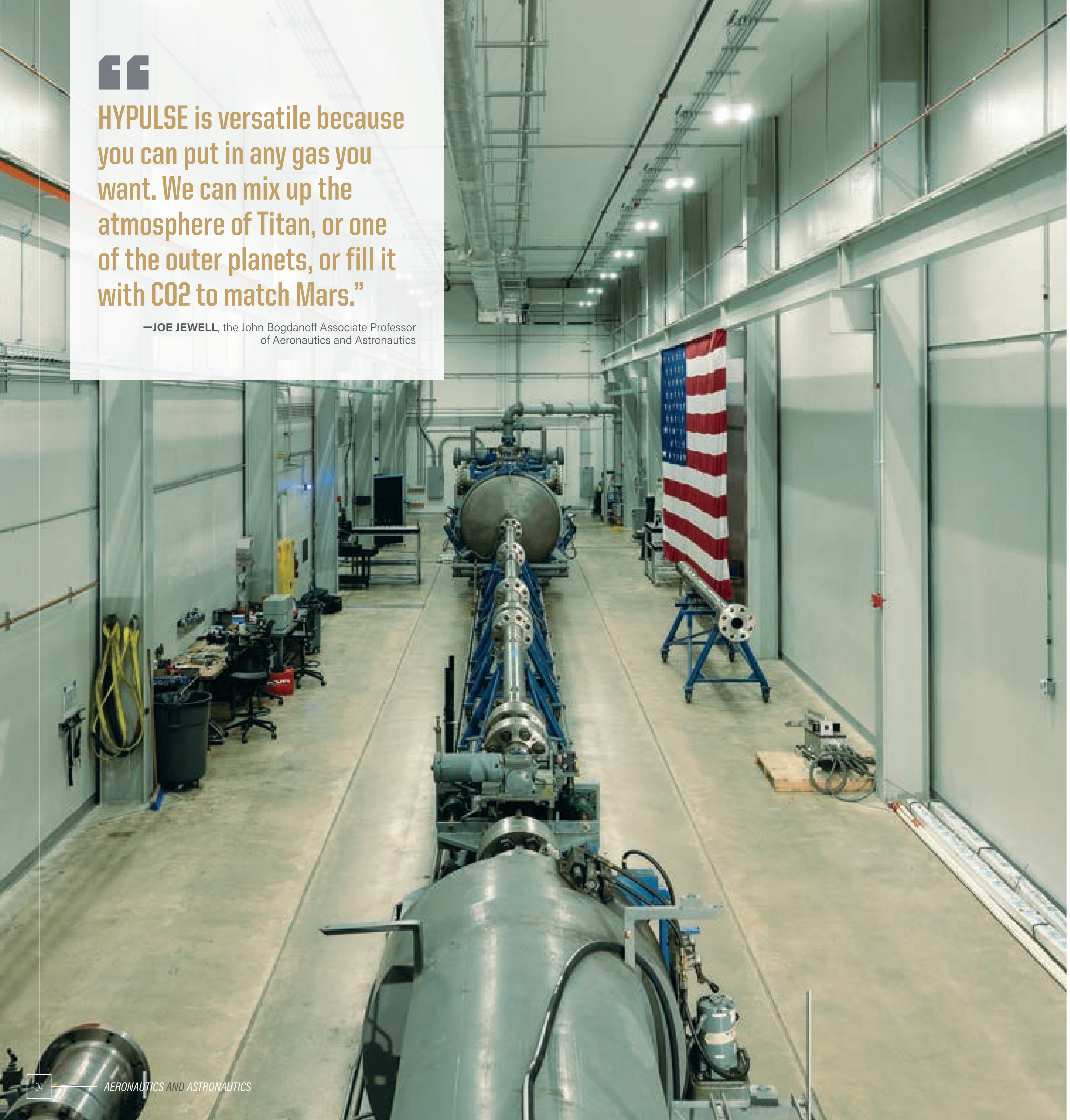
Smiles explode across the faces of everyone in the room.

Associate professor and HYPULSE director Joe Jewell and Zucrow Labs managing director Scott Meyer share a high five, and cheer for the team: "Great job, gentlemen!"

They all clap for one another. They clap for themselves. Running back the high-speed video, they click through the frames one by one, watching the flow transition from dirty air to the steady-state test blast. They see what they've been hoping for: A distinct shock wave bending downstream of a metal bar in the test section, that they later calculate at Mach 7.

As eager PhDs, the students begin looking for ways to analyze what they see. Jewell tempers their

> **HYPULSE is versatile because you can put in any gas you want. We can mix up the atmosphere of Titan, or one of the outer planets, or fill it with CO2 to match Mars.”**
>
> —**JOE JEWELL**, the John Bogdanoff Associate Professor of Aeronautics and Astronautics



PHOTOS: CHARLES JISCHKE

Left: Long view of the HYPULSE shock tunnel at the Purdue Hypersonics and Applied Research Facility.

Top: Graduate students Adrian Flores and Kyle York insert a burst disk into the double diaphragm section of the tunnel. The double diaphragm uses two scored metal disks as a starting mechanism for the tunnel. When these disks rupture, the high pressure from the driver enters the shock tube and creates an incident shock, thus starting the tunnel. Both disks are replaced every time the tunnel is fired, so this is a very typical scene at HYPULSE.

Bottom: Grant Dilley, a PhD student and research assistant, installs a test model into the test section of the shock tunnel. The model is a 7 degree (half angle) cone with a 6-inch base, with a length of 2 feet. The sharpness of the cone provides a clean shockwave which can be used to calculate the speed of the flow.

enthusiasm. His own PhD work more than a decade prior, using the T5 Reflected Shock Tunnel at Caltech, gives him perspective. “Be happy you got a Schlieren,” he says, referring to the special optical method used to photograph pressure shockwaves and density gradients — “but don’t claim it was science!”

Reviewing the display screen from an oscilloscope, they also see that each of the three pressure transducers indicated a pressure spike. They cheer again. Not only have they shown that it works, but they’ll also be able to calculate the shock speed and flow conditions from that data, and fine-tune the camera triggering to run it at higher framerates. Now they can submit research proposals.

It’s pure excitement. Until —

“Oh no!” one student says. “It didn’t save the data.”

The room falls silent. Their mouths hang open as they imagine their months of work nearly vanishing. Or picturing what went wrong. Or wondering how long it will be until they can test again.

“April fools?” he says, sheepishly. The room laughs in relief. “Too soon, man!”

Atmospheric cocktails

Jokes aside, the first test of Purdue’s HYPULSE reflected shock/expansion tunnel was an unqualified success. But this test, four years in the making, was just a starting point. They verified the pumps, valves, seals, sensors and data collection systems, and identified weaknesses to address on their way to testing at higher levels of pressure and enthalpy. Jewell expects they’ll exceed Mach 25 — orbital velocity — by the end of 2025.

This system’s original design, shown in yellowed drawings signed by NASA draftsmen, dates back to the 1960s. It was upgraded many times in the decades following as it continued to change hands, finally being donated to Purdue in 2020 by Northrop Grumman.

Graduate student Adrian Flores operates an overhead crane to place one of the tube sections that route air from the pressure tanks to the

PHOTOS: CHARLES JISCHKE

Jewell’s experience — which includes running the Boeing/AFOSR Mach 6 Quiet Tunnel, a shock tube, and other aerodynamic research equipment at Purdue — informed the construction plans for the HARF building that would house HYPULSE. He led adding upgrades and refinements as the system was installed, making it capable of taking millions of data points per second with modern instrumentation techniques.

That extreme headroom makes it suitable for far more than cutting-edge hypersonic missile systems — its flexibility makes it capable of testing spacecraft that would enter atmospheres other than Earth, or on very high Mach number trajectories returning astronauts from the moon or Mars.

“HYPULSE is versatile because you can put in any gas you want. We can mix up the atmosphere of Titan, or one of the outer planets, or fill it with CO2 to match Mars,” Jewell says.

“This opens up a lot of potential for Purdue. Very few universities have anything like this. We have a huge amount of interest in it,” he adds. “HYPULSE opens up entirely new pathways for hypersonic research.”

After the cheers died down and Jewell had congratulated each of his students, he took a moment to reflect on his progress. Appropriate to the theme of the day, he expressed disappointment — but firmly tongue-in-cheek.

“I’ve been saying for years that we would have this running by the first quarter of 2024,” he says. “Getting it running on April 1, well, it made me a liar by one day.”

Front row, left to right: Connor Hennessy, David Tibbo, Kyle York and Grant Dilley. Back row, left to right: Samant Mahipathi, Adrian Flores, Joseph Jewell, Jared Slack and Scott Meyer.

YASH TRIVADI

Research assistant professor Zherui Martinez-Guo runs Purdue's Impact Science Lab.

DUCKS GOING BALLISTIC

Impact Science Lab provides crucial modeling data to improve Rolls-Royce simulations of bird strikes

Birds and aircraft don't make good friends in the air. A flock of geese, through severe misfortune or self-sacrifice, can take down an entire airliner if they're ingested into the engines. The famous "Miracle on the Hudson," where Captain Sully Sullenberger (MS LA'73, HDR '11) ditched United Airlines Flight 1549 into the Hudson River, is an example where all humans on board survived such an event.

Humans have not always been so fortunate.

That's why the FAA requires that new engine designs pass a bird ingestion test. There's even a document with guidelines on how to fire birds — already dead ones, from a grocery store — into the throat of a full-scale prototype at "no less than 100 percent takeoff power or thrust." This being a destructive test, simulating it in a computer first can reduce costs in addition to preventing surprises when it's time for the real deal.

But meat is notoriously difficult to simulate.

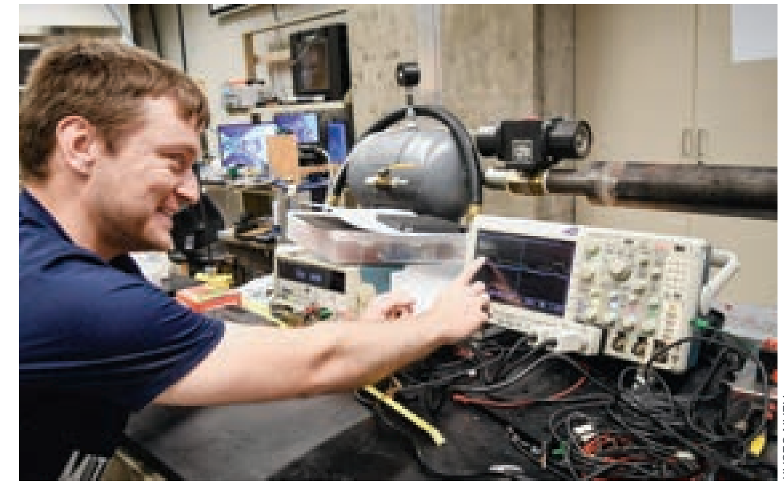
"Computer models tend to treat things as solids or liquids," says Tyler Dillard, a master's student in aeronautics and astronautics at Purdue. "Biological material doesn't behave that way. It's very anisotropic. It responds very differently to loading in different directions and at different loading rates."

Dillard knows this firsthand. Using the Kolsky bars, hydraulic presses and other equipment in Purdue's Impact Science Lab, he's collecting data for an ongoing Rolls-Royce-funded project to provide fundamental-level mechanical responses of biological materials.

Dillard is using duck meat, specifically. It's USDA approved, for consistency. His faculty advisor, Research Assistant Professor Zherui Martinez-Guo, runs the Impact Science Lab.

"We need to understand all parts of the material. We're in the third year of the Rolls-Royce project and moving into higher velocity impact scenarios. We're getting into real interesting territory," Martinez-Guo says.

Matthew Kappes, senior technical specialist Rolls-Royce, explains that this fundamental understanding is a boon for their engineers as well as their bottom line.



ALAN CESAR

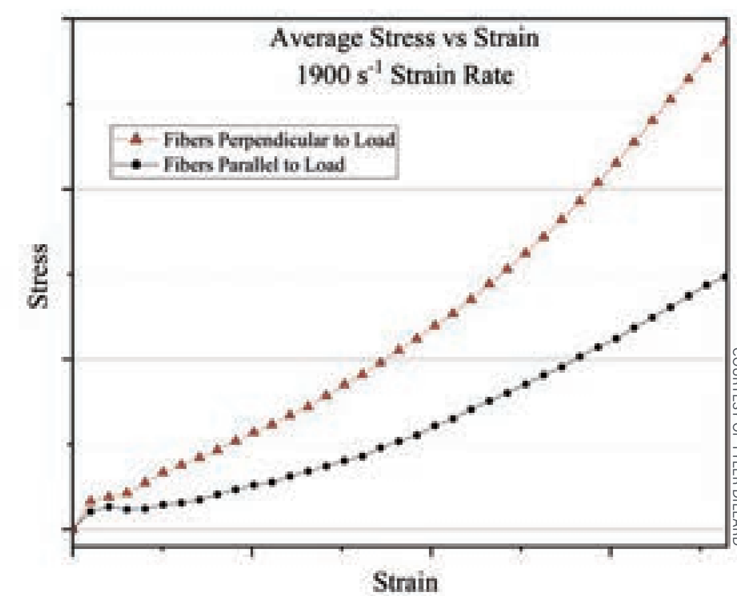
Tyler Dillard reviews an oscilloscope plot from a Kolsky bar.

"Rolls-Royce is continuously pursuing refinement in the understanding of damaging ingestion threats, including birds. The specialized and novel capabilities of the Purdue Impact Science Lab provide an avenue to generate additional insight into the fundamental behaviors of bird material," Kappes says.

"With improved material understanding, we can leverage advancements in computer-aided simulation to generate an improved analytical understanding of the bird threat. Improved fidelity analyses reduce the number of costly and destructive engine hardware tests. This reduces the time to evaluation, enables more designs to be evaluated with confidence, and reduces the cost to deliver bird-resistant engine solutions."

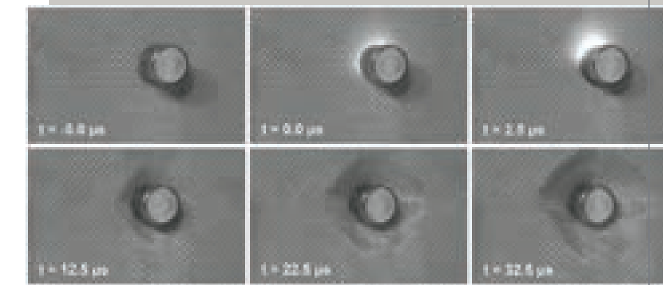
Martinez-Guo cheekily adds one more line item to the cost of the bird ingestion test:

"Besides destroying an engine, you lose an entire turkey as well, and we all know how expensive those are during Thanksgiving."



COURTESY OF TYLER DILLARD

This dimensionless chart, drawn from Tyler Dillard's experimental research data, shows the differences in observed mechanical properties of biological materials based on the direction of the load relative to the orientation of the fibers in the meat. The anisotropic nature of biological materials has made them historically difficult to simulate in computer models. "Few labs and test setups are able to induce strain rates this high. That's one of the things that makes our lab special," Dillard says.



This high-speed image sequence shows a projectile impacting a fabric target at Purdue's Impact Science Lab. This image was published in "Effect of replacement strike-face material on the ballistic performance of multi-ply soft armor targets," coauthored by Zherui Martinez-Guo, in the "Textile Research Journal" in 2019.

IMPACT SCIENCE LAB ACCEPTED INTO EXCLUSIVE TECHNICAL SOCIETY ON AEROBALLISTICS

Purdue's Impact Science Lab, and Purdue University by association, have been accepted into the Aeroballistics Range Association. The ARA is an exclusive technical society of organizations involved in experimental study served by guns and related mechanical launchers.

Purdue, like all members, was voted in based on its unique capabilities. Other ARA member organizations include national labs and defense agencies from around the world, including NASA, the Japan Aerospace Exploration Agency (JAXA), Air Force Research Laboratories (AFRL) and Sandia National Labs.

"We're very specialized. We have hydraulic presses, Kolsky bars, different gun sizes from small particles to large plates, high speed cameras and various optical, laser and X-ray diagnostics. We can get snapshots of how materials transform in time and test materials up to very high loading rates. It's a tricky regime, but it's something our lab is good at." says Zherui Martinez-Guo (BSAAE '11, MSAAE '14, PhD AAE '20), the lab's lead professor and Purdue liaison to the ARA.

Martinez-Guo took over the Impact Science Lab from former AAE professor Weinong Chen, who is now chair of aerospace engineering at Iowa State University. Martinez-Guo conducted his PhD research in the Impact Sciences Lab, studying the ballistic impact resistance of high-performance composite fibers. He served as a distinguished postdoctoral associate at Idaho National Laboratory before returning to Purdue as a research assistant professor in 2024.

IN-FLIGHT RECHARGING

RAN DAI'S RESEARCH TEAM IS PUSHING AUTOMATION TECHNOLOGY TOWARD AN AIR-RECHARGING LOGISTICS NETWORK

Range anxiety isn't limited to electric cars. As people and companies explore wider applications for battery-powered drones, their limited endurance remains a critical challenge. Electric motors are simple and reliable, but batteries still lack the energy density necessary for long-duration missions.

If drones could fly longer, they could be more effective at missions like providing continuous internet connectivity over a rural area, tracking progress of a wildfire, or monitoring an international border. But deploying recharging stations on the ground comes with significant drawbacks.

AAE associate professor Ran Dai has a different idea, borrowed straight from the Air Force.

PHOTOS: ALAN CESAR

"If a drone needs extra charge, going back to the charging station would require a long-term break from the mission. It is better if we can send another drone with charging capability to charge a smaller drone in the air," she says.

Dai has developed a guidance, navigation and control (GNC) system that allows drones to dock autonomously in the air. She has paired this with the idea for a larger network of charging drones, all operating in unison to maintain a continuous, large-scale mission.

It began on the ground

Dai's previous work, funded by the NSF CAREER grant she earned in 2015, planted the seeds for this approach. With that grant, she designed an autonomous, ground-based, multi-vehicle system that could handle a long-duration mission. A mobile charging vehicle, fitted with solar panels, would support the missions' energy needs. It had charging stations for smaller, more agile "worker" vehicles, which would detach and travel to hard-to-reach locations.

Dai's team built the larger charging vehicle and customized a few smaller, off-the-shelf wheeled drones to serve as the workers, then programmed GNC systems for both. The robots communicate in a connected network, so the smaller robots could conduct their mission and return to dock and charge when they'd finished.

In 2018, her research team also published a paper in IEEE exploring the idea of adding solar panels as range extenders to an unmanned aerial vehicle (UAV). Through simulation and real-world experimentation, they investigated the panel's effects on the quadcopter UAV's aerodynamics and its GNC systems.

Dai took the lessons from each of those projects and earned an NSF Foundational Research in Robotics grant to explore a new paradigm: extending a UAV's mission through a solar-powered vertical take-off and landing (VTOL) aircraft that can provide in-air charging.

Combining optics, altitude and GPS

The main challenge with in-air recharging is simply bringing two drones together during flight, Dai says. The GNC system must be precise enough to bring them together and connect their electrical contacts, but computationally light enough to run on their small microcontrollers.

They can't rely on GPS alone -- GPS is only accurate to within 3 meters (10 feet), and urban environments with tall buildings can cause additional variance.

The smaller working drone only needs to control its descent rate during the docking process. The supply drone, with its ample power and size, can support a camera and the heavier computational load of visual processing software. Dai's team programmed it to hover at a steady elevation and align itself with the specific markings on the bottom of the smaller drone.

For the final inches of approach, the team constructed an in-air landing platform for the top of the supplier. It's essentially a big, 3D-printed funnel that matches the support on the receiver drone.

When it reaches the bottom of the funnel, magnets maintain a solid electrical connection.

"We use fast DC charging that can be completed in two to three minutes, so they can resume their original mission," Dai says.

From left: Associate Professor Ran Dai and her students: Yooseung Choi, Victor Ene, Megan Collins, Clifford Gamble, Aayush Iyengar and Abhishek Kini

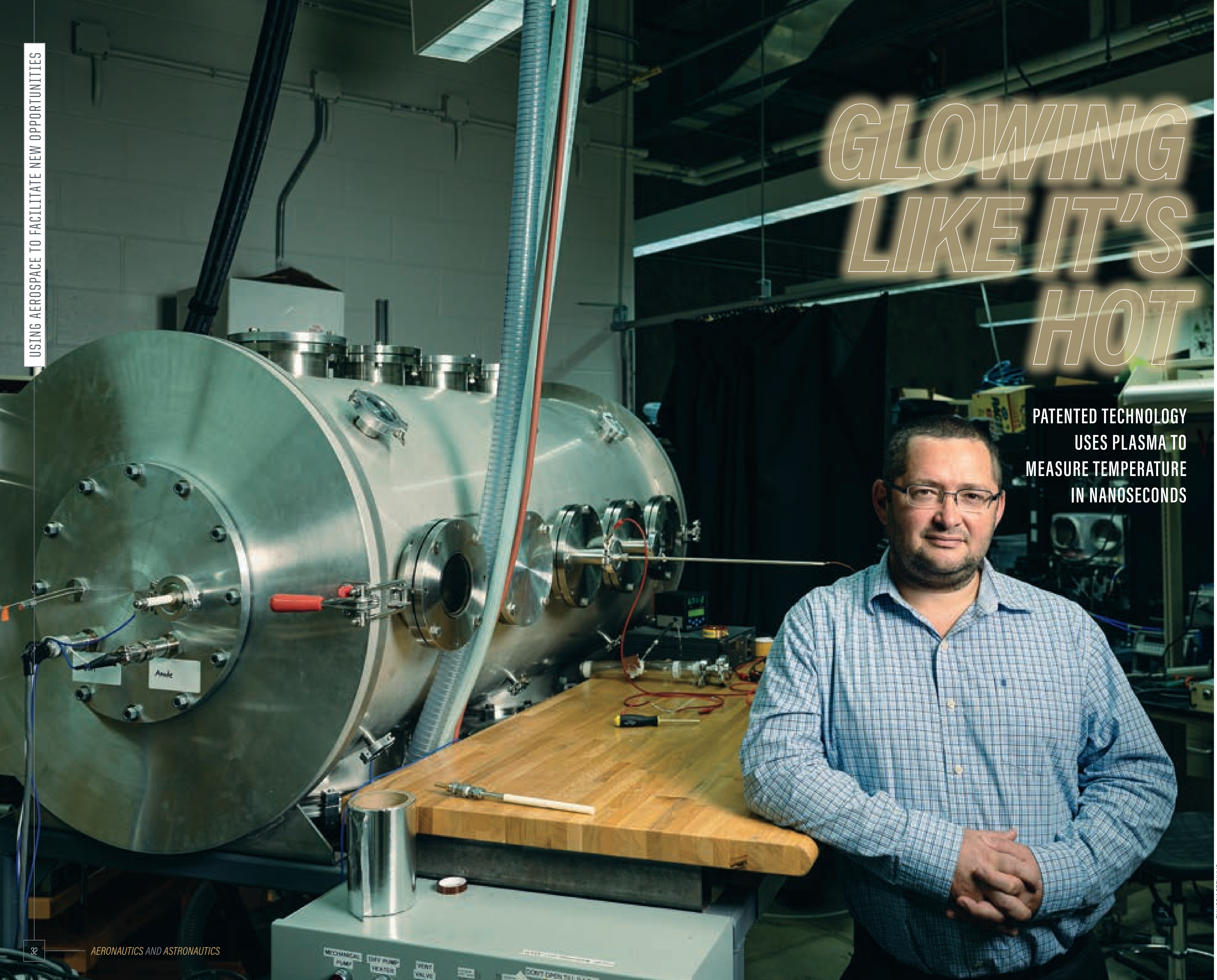
An autonomous charging network

This individual pairing is just one part of a larger, in-air power logistics network. Dai and her team have conceived a whole apparatus that would involve many supply drones and working drones, each conducting their tasks autonomously and communicating when they need recharging.

Work on a UAV project like this would be much more difficult without research spaces like Purdue's UAS Research and Test facility (PURT). It's the largest indoor motion-capture facility in the world, with tools for spoofing GPS and simulating other sensor inputs. PURT is the perfect controlled environment to speed up GNC development.

"We don't need to worry about weather effects, and we don't need FAA approval to fly inside there," Dai says. "Without PURT, it would be much harder to do this work."

Her team's developments on this new and novel system will be published and presented at AIAA's SciTech annual convention in January 2025.



GLOWING LIKE IT'S HOT

PATENTED TECHNOLOGY USES PLASMA TO MEASURE TEMPERATURE IN NANOSECONDS

CHARLES JISCHKE

Like many discoveries, Alexey Shashurin's came unintentionally.

Shashurin, an associate professor, has been studying nanosecond repetitively pulsed discharges (NRPs) or, more plainly, nanosecond sparks in air. Quickly depositing a large amount of energy, more than 1 megawatt of power for the duration of about 10 nanoseconds, into air gaps smaller than 1 millimeter, has broad aerospace applications.

"These miniature discharges play a very important role in aerodynamics and combustion. For example, you can put these tiny plasma elements, known as plasma actuators, over the wing of the airplane to control the flow around the wing. This way, you can prevent undesired flow patterns and stimulate favorable ones," he says.

"The sharp, nanosecond-scale rise of voltage to many-kilovolts leads to a very rapid and intense breakdown, energizing air particles to highly excited energy levels, producing a variety of reactive species and ionization. During the relaxation of stage after the spark, a large amount of heat is released, leading to extremely fast gas heating. This creates strong pressure gradients, resulting in a shock wave and induced vorticity that can be further used to fulfill a particular aerodynamic purpose."

Plasma generators can also support combustion, which is especially useful in hypersonic vehicle engines like ramjets and scramjets. Air moves so quickly through those engines that it's tricky to keep a fire going. A plasma discharge inside the flame can help recover combustion flow, Shashurin explains.

His fundamental research involves the "diagnostics of these discharges and understanding discharge physics." He is characterizing plasma behaviors to inform computer models, making simulations of these applications more accurate.

With an initial grant from the U.S. Department of Energy in 2017, a team led by associate professor Sally Bane and Shashurin as co-principal investigators made a research breakthrough — but he noticed something else, too: "From that initial support, we characterized the nanosecond spark temperature using spectroscopy, something that was not done before. And on the way, we found out that this measurement approach can be used in general, just as an instantaneous thermometer for gas."

He had discovered a now-patented way to get a instantaneous and accurate temperature measurements of gas using these NRPs.

> “The innovation part is what makes the research in general exciting to me. How to make something work, how to measure something that could not be measured before, or to suddenly understand something which was not yet understood. This project is very much like this.”
>
> —**ALEXEY SHASHURIN**, Associate Professor of AAE

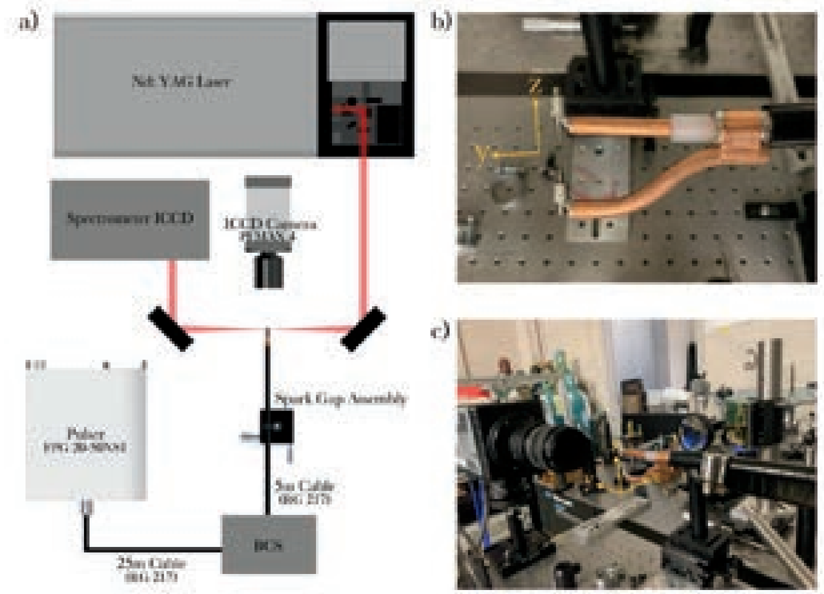
A novel approach

A plasma is a gas so highly energized that it emits light. This can happen at a huge range of forms and conditions, from fluorescent lights to the surface of the sun. Breaking down the light emitted by plasmas into its component wavelengths, through spectroscopy, can indicate the temperature of the energized gas.

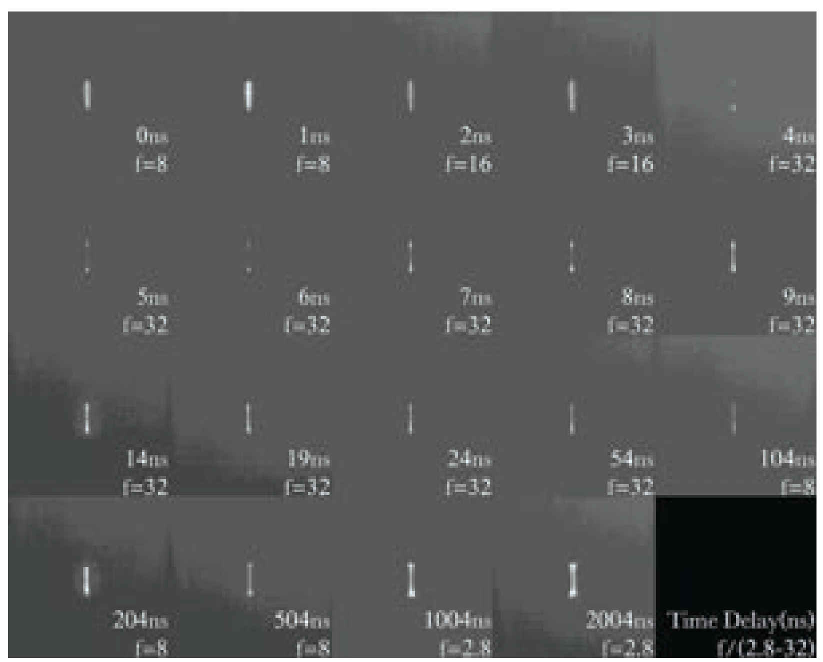
The temperature of a spark is typically thousands of Kelvin. But doing spectroscopy at a very high framerate yielded a surprise.

“When we were applying nanosecond pulse of energy, we saw there was a delay in the heating of the gas. For the first five to 10 nanoseconds of the discharge, the gas is not yet heating up. However, it’s already strongly glowing, which allows us to collect temperature information from it. So, these quick five-nanosecond pulses can be used to detect air temperature or essentially as a very fast thermometer,” Shashurin says.

Measuring air temperature using a spark could be useful when it’s important to get an instantaneous precise reading, or where traditional temperature probes are impractical. Thermocouples can melt, perturb the flow, or underestimate the temperature due to cooling by the thermocouple wires themselves.



This diagram shows a typical experiment setup for doing high-speed spectroscopy on a plasma spark.



This series of images shows the lifecycle of a plasma pulse, or spark, across a 3 mm gap.

Shashurin’s patented approach works on gases in a large range of temperatures varying from room temperature to thousands of Kelvin, and provide response on the timescale of several nanoseconds.

The technique is detailed in U.S. Patent No. 11,946,871, granted in April 2024.

A collaborative effort

Shashurin received additional funding from the U.S. Department of Energy in 2022, allowing him to test sparks created by a more powerful nanosecond pulse generator at Purdue’s Electric Propulsion and Plasma Laboratory. He says working at Purdue puts him near colleagues like Bane, who also does time-resolved plasma spectroscopy. Even when they’re not working on the same project, they often share ideas and equipment. Purdue’s reputation also helps attract the funding that makes these discoveries possible.

“We have a very solid experimental foundation for conducting advanced optical and microwave diagnostics work for combustion and aerodynamics applications. All these strengths are helping to win this research and to utilize all this unique equipment,” he says.

Intra-university collaboration can help fill gaps in Purdue’s vast capabilities. In the summer of 2023, Shashurin and his graduate student Won Joon Jeong packed equipment into the back of his car and drove to Princeton University in New Jersey.

“We each have some unique pieces of equipment in our labs, but sometimes we need several of them together in one place to make things work. We brought our unique nanosecond pulser and unique coherent microwave scattering system to Princeton. They already had the Raman spectroscopy system ready for us,” he says.

Shashurin’s joy in working with other top minds is palpable when he talks about his work —

“As expected, we saw a more energized, denser plasma with this new more powerful nanosecond pulser. Now we are putting together laser interferometry to monitor how high the electron density in these sparks actually is. Our gut feeling is that its ionization degree is very high, but we need to confirm experimentally,” he says.

The true thrill, Shashurin says, is that moment of discovery.

“The innovation part is what makes the research in general exciting to me. How to make something work, how to measure something that could not be measured before, or to suddenly understand something which was not yet understood. This project is very much like this.”

Alexey Shashurin packed some of his unique equipment into the trunk of his car in summer 2023. He and graduate student Won Joon Jeong hit the road for New Jersey to work with researchers at Princeton as part of his DOE award supporting joint experimental effort of Purdue and Princeton Collaborative Low Temperature Plasma Research Facility.

COURTESY OF NASA

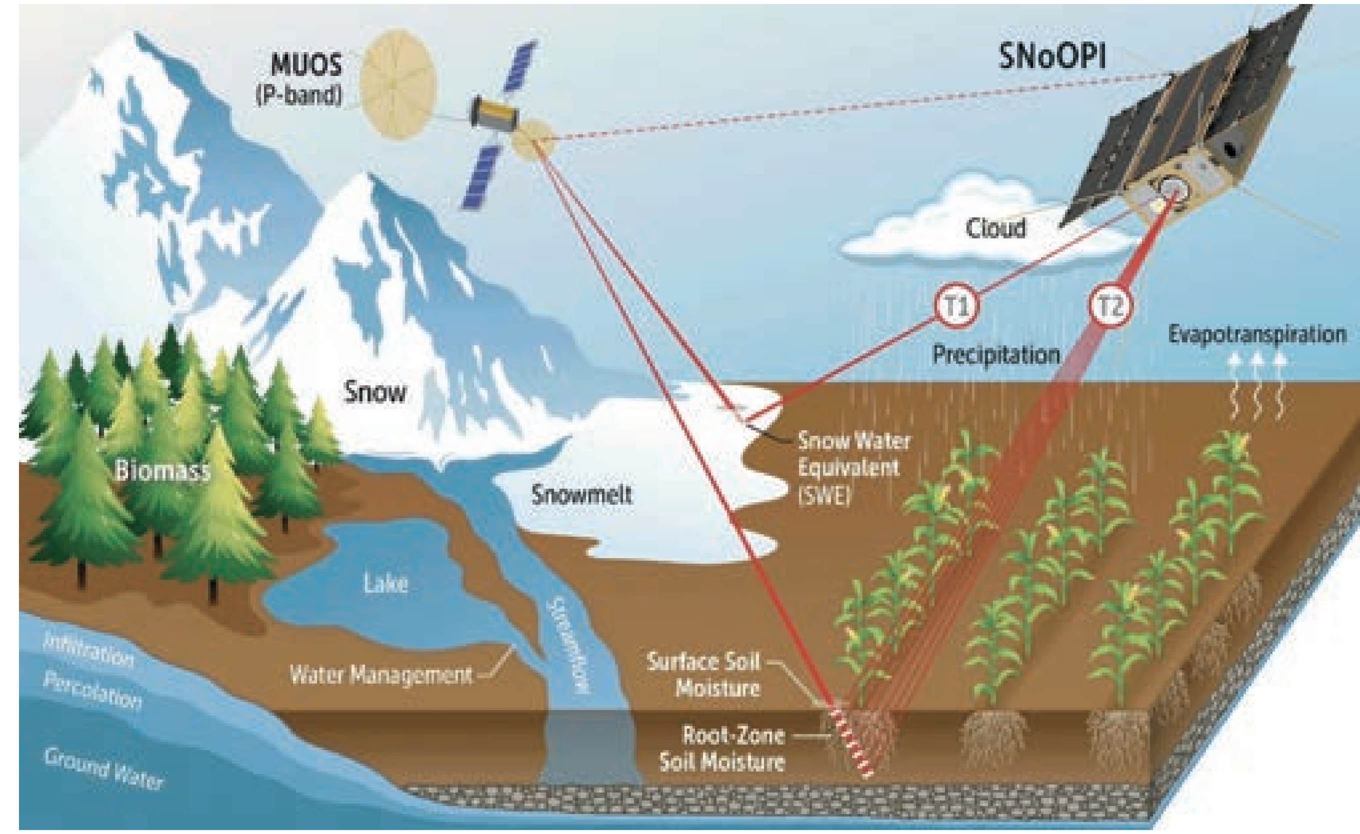
SNOOPI DEPLOYED TO LOW EARTH ORBIT

SNOOPI, an experimental satellite to test and validate a new instrument and technique for Earth remote sensing, was released into low Earth orbit on April 18, 2024, from the International Space Station. This project, led by professor James Garrison is a proof-of-concept mission to determine if communications satellite signals reflected from Earth can be used to measure soil moisture below the surface. It is funded by NASA's Earth Science and Technology Office and was conducted in collaboration with NASA's Goddard Space Flight Center and Jet Propulsion Laboratory.

After confirming solar panel deployment, a power positive state and instrument antenna deployment, the SNOOPI team began making regular contacts with the small satellite from NASA Direct-to-Earth (DTE) tracking stations. This cubesat is the first in-space demonstration of using "signals of opportunity" from non-cooperative communication satellites for Earth remote sensing.

SNOOPI is designed to monitor signals in P-band, around 300 MHz, which are used for basic satellite communications. The key advantage of this method is that these frequencies can reach five times deeper into soil and snow.

"This allows a direct measurement of the moisture contained within the root zone, the layer of soil in which most plant roots exist to absorb the water," Garrison says. "Monitoring of this region provides an important connection between water contained within the soil and that in the atmosphere."



Future missions could use SNOOPI's technology to globally monitor how much water is stored below the surface of the soil and in the snowpack. Earth-monitoring via signals of opportunity (SoOp) could predict droughts and floods, assist with forecasting agricultural yields, monitor trends in climate change and even be applied for predicting wildfire risk. This ability can provide critical information for an increasingly shifting world when it comes to weather, rainfall and climate-smart agriculture. By better understanding where water is, we can predict where it might go and how it can help various stakeholders be more climate resilient.

To support the SNOOPI mission, a monitoring station, shown with Garrison and his students, was installed at Purdue's Agronomy Center for Research and Education in 2023. The antenna array collects accurate measurements of the signal power and spectrum of the non-cooperative source for radiometric calibration of reflected signal measurements.

The SNOOPI mission ended on Sept. 28, 2024 when it reentered. The team is now studying the data collected from the prototype instrumentation to compare against models and observations from various instrumented ground sites.

This proof-of-concept mission follows decades of Garrison's work. He performed some of the earliest research on SoOp. He was also on the science team for NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission, which used this technique to measure wind speed over oceans. Garrison was also elevated to fellow of the Institute of Electrical and Electronics Engineers (IEEE) for his contributions to the SoOp field, and his students have earned prestigious research grants for related work.

SNOOPI is a NASA ESTO funded collaboration between Purdue University, NASA GSFC and NASA JPL.

James Garrison stands with the students in his research group by the antenna array at Purdue that was installed to communicate with SNOOPI.

ALUMNI NEWS

OUTSTANDING AEROSPACE ENGINEER AWARDS

The designation of Outstanding Aerospace Engineer recognizes the professional contributions of graduates from the School of Aeronautics and Astronautics and thanks them for the recognition their success brings to Purdue and the school.

Five AAE graduates were recognized with the Class of 2023 Outstanding Aerospace Engineer award on April 4, 2024.

Recipients must have demonstrated excellence in industry, academia, governmental service or other endeavors that reflect the value of an aerospace engineering degree. The 230 Outstanding Aerospace Engineers represent just over 2% of the school's alumni.

David B. Doman (MSAAE '93)

Principal Aerospace Engineer
U.S. Air Force

Doman is the author or co-author of more than 190 widely cited scholarly publications and has been awarded eight U.S. patents. He served as an associate editor for the "Journal of Guidance, Control and Dynamics" for nine years and currently serves on its advisory board. He is a former chair of the AIAA Guidance, Navigation and Control Technical Committee. In 2011, he received the highest award presented by the U.S. Air Force for basic research, the John L. McLucas Award, for contributions to the science of dynamics and control of flapping wing micro air vehicles.

Robert L. Bayt (BSAAE '93, MSAAE '95)

Lead for Future System Formulation
Moon to Mars Program, NASA

Bayt joined many technical societies at Purdue and was a founder of the local chapter of the Students for the Exploration and Development of Space (now called Purdue Space Program). He also took co-op tours at NASA's Johnson Space Center and Goddard Spaceflight Center. Robert earned a PhD at MIT, researching micromechanical propulsion systems to support the growing interest in micro-satellites. He now supports the Artemis missions by transitioning new system concepts into active programs that will extend capabilities on the lunar surface. He partners with international space agencies and commercial entities.

Rob Chambers (BSAAE '92, MSAAE '93)

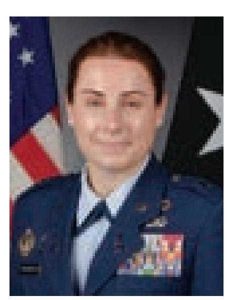
Senior Director of Space Exploration Strategy
Lockheed Martin

Chambers' career spans many spaceflight systems, developing guidance and controls subsystems, avionics, and flight software for projects ranging from Earth remote sensing satellites to landing vehicles and deep space habitation. In his role as director of strategy for space exploration at Lockheed Martin, he is defining, promoting and executing a cohesive set of growth plans for the company's space exploration programs. Through projects that span from earth science to robotics, from space habitation to nuclear propulsion, Chambers is focused on extending humanity's knowledge of our planet, our solar system and the universe at large.

Thomas C. Cannon Jr. (BSAAE '64, MSAAE '69, PhDAEE '70)

Chief Executive Officer, TransNet Technologies

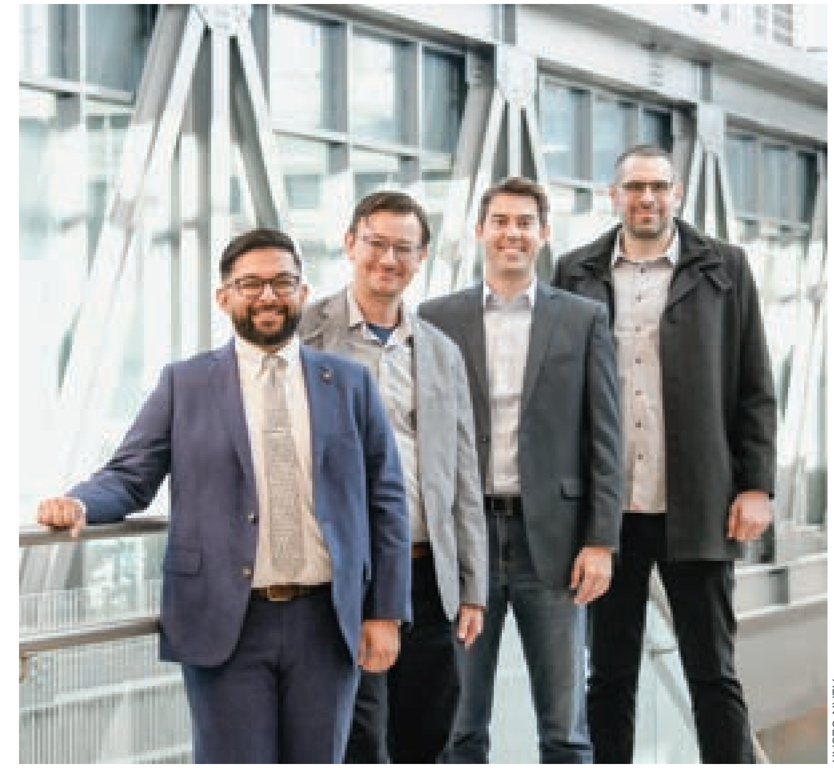
Cannon helped make widespread fiber optic communications possible. Beginning his career at AT&T Bell Labs, working on the Safeguard antiballistic missile program, he developed the equations that defined how to design and manufacture cables without breaking the optical fibers inside. He also led the team that developed the ST Connector, lowering connector cost from $250 to $2.50, and led the team that invented the optical connector that transmitted firing signals to the Patriot missile during operation Desert Storm. Before founding TransNet Technologies, Cannon headed departments at Bell Labs, Sandia Labs and the Naval Surface Warfare Center.



Kristin Panzenhagen (BSAAE '00)

Commander, Space Launch Delta 45
U.S. Space Force

Brigadier General Panzenhagen entered the Air Force in 2000 as a distinguished graduate of Purdue's Air Force ROTC detachment. She began her career as an aircraft maintenance officer, then transitioned to the developmental engineering career field, where she performed aircraft propulsion and structures research and executed space launch and on-orbit satellite operations. She had three deployments to Iraq and Saudi Arabia. As program executive officer for assured access to space, she leads personnel on multiple space launch and range programs. As commander of Space Launch Delta 45, she executes range operations for both government and commercial space launches.



ALAN CESAR

Four of AAE's 38 by 38 honorees — Dave, Gillies, Sunday and Alami — came to campus to receive the award and talked with students in a panel discussion.

38 BY 38 AWARDS

Six AAE alumni were selected for Purdue Engineering's inaugural 38 by 38 Awards, a recognition of high achievement by 38 young alumni. The award was inspired by the legacy of alumnus Neil Armstrong, who was 38 years old when he set foot on the moon. The AAE honorees are:

- **Zaid Alami** (BSAAE '12), Country Managing Director, Indonesia, The Boeing Company
- **Sirisha Bandla** (BSAAE '11), VP of Government Affairs & Research Operations, Virgin Galactic
- **Kara Cunzeman** (BSE '08, MSAAE '10), Director of Strategic Foresight, The Aerospace Corporation
- **Ronak Dave** (BSAAE '14), Flight Director, NASA
- **Daniel Eric Gillies** (BSAAE '06), GOES-R & GeoXO Deputy Program Systems Engineer, NOAA
- **Matthew Sunday** (BSAAE '12), Director and Chief Engineer of Avionics Engineering, The Boeing Company

SPACE CAMP HALL OF FAME

Cynthia Mahler and **Kevin Metrocavage** were inducted into the Space Camp Hall of Fame in 2024. This honor recognizes their outstanding contributions to space exploration and education.

Mahler (BSAAE '98, OAE '23) is former director of Boeing's University Research & Development Partnerships Program. She has earned a NASA Silver Snoopy and other awards for her contributions to ISS training and other programs. She is also founder of Purdue Space Day, which has inspired thousands of young minds to pursue careers in space sciences.

Metrocavage (BSAAE '96, OAE '21) is currently the ISS operations manager at NASA headquarters. He is responsible for maintaining overall situational awareness of the planning and execution of ISS complex operations.

OTHER AWARDS AND HONORS

Aviation Week Network named **Mike Moses** (BS Physics '89, MSAAE '95, OAE '11) among its 66th annual Laureate Awards in November 2023. The award honors his extraordinary achievements in the global aerospace arena. Moses is president of Virgin Galactic.

Rick Russell (BSAAE '69) was inducted to GE Aerospace's Propulsion Hall of Fame. He was instrumental in the design, certification, and in-service excellence of the CFM56 and GE90 engines. His leadership across numerous engine lines contributed to the company's growth in the aircraft engine business.

Send your news and updates to aae@purdue.edu or tag @PurdueAeroAstro on LinkedIn, Instagram, X or Threads.

FACULTY NEWS

NEW FACULTY

AAE has hired several new faculty members to keep up with the program's tremendous growth. Below are the new faces joining us this academic year. Look for feature stories coming to the AAE website.

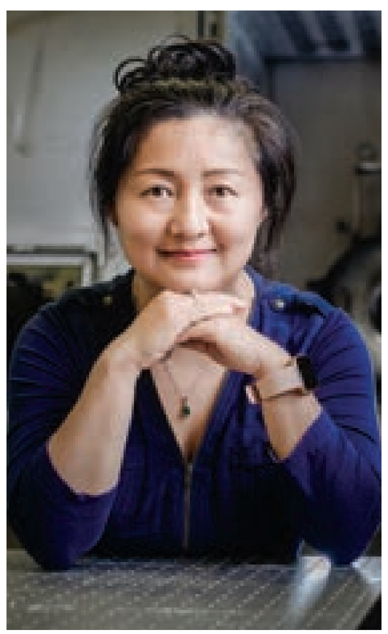
Takashi Tanaka
Associate Professor

Kevin Parsons
Associate Professor of Engineering Practice

R. Bruce Alstrom
Assistant Professor of Engineering Practice

Zehui Lu
Visiting Assistant Professor

Suman Chakraborty
Visiting Assistant Professor

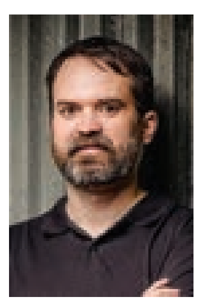


QIAO EARNS FULBRIGHT SCHOLAR AWARD

Professor **Li Qiao** will live in Japan and collaborate with researchers at Tohoku University on "Exploring Ammonia as a Hydrogen Carrier for Aerospace Applications." Her goal is to better understand the fundamental combustion properties of ammonia, and to explore its application in propulsion systems for small and midsized aircraft.

SUN TAKES OVER AAE GRAD PROGRAM

Professor **Dengfeng Sun** has been appointed the new associate head of the Gambaro Graduate Program of Aeronautics and Astronautics. His five-year term leading the No. 2-ranked aerospace engineering graduate school officially began on Aug. 12, 2024. Outgoing associate head Greg Blaisdell remains on faculty.



GOPPERT PROMOTED

James Goppert, managing director of the Purdue UAS Research and Test facility, was promoted to research assistant professor.

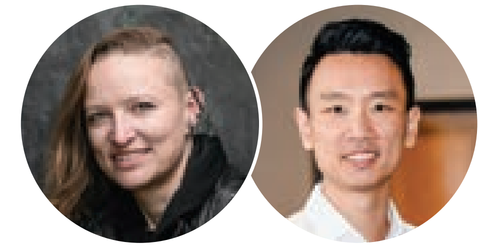
JOURNAL OF THE ASTRONAUTICAL SCIENCES NAMES ITS BEST PAPER AWARD FOR HOWELL

Maruthi Akella, editor-in-chief of the Journal of the Astronautical Sciences, announced the journal would begin issuing an annual award in honor of professor **Kathleen Howell**. The naming is in recognition of Howell as the Journal's former longstanding editor-in-chief, for her "outstanding leadership and professional service contributions" to the publication.

The award's first winner is Ashley Biria for his paper titled, "Revisiting Universal Variables for Robust, Analytical Orbit Propagation Under the Vinti Potential."

ASTROID NAMED FOR HOWELL

An asteroid in the solar system has been named after AAE professor **Kathleen Howell**. In a November 4 report, the International Astronomical Union's Working Group on Small Bodies Nomenclature (WGSBN) gave a main-belt asteroid the name (5396) Kathleenhowell.



FRUEH AND KWOK NAMED AIAA ASSOCIATE FELLOWS

Associate professors **Carolin Frueh** and **Kawai Kwok** have been named to the 2025 class of Associate Fellows of the American Institute of Aeronautics and Astronautics (AIAA). This designation is reserved for professionals who have demonstrated excellence in their respective fields, contributing valuable knowledge and innovation to the aerospace industry.

YU RECEIVES AWARDS FROM AMERICAN SOCIETY FOR COMPOSITES AND ASME

Wenbin Yu was named Fellow and Outstanding Researcher by the American Society for Composites at the organization's 39th Annual Technical Conference. Yu is the Milton Clauser Professor of Aeronautics and Astronautics.

He also co-authored a paper on fatigue simulation in aerospace composites that earned the ASME/Boeing Structures and Materials Award at the 2024 ASME Aerospace Structures, Structural Dynamics and Materials Conference. His co-authors on the paper were his former PhD students Xin Liu (PhD AAE '20), Su Tian (PhD AAE '22), and Zhenyuan Gao (PhD AAE '19), and his former postdoc Liang Zhang.

CALDWELL CO-CHAIRS PANEL ON MARS SCIENCE OBJECTIVES

What topics should humans study on the surface of Mars? Professor Barrett Caldwell is co-chairing a panel at the National Academies of Sciences, Engineering and Medicine, to identify the highest-priority science objectives for Mars, plus the developments needed to enable that research.

DEPARTMENT HEAD CROSSLEY GETS 2 MILLION VIEWS IN WIRED AVIATION SUPPORT VIDEO

Is severe turbulence safe to fly through? Could electric airplanes replace fuel-burning ones? Bill Crossley, the Uhrig & Vournas Head of Aeronautics and Astronautics, answered these aviation questions and more in the Tech Support video series from WIRED. The video surpassed 2 million views in less than six weeks. Find it on WIRED's YouTube channel.

FACULTY AND STAFF INVITED ABOARD NAVAL AIRCRAFT CARRIER

Professor Tim Pourpoint joined professors Karen Marais and Steve Son, plus Zucrow Labs managing director Scott Meyer and other Purdue representatives, on an eye-opening experience aboard the USS Abraham Lincoln aircraft carrier. Pourpoint was impressed by the level of responsibility and pride of the crew. "They make a nuclear aircraft carrier run, and they operate equipment to trap fighter jets every 50 seconds," he says.

The trip also gave Pourpoint insight to the Navy's propulsion needs. "It was an amazing opportunity to put into context some of the technical ideas I have had to support propulsion systems. That should mean better proposals to the Navy."

DELAURENTIS AND PHD STUDENT RECEIVE PRESTIGIOUS SYSTEMS ENGINEERING AWARDS

Professor Dan DeLaurentis received the Founders Award from the Systems Engineering Research Center (SERC) during the organization's annual Research Review conference. It's the culmination of a long career with the network he joined in 2008 — its first year.

Also at the conference, Sonali Sinha Roy received the Dr. Barry Boehm Award for Doctoral Student Research Excellence, for her presentation titled, "A State-Based Probabilistic Risk Assessment Framework for System-of-Systems Operations." Sinha Roy was a PhD candidate studying under Delaurentis at the time. She has since completed her doctorate.

FACULTY NEWS

FACULTY RETIREMENTS AND EMERITUS AWARDS

Stephen Heister, the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration, is set to retire from Purdue after the fall 2024 semester, having served more than 34 years on the faculty. As the former managing director for Maurice J. Zucrow Laboratories, Heister is credited with growing Zucrow into a premier academic propulsion lab — and the largest in the world. The facility now supports more than 200 students.

Heister has also made numerous contributions to propulsion research and made significant impact as an engineering educator. He will receive the J. Leland Atwood Award from AIAA and ASEE at the SciTech annual conference in January 2025. The award recognizes contributions in the aerospace field and in educating the next generation of aerospace engineers.

Jim Longuski was approved by Purdue University for the title of Professor Emeritus of Aeronautics and Astronautics after quietly retiring in January 2024. Longuski earned eight different awards for outstanding teaching throughout his career and was inducted to Purdue's Book of Great Teachers in 2008.

Longuski published more than 200 journal papers, authored textbooks and popular books on aerospace engineering, including "The Seven Secrets of How to Think Like a Rocket Scientist." He also collaborated with astronaut Buzz Aldrin, creating a senior design course that analyzed Aldrin's plans to establish a permanent human presence on Mars. He worked at NASA's Jet Propulsion Laboratory prior to joining the Purdue faculty, contributing to trajectory and mission design for Project Galileo.

James Doyle was also approved by Purdue University for the title of Professor Emeritus of Aeronautics and Astronautics after retiring in 2024. Doyle's research focused on methods to analyze the response to dynamic impact on complex structures and led to authorship of several books dealing with experimental stress analysis, wave propagation and nonlinear analysis.

With his broad interest in experimental mechanics, Doyle was a leader in AAE's efforts to provide top quality education in both experimental and numerical techniques to characterize structural response to various types of static and dynamic loading. He received multiple awards for teaching and research from the Society for Experimental Mechanics throughout his career.

STAFF NEWS

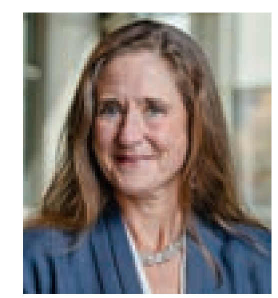
AAE STAFF WIN EXCELLENCE AWARDS FROM COLLEGE OF ENGINEERING

In the past two years, eight AAE employees received recognition for their outstanding work from the Purdue College of Engineering's annual Staff Awards of Excellence.

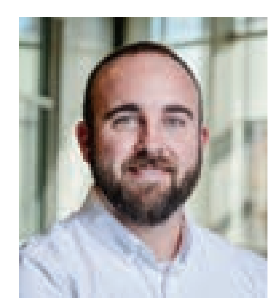
Lead research engineer Rohan Gejji received the Fall 2024 Outstanding Research Staff Award for extraordinary contributions in research excellence, innovation in experimental methodologies, fostering a culture of collaboration and mentoring the next generation of engineers.

AAE also had finalists in three other categories: operations manager April Sauer, for the Customer Service Excellence Award; senior test engineer Jason Gabl and administrative assistant Liz Quinlan for the Outstanding New Employee Award.

Rohan Gejii



April Sauer



Jason Gabl

Liz Quinlan

Left to right: James Goppert, Tony Cofer, Maureen Kane and Alan Cesar.

In 2023, James Goppert, managing director of the Purdue UAS Research and Test Facility (PURT) won the Outstanding Research Staff Award. He was selected for "striving to increase opportunities to collaborate with researchers across the university and further with the design and construction of the Purdue UAS Research and Test Facility."

Tony Cofer, spacecraft laboratory engineer, was also a finalist for the Outstanding Research Staff award in 2023. AAE event planner Maureen Kane was a finalist for the New Employee Award for support and service staff, and marketing director Alan Cesar was a finalist for the New Employee Award for management and professional staff.

FACILITY NEWS

Students Benefit from Dedicated Maker Space

With AAE student clubs vying for top finishes in collegiate competitions, they had outgrown the space available to them in the Neil Armstrong Hall of Engineering. At their request, the school secured a 5,000-square-foot makerspace in the Purdue Technology Center and filled it with equipment, storage and workspaces to help them succeed.

"This space is a lot bigger than we had before, and it really helps to bring the whole team together and have all the tools and supplies we need in one place," says Isha Patel, president of the Purdue Aerial Robotics Team (PART). The makerspace is located off campus in the Purdue Research Park, about two miles from Armstrong Hall, so Patel says coordinating transportation was an initial hurdle. "But it wasn't too tough. Some of us carpool, and there's a CityBus route with a stop nearby," she says.

PART's 120 members are spread across seven multidisciplinary teams to prepare a vehicle for the Student Unmanned Aerial Systems Competition (SUAS). John Rolfe, who serves as PART's competition lead, says the shared space means they get to interact more often with other clubs. They have shared tools, parts and ideas back and forth between them.

"It's good to have PSP [Purdue Space Program] nearby. They have been working on their rocket for an upcoming launch while we prepare for our competition. We've borrowed odds and ends back and forth, and shared ideas too. It's been really fantastic," Rolfe says.

"We're also able to be safer here when we're working with composites, which is great for all our members."

PHOTOS: ALAN CESAR

VINCENT WALTER

UAV research center celebrates opening of 'Smart Crossways' operations center at Purdue Airport

Bill Spencer, senior staff engineer for advanced aircraft at California-based General Atomics Aeronautical Systems, observes research fellows and PhD candidates Jayanth Shreekumar, electrical and computer engineering (left) and Chuhao Deng, aeronautics and astronautics, as they run a flight demonstration exercise of an uncrewed aerial vehicle at AIDA^3's Smart Operations Center at the Purdue University Airport.

An interdisciplinary team of Purdue researchers are bringing together their collective expertise to develop the nation's first smart air corridor.

The Smart Crossways of America, a 200-mile-long air corridor, will enable uncrewed aerial vehicles to safely transport cargo, medicine and people from Purdue's West Lafayette campus to the Naval Surface Warfare Center, Muscatatuck Urban Training Center in southern Indiana and Indianapolis.

In September 2024, Purdue's Center on AI for Digital, Autonomous and Augmented Aviation (AIDA^3) unveiled its Augmented Aviation Lab (AAL), a state-of-the-art testing facility for Smart Crossways at the Purdue University Airport. A series of live demonstrations also showcased the capabilities of autonomous aerial vehicles (AAVs) in an urban air-mobility environment.

AIDA^3 also led an NSF-funded two-day workshop on "AIrTonomy: The Smart Crossways of America," which included industry and academic leaders focused on the development of AAVs for cyber-simulated and real-world environment.

"The Smart Crossways corridor will provide the Purdue-led AIDA^3 team and collaborators a key, real-world test environment as it looks to explore and foster a converging field of R&D focused on AI-enabled autonomy envisioning the future or urban air mobility," said AIDA^3 founding director Sabine Brunswicker, a professor for digital innovation in Purdue's Polytechnic Institute.

"We call this field AIrTonomy and emphasize its vision to develop safe and trustworthy artificial intelligence and machine learning systems for AAVs to operate safely in urban environments. We want to ensure that future autonomous drones and air taxis can safely move things and people beyond visual line of sight."

An essential part of this effort is a planned 15-mile-wide Purdue Unmanned Proving Ground, or PUP. "PUP brings together five unique indoor and outdoor facilities and infrastructure components that ensure research can iterate rapidly from 'lab to life,'" said Karen Plaut, Purdue's executive vice president for research.

The research team, which includes faculty and students from the School of Aeronautics and Astronautics, is working with Saab to install ground communication and networking infrastructure for urban airspace management.

The AAL facility unveiled at Purdue Airport is equipped with high-definition screens, motion-capture cameras and VR/AR technologies to facilitate immersive interactions with "outer" spaces. The AIDA^3 team showcased how an operator can remotely pilot a large, uncrewed, fixed-wing aircraft using these tools and an AI system created by the AIDA3 team.

James Goppert, managing director of PURT and research assistant professor in AAE, added: "By the end of 2025, we hope to showcase that we can operate 10 ULTRAs in real urban airspaces with just one operator."

Maurice Zucrow (at left) with leading rocket engineers. He chaired the Panel on Propulsion and Fuels that was part of the Guided Missiles Committee of the government's Research and Development Board (1947–1952).

ZUCROW LABS *CELEBRATES* 75 YEARS

The history of Zucrow Labs is the history of a moment and a man. "Cometh the hour, cometh the man," is the classic adage, and in this case the hour was the need for rocket propulsion systems at the birth of the space age, and the man was Maurice J. Zucrow.

As Zucrow Labs marked its 75th anniversary in 2024, it's hard not to pay tribute to the man who joined the Purdue University faculty in the School of Aeronautics and Astronautics in 1946. In 1948, he wrote the seminal and definitive book on jet propulsion, "Principles of Jet Propulsion and Gas Turbines," essentially laying out the fundamentals of rocket science. This was followed quickly by the construction of the Rocket Propulsion Laboratory to support his research.

In the decades since, Purdue has become synonymous with aviation propulsion and space flight. From Amelia Earhart to the first and last men on the moon, to the development of the Space Shuttle main engines, Zucrow works with government entities, corporations, defense, academic institutions and more, welcoming everyone from Wernher von Braun to Elon Musk.

Set on more than 24 acres, Zucrow Labs retains its mantle of preeminence today as the largest academic propulsion lab in the world, with active research programs in rockets, turbines, compressors, energetic materials, fluid mechanics, hypersonics and all kinds of combustion.

If it propels the world forward, you'll find it at Zucrow.

Dawn of the Space Age

It was a momentous time in 1946, when Zucrow joined the Purdue faculty. While the start of the Space Age is often dated by the Soviet Union's Oct. 4, 1957, launch of Sputnik, the decisive research into propulsion and rocket technology that was the *sina qua non* for orbital journeys was proceeding apace in the decade prior to that stunning feat.

The operational capabilities of the rocket-propelled V-2 during World War II demonstrated the possibility for space flight. Recognizing the potential of jet propulsion, legendary Purdue Engineering Dean A. A. Potter and President Fredrick Hovde — who, during World War II, had been the U.S. chief of rocket ordinance research, for which he received the President's Medal for Merit — searched for the top person in the field to teach and oversee a research program. Zucrow fit the bill and accepted the offer to come to West Lafayette.

After his hiring, the first order of business was constructing a large physical facility with enough space for the analytical and experimental programs. Purdue was assisted by a grant from the Office of Naval Research; its $20,000 award was matched by the Purdue Research Foundation to construct a new rocket facility, the Rocket Propulsion Laboratory.

The facility was set in a farmer's field at the southwest edge of campus. Adjacent to Purdue Airport, the country's first university-owned airport, the lab had space for two rocket motor firing cells, a control and instrument room, a machine shop for building rocket motors, a chemistry lab and graduate student desks. There was no electric power; the juice came from a four-cylinder diesel electrical generator set, which was war surplus from the Navy.

There was also no phone service to the remotely located lab. Communication with Zucrow's office in the AeroSpace Sciences Laboratory a mile away was jerry-rigged via an army field telephone, which was operated by hand crank and also war surplus. Lines were strung on fence posts.

The Rocket Propulsion Laboratory was connected with Purdue power, water and phone service in 1951. Additional test cell space enabled expansion, from initial work on the effects of high chamber pressure operation on performance and heat transfer to ignition characteristics of propellants and droplet combustion. The techniques for obtaining rocket propellant ignition delays developed at Purdue became the industry standard for many years.

After building the Rocket Propulsion Lab for his work, Purdue then constructed the Combustion Laboratory in 1952, the Gas Turbine Laboratory in 1954, and in 1965, the High Pressure Rocket Research Laboratory, which turned out to be the culmination of Zucrow's career, as he retired a year later. Zucrow passed away in 1975.

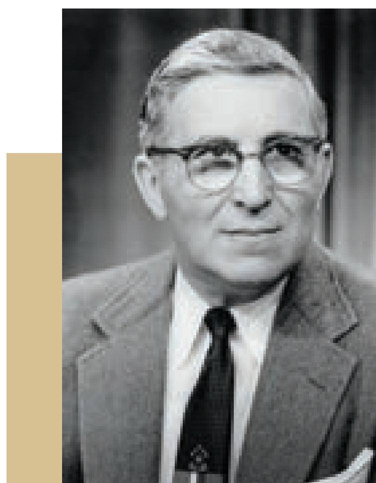
The largest expansion in the history of Zucrow Labs occurred in 2015-2017 with construction of the High Pressure Combustion Laboratory (ZL8), adding five new high-pressure combustion test cells, a state-of-the-art laser diagnostic lab, a 1,500-degree-Fahrenheit air heater, and additional control rooms, offices and workshops.

From Potholes to High-Speed Propulsion

At this point, the facility was unrecognizable from its 1948 origins.

"When I became director of the Labs, you had to drive under a one-lane railroad bridge and turn onto a pothole-filled road to get here," says Robert Lucht, the Ralph and Bettye Bailey Distinguished Professor of Mechanical Engineering and director of Zucrow Labs. "Beginning in 2015, Zucrow Labs became a permanent construction site. The first thing we did was repair

> "There is no other university-affiliated institution that can manufacture and then test propulsion technologies, including hypersonic technologies, at flight-relevant scales and conditions all in the same place."
>
> —**ARVIND RAMAN**, the John A. Edwardson Dean of the College of Engineering



One-of-a-Kind

Born in Kyiv, Ukraine, in 1899, Zucrow emigrated with his family from there to London in 1900. He grew up in a tough but close-knit neighborhood in the East End, became a boxer and excelled in school. He immigrated to the United States in 1914 and entered Harvard in 1919, becoming the first to graduate with a bachelor's degree in engineering from that school. He was also the first student to receive a PhD from Purdue's College of Engineering, completing his dissertation in mechanical engineering in 1928.

Maurice J. Zucrow and students displaying their rocket research. Zucrow taught at Purdue from 1946 until his retirement in 1966.

Top: Maurice J. Zucrow Labs celebrated its 75th anniversary in 2024.

the road and replace the railroad bridge so trucks could get in. This began a building spree that has continued right to the present day."

The coming years brought an expansion and two new modern test cells for compressor research in ZL1 and a state-of-the-art facility for synthesis of advanced energetic materials in ZL4. In 2023, the Hypersonics and Applied Research Facility opened. The first-of-its-kind, $41 million research facility boasts hypersonic wind tunnels, shock tubes, manufacturing labs and secure entry for national defense research.

A new $73 million High-Speed Propulsion Lab known as ZL9 was dedicated in October (see inside cover).

Today, Zucrow Labs remains at the forefront of creating and refining the "fundamentals of rocket science that first empowered the U.S. to build ballistic missiles for the Cold War and civilian rockets for space exploration," says Mike Smith, a professor of history in Purdue's College of Liberal Arts and author of "The Rocket Lab: Maurice Zucrow, Purdue University and America's Race to Space," the story of Zucrow's life and times.

Purdue President Mung Chiang put it this way, at a 75th anniversary dedication ceremony: "We dedicate here today, as Dr. Zucrow dedicated his team in 1946. And we dedicate ourselves to the everlasting journey to create and disseminate knowledge. We dedicate our support to the talents of Boilermakers, and we dedicate to propel Purdue Engineering to the pinnacle of research excellence."

IN MEMORIAM

1940s

Thomas C. Costin (BSAE '48)
Eldon E. Kordes (MSAE '49)
Jack E. Willer (BSAE '47)

1950s

Cyrus E. Baker Jr. (MSAE '58)
Gearld K. Cooper (BSAE '46, MSME '49, PhD AE '55)
William H. Dunton (BSAE '50)
Wayne D. Howell (BSAE '51)
Julius F. Ickler (MSAE '59)
Jack R. Jordan (BSAE '52)
Thomas H. Lowe (BSAE '56)
Donald J. Marcotte (BSAE '53)
Kenneth G. Motzny (BSAE '59)
Martin L. Myers (BSAE '53)
John L. Rich (BSAE '54)
Lynn A. Schwartzkopf (BSAE '57)
Joseph D. Smith (BSAE '59)
John W. Thomas (BSAE '55)
Gerald G. Ward (BSAE '57)

1960s

Gerald A. Allen (BSAE '60)
William H. Burwell (BSAE '60)
William H. Frey (BSAE '65)
John M. Gromek (MSAE '63)
James C. Hoffman (BSAE '66)
Kenneth W. Jonaitis (BSAE '66, MSAE '68)
Douglas G. Kinney (BSAE '64)
John E. LeRoy (BSAE '61)
Harold J. Linnerud (BSAE '61, MS Engineering Administration '62)
Brett M. Nordgren (BSAE '61)
Wendell S. Norman (MSAE '58, PhD AE '61)
Gerald J. Patrick (BSAE '66)
Ronald G. Rehm (BSAE '60)
James R. Scohy (BSAE '65)
Thomas M. Smith (BSAE '59, MSAE '67)
Ronald J. Swartz (MSAE '60)
Edward J. Szwabowski (BSAE '61)

1970s

George W. Beal (BSAAE '73)
Douglas L. Bowers (BSAE '72)
Lawrence P. Carmody (BSAE '70)
Richard M. Carroll (BSAE '52, MSIE '73)
Darryl W. Hall (BSAE '72, MSAE '72)
Dennis J. Helfritch (MSAE '66, PhD AE '72)
Thomas L. Larsen (PhD AE '72)
Stanley J. Misiuk (BSAE '70)
Edward A. Owczarek (BSAE '70)
Robert W. Reid Jr. (BSAE '66, MSAE '67, PhD AE '70)
John T. Riechers (BSAAE '76)
Denise M. Vandenberg (BSAAE '73)
Joe E. Warren (BSAE '66, MSME '68, PhD ME '71)

1980s

Paul D. Baumgartner (MSAAE '89)
Susan J. Cabler (BSAAE '80)

1990s

John M. Emerson (BSAAE '90)
Rebecca A. Gick (BSAAE '91, MSAAE '94, PhD AAE '99)

In Memoriam listings are based on those reported to us. Did we miss someone? Please let us know. Email Ashley Thompson: althompson@purdueforlife.org

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