AEROGRAM

FALL/WINTER 2022

PURDUE UNIVERSITY SCHOOL OF AERONAUTICS AND ASTRONAUTICS

THE PHYSICS OF PLASMAS

Unique spectroscopy technique may unravel the mysteries of energized matter

PAGE 20

CRADLE EXPANDS

POWERS BECOMES 27TH PURDUE ASTRONAUT

Audrey Powers couldn't receive her Outstanding Aerospace Engineer (OAE) award in person in October 2021, but she had the perfect reason for canceling. Her career in aerospace led her to the role of vice president of mission and flight operations at Blue Origin, and during the OAE ceremony Powers (BSAAE '99) would be preparing for a trip to space.

Taking off aboard Blue Origin's New Shepard spacecraft on October 13, Powers conducted vital work for the company's engineering team through checkouts of human integration and emergency systems. Those contributions made Powers the latest Purdue graduate to enter the Cradle of Astronauts and the third commercial astronaut to earn that recognition. She also took a Purdue pennant on the trip.

"I'm very emotional about it. To think that my name would be spoken in the same sentence as these other astronauts who graduated from Purdue is just … I absolutely do not feel like I am their equivalent," Powers says. "I've worked in this industry my entire career. I'm not downplaying the contributions I've made or the hard work I've put in to help the commercial aspects of this industry get up and running. But it's overwhelming to me that I would be compared to these people."

Powers received her 2021 award in person at the OAE banquet in April 2022.

AEROGRAM

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IN THIS ISSUE:

Alumna Audrey Powers (second from left), Blue Origin's vice president of mission and flight operations, became the company's first employee to launch on its New Shepard spacecraft in October 2021. Powers, who flew with actor William Shatner and two private citizens, is the third commercial astronaut in Purdue University's Cradle of Astronauts.

BLUE ORIGIN

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ON THE COVER: Karna Patel (left) and Anup Saha, doctoral students advised by AAE associate professor Sally Bane, use an alignment laser to prepare for a plasma spectroscopy experiment. (Rebecca McElhoe)

LETTER FROM THE HEAD

WILLIAM CROSSLEY
J. WILLIAM UHRIG AND ANASTASIA VOURNAS HEAD OF AERONAUTICS AND ASTRONAUTICS

Dear alumni, friends, students, staff and faculty,

This is the fourth edition for which I get to provide a welcome letter to Aerogram. That also means it is the fourth time that I get to highlight records for the School of Aeronautics and Astronautics.

As a sign of our continuing success as a top aerospace engineering academic program, our 1,176 undergraduate and 604 graduate students represent a six-fold increase from when I started as an assistant professor at Purdue in 1995. Our U.S. News and World Report rankings have us at 5th for both undergraduate programs and graduate programs. According to the American Society for Engineering Education (ASEE), we graduated the most aerospace engineers with bachelor's degrees in the U.S. last year.

To keep up with our seemingly ever-increasing enrollment and to bolster our research capabilities, we added two new faculty members this year. Husheng Li joins us as professor in our autonomy and control area. He has an electrical engineering background. Husheng conducts research and will teach courses relevant to aerospace communications and avionics (Page 31). Keith LeGrand joins us as an assistant professor in our astrodynamics and space applications area. Keith works on multi-target tracking amongst other important issues for access to and use of space, which aligns very well with the AAE-led college initiative in Cislunar space (Page 30).

Another record for AAE is our research expenditures. While this is an imperfect measure of our research productivity, I am nonetheless pleased to report that our total for the academic fiscal year (July 2021-June 2022) was nearly $22 million, which far exceeded last year's $17.5 million. The Department of Defense, NASA and our industry partners are our three largest research partners by expenditures.

We have many valued industry partners and, at the time of this letter, Purdue has just finalized a master research agreement with Northrop Grumman, which will make it easier for faculty, students and research staff to interact with Northrop Grumman on topics of interest.

Similarly, Purdue's renewed partnership with Rolls-Royce has a $75 million value over 10 years. This will reinforce the base research AAE has with Rolls-Royce in experimental capabilities of gas turbine engines, and is an opportunity for new areas of collaboration.

In another facet of our industry partnerships, we were able to restart the William E. Boeing Distinguished Lecture this fall by welcoming Grazia Vittadini, the chief technology and strategy officer for Rolls-Royce, as the lecturer. Her talk was an excellent overview of the challenges the industry faces, balanced with the promise we bring to make aviation a sustainable and societally necessary enterprise. We were also grateful to have Todd Citron, the chief technology officer for Boeing, visit Purdue and introduce Vittadini for her lecture (Page 33). Sustainable aviation is an important issue for us; while it does not appear in this issue of Aerogram, many of the AAE faculty — including me — are working on efforts to enable aerospace and aviation to "make the world smaller" while remaining a steward of our environment.

With the current size of the School of Aeronautics and Astronautics, I cannot begin to cover all of our exemplary achievements, groundbreaking research and educational efforts. In addition to the themes of sustainable aviation and Cislunar space that I have mentioned here, we are also pursuing work in maintaining national defense and security and in enabling new opportunities through aerospace. There are several highlight stories in this issue of Aerogram, but there is so much more going on in AAE at Purdue. I encourage you to follow us via social media (LinkedIn, Twitter, Instagram, Facebook) or visit our website.

We are ever grateful for your continuing interest in AAE. Your support enables our success.

JOHN UNDERWOOD

AERONAUTICS AND ASTRONAUTICS BY THE

NUMBERS

RANKED

5TH

BEST UNDERGRADUATE AEROSPACE/ AERONAUTICAL/ ASTRONAUTICAL ENGINEERING

U.S. News and World Report (2023)

RANKED

5TH

BEST GRADUATE AEROSPACE/ AERONAUTICAL/ ASTRONAUTICAL ENGINEERING

U.S. News and World Report (2023)

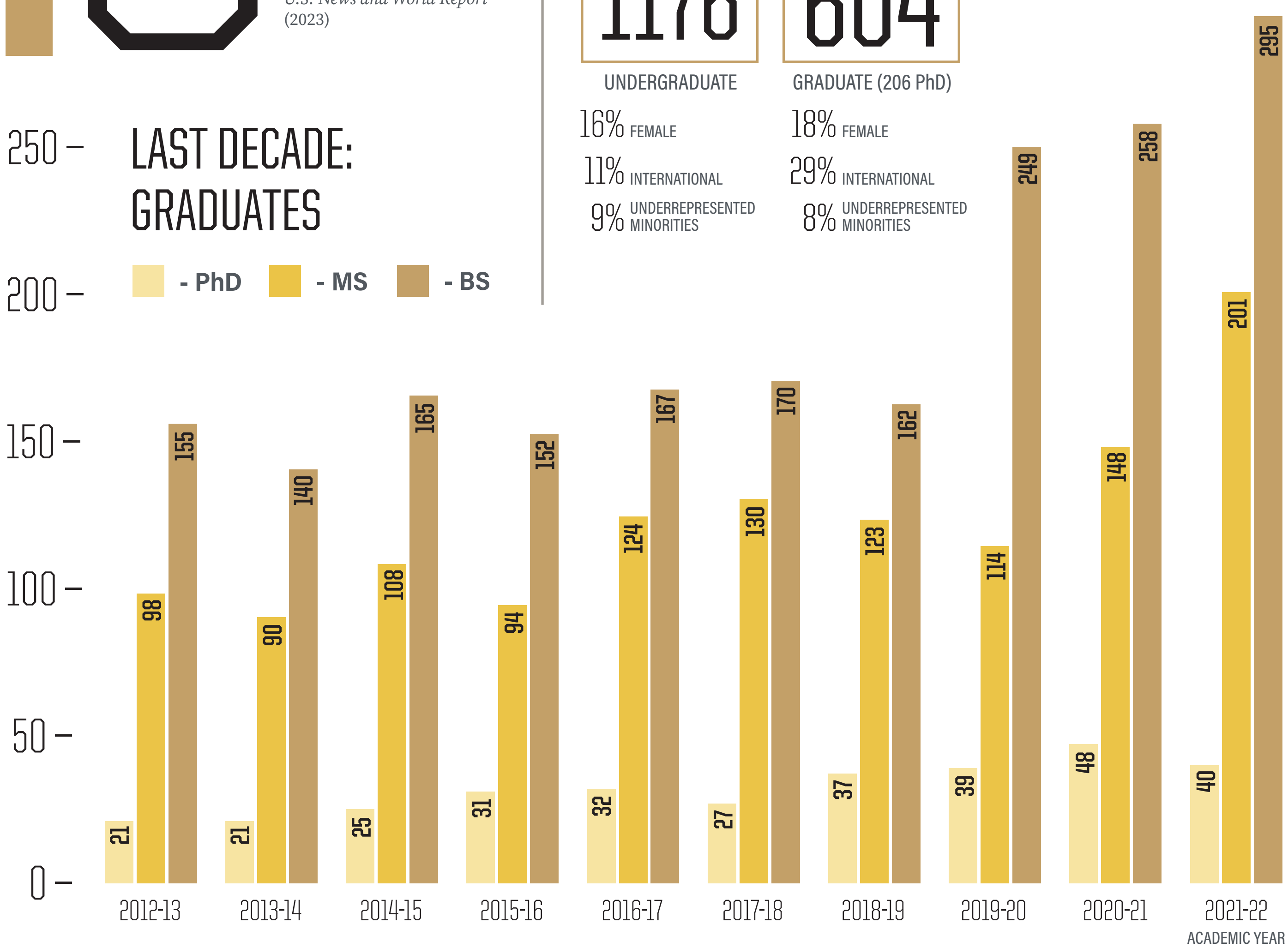
THE FACULTY (FALL 2022)

43	29	08	06
TENURED/TENURE-TRACK FACULTY	FULL PROFESSORS	ASSOCIATE PROFESSORS	ASSISTANT PROFESSORS
01	01	03	13
LECTURERS	RESEARCH FACULTY	VISITING FACULTY	COURTESY FACULTY

THE STUDENTS (2022 FALL ENROLLMENT)

1176	604
UNDERGRADUATE	GRADUATE (206 PhD)
16% FEMALE	18% FEMALE
11% INTERNATIONAL	29% INTERNATIONAL
9% UNDERREPRESENTED MINORITIES	8% UNDERREPRESENTED MINORITIES

LAST DECADE: GRADUATES



Alina Alexeenko, professor of aeronautics and astronautics

SOLAR VIEWS

Students contribute solar sail monitoring technology to NASA mission

Students across Purdue's College of Engineering are contributing to the largest solar sail project ever to be deployed. Solar sails have the potential to provide a new type of propulsion, one that uses no fuel, for many types of space missions.

"Solar sails are large, mirror-like structures made of a lightweight material that reflects sunlight to propel the spacecraft," says Les Johnson, principal investigator for the NASA Solar Cruiser. "The continuous solar photon pressure provides thrust with no need for the heavy, expendable propellants used by conventional chemical and electric propulsion systems."

Johnson says the Solar Cruiser mission will have a sail approximately 51 times larger than LightSail 2 – itself an active mission, launched in 2019, that also saw Purdue contributions.

Solar Cruiser will carry an enormous, four-section sail with a total surface area of 1,653 square meters. That size and its role as a deep-space spacecraft differentiates it from prior, smaller solar sails that have remained closer to Earth.

"The Solar Cruiser's propulsive performance will enable future science missions that can study the sun from novel vantage points that cannot be reached by any other spacecraft propulsion system," Johnson says.

Alina Alexeenko, professor of aeronautics and astronautics, says that, once launched, the spacecraft will head to the libration point between the sun and the Earth — the distance where the gravity between the two bodies is equal. It will use the sail's propulsive force to maintain that relative position.

This mission will demonstrate and provide data on how a solar sail can work to navigate a spacecraft outside of Earth's orbit, among other goals, marking a path for developing future solar sails.

Future sail-equipped spacecraft can provide increased notice of solar storms, which would give satellite operators as well as space explorers more time to take precautions against damage, Johnson says. "A Solar Cruiser solar sail could increase the warning times of solar storms by up to 50%."

The sail's deployment, as well as its behavior during use, will need to be monitored closely in order to understand how the material will perform in future missions. That's where Purdue's Solar Sail Vertically Integrated Projects (VIP) Program is providing important contributions.

Looking across a football field from waist height

NASA's design of the Solar Cruiser incorporates a camera with multiple, overlapping fields of view of the sail. Andrew Binder (BSAAE '19), a graduate student in aeronautics and astronautics, is leading the VIP students this year in devising and testing methods for monitoring the topography of the sail to determine its effectiveness.

But in space, nothing is easy. In this case, the camera will be looking almost directly across the sail.

"You get one camera, it's about a yard off the plane of the sail, and it's got to be able to study this football-field-sized area around it. Which is a hell of a problem," Binder says. "You've got a very shallow angle of incidence on this solar sail, and the question is, can you learn anything from that?"

Previous work in studying solar sails has either involved sensors along its surface, or with dots along the sail to aid in visual processing. Those approaches have major disadvantages.

"If you think of a piece of rice paper, it's pretty consistent with how fragile and delicate these solar sails are. If you apply a sticker to it, it's going to affect how it folds and how it moves," Binder says. "It's really important that the solar sail behaves well, because you've not only got to deploy it, but it has to be as light as possible because the force you're getting from the sun is not especially strong."

The challenge placed before Purdue students is to monitor the sail without sensors or visual keying. The approach Binder is pursuing with the students in the VIP course, and oversight from Alexeenko, is to stitch images together from that camera's viewpoints to determine the shape of the sail.

"If you take a panorama shot with your phone, it takes a bunch of images and compiles them together into one shot. There are similar things you can do for three-dimensional surfaces. You could take a bunch of pictures of a desk and stitch them together to create a 3D model of your desk," Binder says. "You can do something very similar with solar sails."

Binder returned to Purdue in 2022 after a meeting with Alexeenko, and the Graduate BRIDGE Program provided the support system for his return to campus after three years working in the commercial space industry.

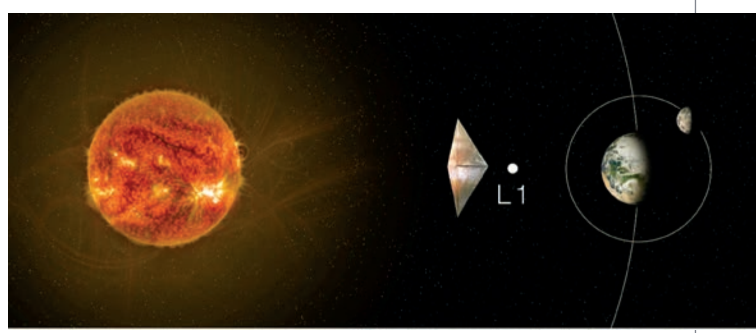
BRIDGE is a summer program designed for incoming graduate students from underrepresented demographics — Binder is Native American, from the Chitimacha Tribe of Louisiana. The program provides a series of research and professional workshops, and fosters a participant peer network.

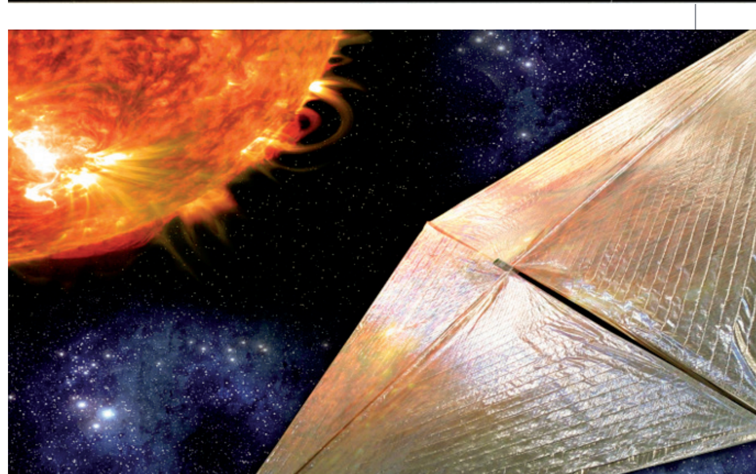
Binder used that summer opportunity to get a head start on his research with Alexeenko, devising a framework for testing various photogrammetry techniques on solar sails. Even though Solar Cruiser has been pushed back from its expected launch date in 2025, the project is still active, and Binder is excited about the work to be done.

"We have an apparatus to do some mock solar sail deployments. The students are going to get a camera, and try to replicate the light conditions. We have this modular wall painted black, to try to simulate the space environment. And, of course, there's all the software photogrammetry work," Binder says. "Even with it being on pause, we have plenty we can still do. We will continue collaborating with our colleagues at NASA Marshall to make sure their needs are met."

Thinking about the semesters ahead, Binder laughs. "It will certainly keep us busy."

Andrew Binder (BSAAE'19), a graduate student in aeronautics and astronautics, is leading the students in Purdue's Solar Sail Vertically Integrated Projects (VIP) course.





The Solar Cruiser will demonstrate solar sail propulsion by flying sunward of L1 and maintaining its position along the Sun-Earth-line using only reflected light for propulsion. (NASA)

THE ROCKET REANIMATORS

Purdue team documents first-ever collegiate reuse of a liquid-fueled rocket

Photos by Andrew LaPrade (BSECE '22)

On their way to the FAR-Mars rocket launch competition, a group of Purdue undergraduate engineering students hoped they would make history.

And they would. Just not in the way they thought.

As a culmination of three years of work, the team would take a six-day trip to launch, fail, launch again, fail again — and still earn a distinction previously held only by large aerospace organizations. The Purdue Space Program (PSP) was the first-ever collegiate team to launch the same liquid-fueled rocket more than once.

They did so in just 24 hours, in the middle of the Mojave Desert, without having expected a second launch. And they returned to launch it still a third time 30 days later.

"Solid rocket fuels are pretty simple and well-known, but very few college teams attempt liquid-fueled rockets," says Chris Nilsen, advisor for PSP and a propulsion design, build, test engineer for aeronautics and astronautics. "There are valves, there are pressurizations, and everything has to be kept very cold. There's a lot of plumbing to figure out."

As a student, Nilsen (BSMDE '19) fired up PSP's first attempt at a liquid-fueled rocket, named Boomie Zoomie. They completed several hot fires and launched a subscale solid-fuel version of the rocket — but even though Boomie Zoomie ultimately never flew, their efforts helped draw students who love rocket propulsion to the School of Aeronautics and Astronautics.

PSP — Purdue's chapter of Students for the Exploration and Development of Space (SEDS) — has grown to more than 400 members and become one of the largest clubs on campus.

In May 2022, Nilsen was driving with PSP's liquids team to the Mojave Desert to see if their rocket — the second iteration of the one he built — would fly. Naturally, the students named it Boomie Zoomie B (BZB).

Building the beta version

For BZB, winning the FAR-Mars Society Launch Contest was the goal the whole time. This ongoing competition, held by Friends of Amateur Rocketry (FAR) and the Mars Society, challenges collegiate teams to build and launch a bipropellant liquid-fueled rocket to between 30,000 and 45,000 feet. The Purdue team was hoping to nab the win and the as-yet-unclaimed $100,000 prize — which included a cash bonus for using liquid methane specifically.

Will Ipsen (BSAAE '22), chief engineer on BZB, said the previous team's many tests confirmed that the first Boomie Zoomie wouldn't reach the expected altitude. They decided to take the lessons learned from it and build something better.

Opposite page: Students on the Purdue Space Program's liquids team prepared the rocket and raised the launchpad for what would become the first of three launches.

Above: When Boomie Zoomie B didn't reach the target height, the team improvised a fix to the slow valve actuators. Their work resulted in the first-ever collegiate relaunch of a liquid-fueled rocket.

They got to work, but also had to cope with the COVID-19 pandemic in the middle of their design phase.

"Collaboration is one of the strongest things we do as a team. When we have a design meeting, we go up to a whiteboard, start drawing designs, and then five other people start grabbing markers to show what they think about some part," says Braden Grossfeld (BSAAE '22), the propulsion lead for BZB. "We couldn't do that over Zoom. But all our stuff is online, so we were still able to just keep trucking through it."

Once they were able to meet in person again and actually construct the rocket, the team worked tirelessly for many hours per week, enduring Indiana's brutal winters to continue running tests at Maurice J. Zucrow Laboratories. When chasing leaks, they sometimes found the bottle of soapy water frozen solid.

"This is all undergraduates, and they built it all themselves," Nilsen says. "They got the machine shop to extend its hours, students were machining things day and night."

They also spent huge amounts of time in testing. "The testing is what sets us apart. In fall [2021], we did 13 cold flow tests to prepare for a hot fire. By the time we're out in the desert, everyone knows what they're doing by heart," Grossfeld says.

That preparation paid off when the time came to build the launch platform and assemble their Black Cat Launch System (BCLS). The BCLS handles rocket fueling and other controls through more than 50 valves and sensors, mounted on a platform just 4 by 4 feet.

"In Mojave, there were 40 mph winds, plenty of sand, hardly any internet, hardly any electricity, and it was pretty hot. I volunteer with student rocket things all the time, and when you get out to the field, it typically takes a day and a half to get a launchpad set up." Nilsen says. "But these undergrads, they all had a job and they were all super motivated. In a matter of eight hours, they basically built a mobile Zucrow test stand and were ready to go."

A major setback, and a second launch

Launch day came and setup went smoothly, and though cloud cover threatened, a break in the sky gave them their chance. They set the sequence and the rocket was off, the team shouting and cheering their years of work.

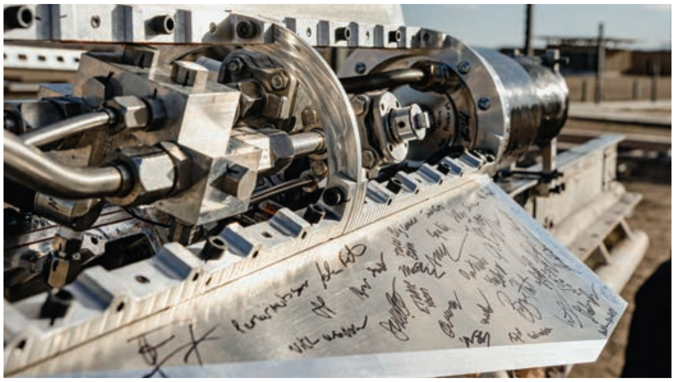
But as their GPS-based ground system began announcing the rocket's altitude, they could tell something was wrong.

"It calls out 4,000, then 6,000, then 7,000. You can hear that it starts slow down," says Maor Gozalzani (BSAAE '22), who was launch operations lead on BZB. "One second you're screaming your heads off with excitement, and then you hear the altitude leveling off. When it eventually calls out 9,000 and then parachute deployment, we're wondering what the hell's going on.

"We have the recording, and it's something that I think none of us can listen to."

Boomie Zoomie B had reached an apogee of just 9,907 feet. The recovery crew found the rocket in good shape, but in their rush to chase it, had forgotten the gear to strap it to the truck. They carried it on their shoulders the two miles back to the launchpad.

Over the next 24 hours, their Boilermaker grit would endure. Knowing they didn't bring enough fuel for two full launches, they diagnosed the problem and made a contingency plan.



"The rocket was intact, but it landed at 40 feet per second. There was sand everywhere, and we would have to replace all the single-use seals," Grossfeld says. "But we thought we could launch it again."

The problem limiting their launch was obvious: The run valves didn't fully open before the vehicle took off, essentially running the rocket at half-throttle.

"We had two external actuators, these big bulky things, and they turn those valves 90 degrees to open them. The design is that the actuators hold the rocket, and as it turns the valves vertical, the rocket slips out and launches. On the ground during a hot fire, the rocket doesn't move, so everything seemed fine," Grossfeld says.

"What actually happened is that the engine starts up so fast — this is in like 50 milliseconds — that the run valves start opening, the fluid gets through, the engine starts up and the rocket is gone just as the valves reach 45 degrees."

They spent nearly all night rebuilding the rocket and implementing their fix to open the valves faster. Running on barely two hours' sleep, the team got BZB up on the launchpad again the next morning, filled with all the fuel they had left — about half a tank's worth.

Their second launch reached 6,700 feet.

To Zombie and beyond

The PSP team decided, though most of them were graduating that spring, that they'd rebuild BZB — again. They hoped to return to Mojave in just a month, to fly in FAR's "Dollar Per Foot" competition for liquid-fueled rockets. It pays out a one dollar per foot of altitude reached.

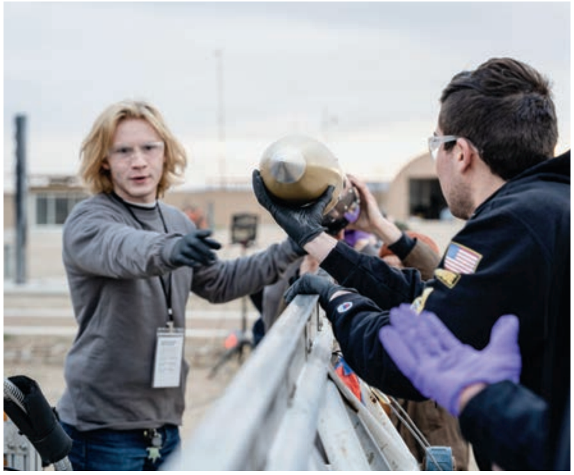
Their in-the-field fix hadn't been quite enough to fully open the valves on the second launch, so team developed a completely new actuator that was small and light enough to be mounted inside the rocket itself. In this design, gunpowder charges would be ignited in two cylinders, each pushing a rod to actuate a valve. They named the device Burnie Turnie, and dubbed the resurrected rocket Boomie Zombie.

Unfortunately, at competition, they showed that zombies and explosives don't kindly mix.

"Oxygen and methane always leak a little bit," Nilsen says. "And naturally, things get a little toasty when you fire a pyro valve."

The igniting valve actuator lit up a pocket of methane inside the rocket's lower section. Two of the panels around that section blew clean away, but one hung on, acting as an air brake. "It got to about 5,000 feet, did a flip in the air and the engine shut down," Nilsen says. "With it being a Dollar Per Foot challenge, they basically covered the cost to go out there."

Valving issues aside, the team is quick to credit manufacturing lead Jeremy Casella (BSAAE '22) for the engine's remarkable efficiency and multi-launch durability. "Anyone from industry that has seen the design of that engine asks who we had professionally manufacture it," Grossfeld says. "When I told them that we had this undergrad Jeremy do it, every single one thought I was lying to them."



What's jobs got to do with it?

Now that most of the BZB crew has graduated and joined the workforce, a new liquids team is developing another rocket — and standing on the shoulders of the teams that came before them.

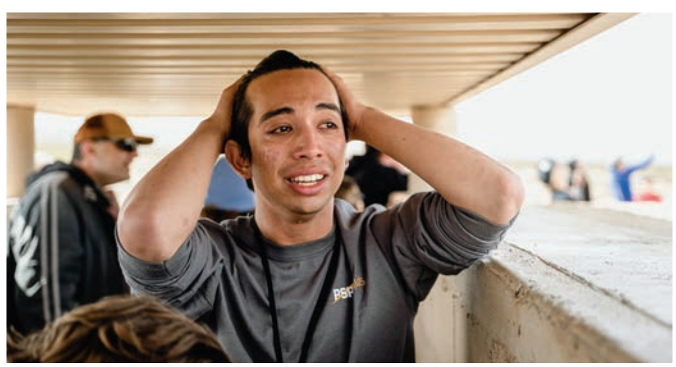
"The biggest enemy of any college design team like this is the brain drain," Ipsen says, "because your best people graduate every year. We provided all the documentation and showed them as much as we could, but best thing you can ask for when you're leaving is that the people coming into the team know more than you did. And I think we're all really proud to say that the kids working on this next one, they're really good."

Casella adds, "Their simulations are even more in-depth than ours were. They're going for a whole new class of rocket. They're going bigger, higher, better."

It's through this kind of knowledge-sharing, which goes beyond rocket building know-how, is among the reasons that many PSP members end up working at commercial space companies. Ipsen is now a test engineer at SpaceX, Casella is a manufacturing engineer at GE Aerospace and Grossfeld is a propulsion test engineer at Impulse Space.

Gozalzani, who is pursuing his AAE master's degree, says the entire leadership team for the newest rocket had internships this summer — most of them at SpaceX.

"The team focuses on professional development," Gozalzani says. "If you're a freshman on the team, you have all these seniors who can tell you how to succeed as an intern, or how to prepare for an interview, or what you should study. That's huge. It's such an amazing resource that you can't find almost anywhere else."



More than 30 members of the Purdue Space Program's liquids team traveled to the Mojave Desert for the FAR-Mars launch competition, a culmination of three years of work. The all-undergraduate team endured 40 mph winds and desert heat to launch their liquid-fueled rocket. The first launch didn't reach the target altitude and drifted two miles afield by its parachute. They carried the rocket back and worked through the night to launch again.

Alumnus Earns Purdue Entrepreneurship Grant

In March 2022, Pluto Aerospace received a $25,000 investment from Purdue Foundry's Boost accelerator program. The company's founder is Chris Nilsen (BSMDE '19), PSP advisor and Purdue AAE propulsion design, build, test engineer.

The Purdue Foundry is an entrepreneurship and commercialization hub managed by the Purdue Research Foundation. They granted this funding to Pluto Aerospace to develop a launch vehicle platform to give researchers rapid, economical and reliable access to suborbital flight environments.

"Boost plugged us in with the Indiana entrepreneurial community," Nilsen says. "The connections we made through Boost played a major part in our recent success.

Nilsen says their Charon platform can carry more payload higher than any available commercial suborbital rocket, and is capable of hypersonic mission profiles. Flights start in 2023.

HYPERSONIC BLAST

Scramjet engine testing facility built to support priority efforts for national security

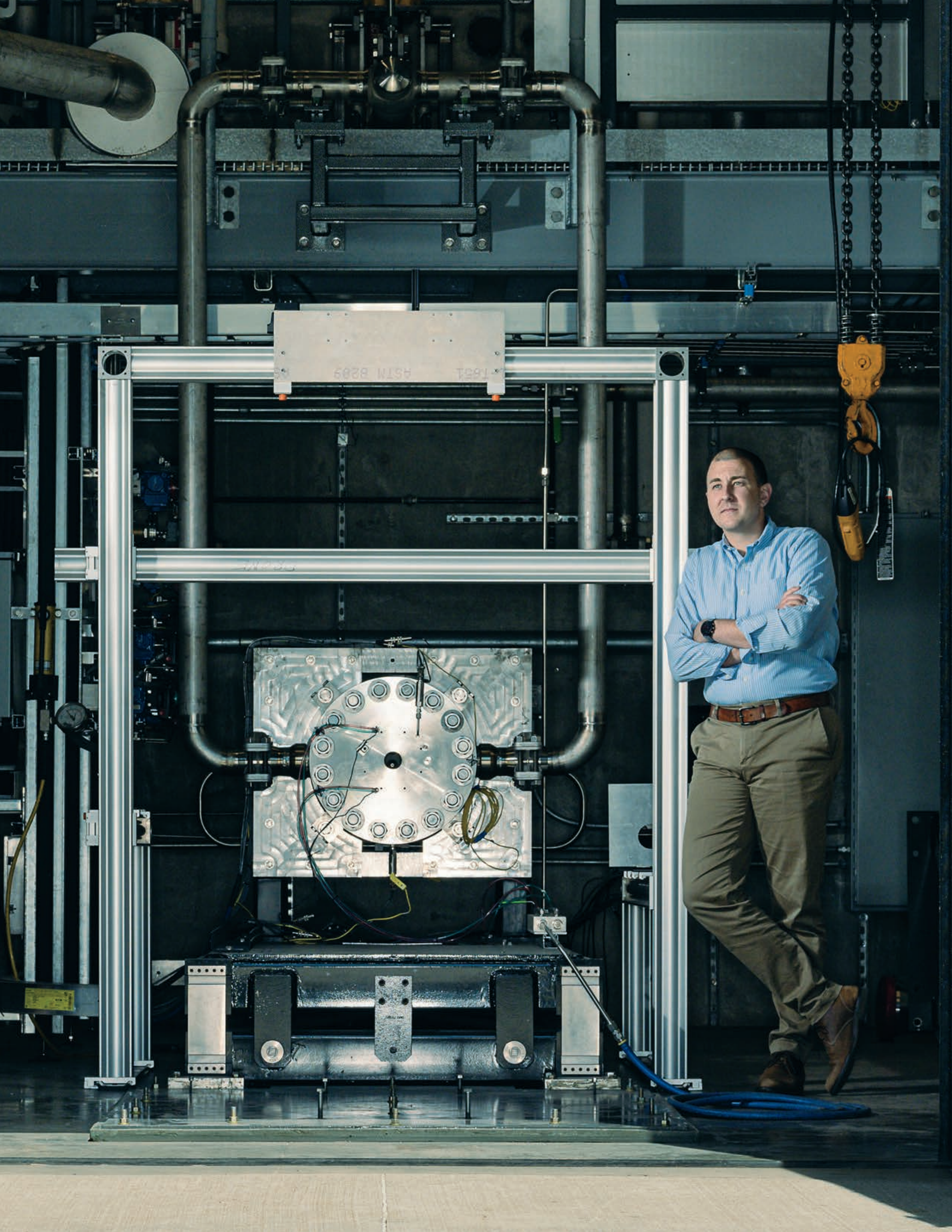
A new test rig at Purdue is set up to fire rocket exhaust into the inlet of a hypersonic scramjet engine. This capability — a first of its kind at any university — is one of a series of platforms at the Maurice J. Zucrow Propulsion Laboratories that enable the rapid development, integration and operation of new propulsion concepts.

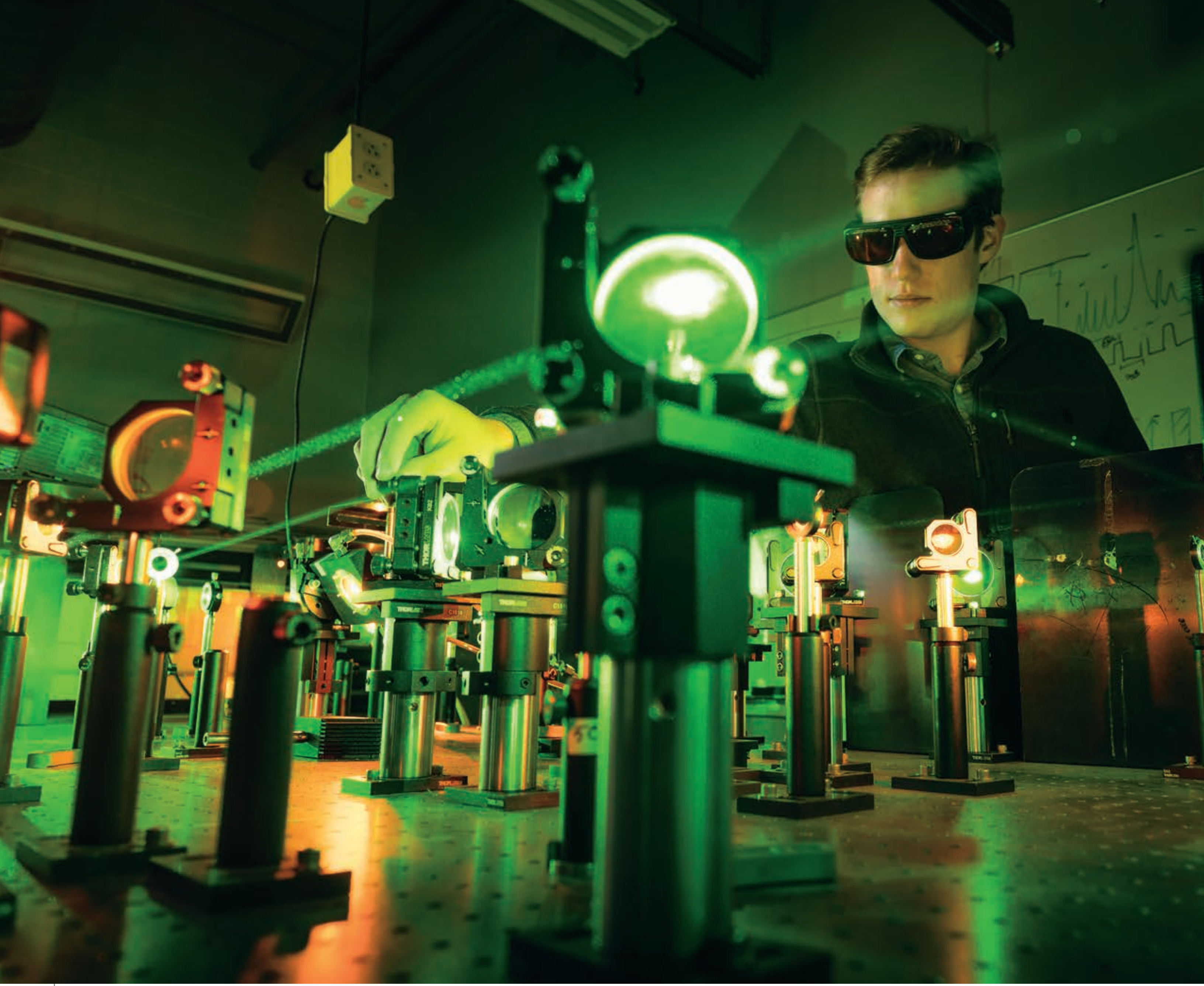
This capability was developed with funding from the Air Force Research Laboratory (AFRL). It represents the United States' desire to rapidly produce new hypersonic engines that will outperform those of its adversaries.

"There's a national need for these facilities," says Carson Slabaugh, associate professor of aeronautics and astronautics. "Our near peers are booked out for years in terms of work, and that's a sign that we need more of these testing capabilities in this country. We can now support critical programs here, including priority efforts for national security."

Why scramjets?

Slabaugh says that in a conventional turbine engine or even a ramjet engine, the incoming air is slowed down to facilitate combustion. But the temperature and pressure of the air entering the





> There's a national need for these facilities. We can now support critical programs [at Purdue.] including priority efforts for national security."
>
> *— Carson Slabaugh, associate professor of aeronautics and astronautics*

combustor increases exponentially with the vehicle's speed, which creates a challenge.

"At lower flight speeds, we're decelerating the flow within the engine so we can actually have a flame inside of the combustion chamber. You can only do that deceleration process up to a certain point. At really high speeds, you just can't decelerate the air enough without huge losses and, even if you could, it's so hot that you can't even add more heat with the fuel," he says.

"At around Mach 5, the factors become so severe that you have to change your method of combustion. You have intake temperatures around 2,000 degrees Fahrenheit and pressures at a few hundred psi. That's like the exhaust temperature of most engines."

In order for a vehicle to go hypersonic with an air-breathing engine, aerospace engineers turn to

Will Senior, a PhD student and graduate research assistant, aligns optics for a laser-diagnostic technique applied in a high-speed air-breathing combustion environment.

scramjets — engine designs where the air and fuel travels through the combustor at a supersonic rate. The main challenge in improving these engines is that there's a very small window of time to complete the burn before the air and fuel has exited the engine.

That's why the advanced tools available at Zucrow Labs are so important to further development. Slabaugh, a leader in the field of laser-based combustion diagnostics, helped develop Purdue's competitive arsenal of laser sources and high-speed detection equipment. Special quartz-based windows replace a portion of the combustor shell, allowing researchers to directly observe the combustion happening inside an engine.

But before Slabaugh could test a scramjet, he needed something that would simulate its operating environment. Wind tunnel systems that supply air from a heat exchanger, Slabaugh says, top out at about 1,500 degrees Fahrenheit. This is roughly equivalent to Mach 4 flight conditions.

To test hypersonic engines, you need to feed it with a rocket.

A cost-effective alternative

Slabaugh says the most straightforward approach is to build a free jet tunnel, which is large enough to test an entire vehicle. Two of these exist in the U.S., one each belonging to NASA and the Air Force.

"In a free jet, you basically have a massive, massive rocket engine that produces high temperature, high pressure air that corresponds to whatever your Mach number is," Slabaugh says. "The crazy thing about that is the scale of these tunnels. They require huge infrastructure to operate, which can also make it prohibitively expensive to test novel, high-risk concepts."

In a direct-connect rig like the kind at Purdue, researchers test just the internal scramjet engine components by connecting the rocket, called a vitiating air heater, into the engine's air inlet.

"Our direct-connect system allows us to replicate hypersonic conditions in a much smaller configuration, so we don't have to run a facility that's quite so large as a free jet. As a way to build confidence in your propulsion system design without having to run tests that are that expensive, we extract the isolator, combustor and expansion sections and we effectively replicate the flow that's going in and the flow that's going out," Slabaugh says.

The vitiator works like a rocket, by reacting hydrogen and oxygen and producing high-temperature water vapor. That rocket exhaust is supplemented with enough nitrogen and oxygen to simulate atmospheric air before it enters the scramjet combustor. A vacuum system, called an ejector, is attached downstream of the combustor to replicate the exhaust-side airflow at high altitude. Computational methods used during data analysis compensate for the effects of the moisture that the vitiator introduces to the system.

Engineering research at scale

This rig, like the other propulsion test stands at Zucrow, lives in an isolated test cell with 20-inch-thick reinforced concrete walls and steel explosion-proof doors.

It's also loud. When Slabaugh and his students first fired up this new rig in May 2022, the sound vibrations were literally rattling electronic component boards apart inside the datalogging computers. "We learned an important lesson about the resilience of our electronics that day and had to make a few adjustments," said Slabaugh.

The repaired computers have been relocated to the other side of the thick concrete walls of the test cells. They now live in the same room as the laser diagnostics equipment that serves as a cornerstone of Purdue's combustion research program — a safe space from the harsh testing environment.

Purdue is the only academic institution to stand up this type of testing capability. Despite the challenges, Slabaugh is excited to have the scramjet test stand operating. "Our team always finds a way forward, because we are committed to working these fundamental, relevant problems at scale."

Any setbacks they face day to day are taken in stride.

"I come to work and shoot lasers at fire," he says with a smile. "I can't complain."

A LEADER IN HYPERSONIC TECHNOLOGIES

NEW FACILITY TO ENABLE INNOVATION, ENHANCE INDUSTRY PARTNERSHIPS

The new Hypersonics Advanced Manufacturing Technology Center (HAMTC) at Purdue will generate materials and manufacturing solutions in hypersonics that bridge the costly "valley of death."

"At a university setting there's a lot of fantastic research, but that doesn't mean it's in a position where industry can readily use it. So most research is matured within a university and then it dies in the valley of death," says Michael Sangid, executive director of HAMTC and the professor of aeronautics and astronautics.

One of the challenges in bridging this valley is the cost of integrating innovation into existing product lines and processes. Because companies want to shield their R&D efforts from their competitors — and the Department of Defense from its near peer adversaries — researchers often have to work on simplified versions of the problems manufacturers are trying to solve. They don't often get to see full product specifications or how industry is hoping to implement those solutions.

HAMTC is different. Operating under the Purdue Applied Research Institute (PARI), which reports to the Purdue Board of Trustees, researchers can directly tackle the challenges faced in industry.

"PARI has enabled us to do more secured and classified research that couldn't normally be done under the umbrella of Purdue, which has uniform guidance for all its contracts," Sangid says. "We can work closer with our industrial partners and our DOD customers, and that's really what enables the vertical integration. We can design, build, join and test, all in the same facility, and conduct each of those steps directly with industrial partners."

The vertically integrated approach means incorporating new materials into vehicle designs, developing the unique manufacturing processes to realize these designs, joining discrete components together into subassemblies, and providing the test infrastructure to understand reliability in hypersonic environments. For each project in HAMTC there is also a digital twin of the physical prototype that aims to accurately predict future performance.

"We're working on the entire process as opposed to a small piece," Sangid says. "There's no need for somebody later to integrate all the pieces or scale the solutions."

Advanced technologies

HAMTC will be housed within the new Hypersonic Aerospace Research Facility (HARF) being constructed at the Maurice J. Zucrow Laboratories (see sidebar). Placing HAMTC inside a hypersonics facility is no coincidence.

"The most pressing aspect we're dealing with is the national need for increased capability for hypersonics. We can make a difference at the national scale," Sangid says.

Though this building won't open officially until the spring of 2023, Sangid has already established partnerships with GE Additive, Dynetics, Lockheed Martin, Aerojet Rocketdyne, GE Edison Works, The Boeing Company and several small businesses.

These companies are already gaining access to Purdue's expertise in aerospace metals, ceramics and composites, including additive manufacturing of those materials.

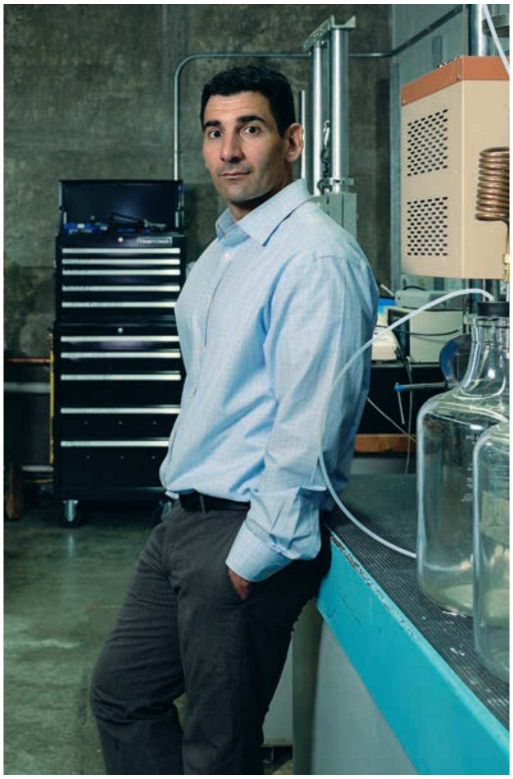
"There's really a materials and manufacturing push here," Sangid says. "We offer machines that can manufacture pieces that are to scale, with the fewest defects, and with as high dimensional precision as possible. At the same time, we are producing new materials that can be printed from those machines."

Chris Schuppe, general manager of engineering and technology at GE Additive, says this kind of industry-academia partnership is valuable to industrializing additive manufacturing.

"The potential for additive manufacturing in hypersonics is huge," Schuppe says. "We are honored to be part of Purdue's team supporting the Department of Defense in manufacturing research that will advance U.S. national security and competitiveness. Our team, many of whom are Purdue alums, is excited to get started."

"PARI HAS ENABLED US TO DO MORE SECURED AND CLASSIFIED RESEARCH THAT COULDN'T NORMALLY BE DONE UNDER THE UMBRELLA OF PURDUE."

–Michael Sangid, executive director of HAMTC



Michael Sangid (top), executive director of HAMTC and professor of aeronautics and astronautics, John Ferguson, a graduate student in aeronautics and astronautics (above), are part of the team working to generate materials and manufacturing solutions in hypersonics that bridge the costly "valley of death."

Alumni Giving Makes HARF Possible

Purdue's Hypersonic and Applied Research Facility (HARF) represents a $41 million investment by the university and its supporters to enhance its research capabilities in aerospace. When completed in spring of 2023, the 65,000-square-foot building will be home to HAMTC, as well as a hypersonic pulse shock tunnel, and the only Mach 8 quiet wind tunnel in the world.

Dave Schweikle (BSAAE '59) was the first donor to take advantage of naming opportunities within HARF. The Dave Schweikle Aero Astro Lab will be HAMTC's home, and accounts for about one-third the footprint of HARF. Additional naming gifts contributing to HARF have come from: Bob Strickler (BSAAE '60, MSAAE '62, PhD ME '68) and Mary Strickler; Mike Corso (BSAAE '71) and Sandi Corso (BS Sociology, '71); Rick Weaver (BS ChemE, '65) and Rita Weaver; and Doug Bowers (BSAAE '72) and Jill Bowers.

"The HARF facility will bring incredible and unique capabilities to Purdue, but no undertaking of this size can be done alone," says Bill Crossley, the J. William Uhrig and Anastasia Vournas Head of the School of Aeronautics and Astronautics. "These gifts will have a profound impact on the work done within HARF, and the school as a whole. The research done within the facility with the help of these gifts will allow Purdue to continue to be a leader in hypersonic technologies."

RADAR WITHOUT RADAR

Reading the global water cycle through satellite communication signals

When a small satellite is released from the International Space Station (ISS) in early 2023, it is expected to prove out a promising new technique for measuring soil moisture and snow water levels from space. This data is important for early flood and drought warnings, crop-yield forecasts and accurate climate modeling — but it's not currently possible to get precise global measurements with current technology, according to NASA's Earth Science Technology Office (ESTO).

Jim Garrison, professor of aeronautics and astronautics and principal investigator on the SigNals Of Opportunity: P-band Investigation (SNOOPI) mission, expects that this technology demonstration will enable future missions to fill that important gap in climate research. It will show whether "signals of opportunity" (SoOp) can be effective alternatives to radar systems that transmit and read back their own signal.

Garrison is the first Purdue professor to serve as principal investigator on a NASA mission. SNOOPI is an ESTO-funded collaboration that includes Purdue University, NASA Goddard Space Flight Center, NASA Jet Propulsion Laboratory and Mississippi State University.

Proving out this method follows from decades of Garrison's work. He performed some of the earliest theoretical and experimental research in the SoOp field, and he was on the science team for NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission, which used a similar technique to measure wind speed over oceans.

What makes SNOOPI unique is that it will listen on lower frequencies than CYGNSS, which will allow it to take moisture readings deeper in the soil than before.

Measuring in the root zone

SNOOPI is designed to monitor signals in P-band, around 300 MHz, which are used for satellite communications. This poses a key advantage over prior moisture-measurement methods.

"While NASA's Soil Moisture Active Passive (SMAP) mission and CYGNSS currently gather soil moisture data, they use the higher-frequency L-band (1–2 GHz), which is sensitive to water only in the top 5 centimeters of soil on the surface of the Earth. SMAP can't gather moisture readings at the root zone, and has trouble measuring soil moisture in more problematic terrain, such as forested and mountainous areas."

Garrison says wavelength is roughly proportional to a signal's ability to penetrate Earth's surface. With the P-band being approximately five times longer in wavelength, they 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."

Although P-band measurements using conventional radar have been demonstrated using aircraft-mounted instruments, bringing those systems to space is not easy. Transmitting and receiving P-band signals from low Earth orbit requires an antenna 10 to 30 meters in diameter. Garrison says a device that large would push the mission well outside the cubesat standard, requiring a dedicated launch and driving costs into the multi-hundred million dollar range.

The European Space Agency (ESA) is attempting to do this with the Biomass mission, which has a 10-meter antenna, but it faces another problem. Because many P-band frequencies are either already allocated for telecommunications or are restricted due to potential interference with defense radar, Biomass will be prohibited from operating over North America or Europe.

The flip side is that there's already a lot of P-band signal lighting up the Earth, just waiting to be seen.

"It turns out that there's some powerful communication satellites that are operating these frequencies. So we came up with the idea of capturing these P-band signals to show that we can, initially, make the subsurface soil measurement," Garrison says.

Using reflective signals that already exist means it's possible to design a small instrument, and build a satellite with low power demands. This was demonstrated on CYGNSS, a constellation of eight micro-satellites listening in on L-band GPS frequencies. SNOOPI is the size of a 6U cubesat — approximately 10 by 23 by 37 centimeters, or a modest stack of textbooks.

"Instead of generating and transmitting its own radio signals toward Earth and analyzing the returned signal, SNOOPI will take advantage of already-available telecommunications signals. This way, we get the source for free," Garrison says. "We don't need to provide a power source for the transmitter, obtain a license or be as concerned about interference from other users in the band."

If SNOOPI succeeds, other missions could use its technology to globally monitor how much water is stored below the surface of the soil and in the snow pack. In the future, signals of opportunity could predict droughts and floods, assist with forecasting agricultural yields and even monitor trends in climate change.

Early Indicators and Mission Plan

Although P-band SoOp is promising, this new technique must be tested and proven in space before NASA will implement it in a science mission. SNOOPI is expected be released into low Earth orbit from the ISS in early 2023.

After a commissioning process, the data team will begin receiving usable transmissions for SNOOPI's 9-month demonstration cycle. Data from a network of ground stations supporting SMAP will be used to validate SNOOPI's readings.

Garrison and his students visited NASA's Goddard Space Flight Center this summer for SNOOPI's final open-sky test before it was packed up for launch. This successful test confirmed that its instrument could read P-band signals beamed down from space; whether it will effectively read signals reflected from Earth won't be known until it's in orbit.

The team was able to get an early look at what could be expected from these signals with help from Spire Global, a satellite services company. "They had a satellite that was reaching its end-of-life. Spire was able to reprogram the software radio for us," Garrison says. "We received about 10 seconds of data, and it was enough to show us that it was possible to read the P-band reflecting back from Earth."

SEEING THE FUTURE

HIGH RATE MANUFACTURING THROUGH THE DIGITAL TWIN

The aircraft design and manufacturing process is unsustainably long, says R. Byron Pipes, director of Purdue's Composites Manufacturing and Simulation Center (CMSC). He believes manufacturers and regulators need to embrace a new approach if the industry expects to reduce its impact on climate change.

"Thousands of airplanes are flying every day that produce CO_2. If you've got to decarbonize, you can't afford to keep them going," says Pipes, who is also the John Bray Distinguished Professor of Engineering, in a joint appointment between the schools of Aeronautics and Astronautics, Chemical Engineering and Materials Engineering.

"The airplanes we've got today, we'll have to replace them all in less than 30 years, and build even more to meet growing demand for travel. This is an impressive challenge," he says.

To reduce aircraft mass and improve efficiency, manufacturers have taken to using composite materials like carbon fiber. Pipes says a major drawback is that those composite parts can take days, or sometimes weeks, to manufacture.

The ongoing work he oversees at the CMSC includes manufacturing techniques like stamping and 3D printing of composite materials. Pipes and his cadre of roughly 30 graduate students also contribute to advanced assembly analysis technology that promises to overhaul the aircraft design process.

Pipes believes this is imperative if the industry hopes to build enough advanced aircraft to meet the demands of the ongoing climate crisis. "This isn't just about making airplanes faster or lighter, this is about whether or not we'll have an industry. So the question is, how fast can we develop these new technologies to replace the planes we've got?"

Speeding up the engineering process

Pipes, a longtime professor and researcher of composites at Purdue, says that the technologies currently used in building modern passenger jets were invented in the mid-1960s.

"It was recipe-driven technology. The design requirements say that you must follow these certain steps in this way, and that way, and that way, in order to guarantee the product performance on the other side," Pipes says.

Through the CMSC, Purdue has partnered with The Boeing Company and Dassault Systèmes to liberate the aircraft manufacturing process from this rigid approach. Pipes says the software that Boeing and Dassault co-developed, underpinned by Dassault's 3DEXPERIENCE platform, can serve as a digital surrogate for a physical object.

Using systems like these, engineers can analyze a whole vehicle's operating conditions and behaviors through its entire lifecycle, even before a single physical component is built.

"We're moving away from document-based engineering and to model-based systems engineering," Pipes says. "An airplane becomes something where everyone can make changes to a digital representation, which puts a lot more information at everyone's fingertips. Competencies can simultaneously participate in developing the knowledge required to make decisions."

This yields tremendous opportunities to optimize the final product because the experimentation cost in the digital world is so low. But a simulation is only as good as the data models it uses. Garbage in, garbage out. That's why Boeing and Dassault approached Purdue for its long-standing reputation in composites research — underpinned by Pipes' own half-century of experience with these materials — to help refine their digital surrogate.

"The software experts are not the composites experts," Pipes says. "Composites is not taught in every aerospace engineering department either, but Purdue has been in the research part of it from the very beginning. I'd say our expertise in that world even exceeds that of Boeing because they've lost the generation that developed the 787 — they've all retired.

"My team is acting as the glue between Boeing and Dassault. Boeing uses some of the tools on the Dassault Systèmes platform, but they utilize our knowledge as worldwide experts in the composites field."

The trick when it comes to surrogates for aircraft is in developing a high level of trust in that system — trust with manufacturers, regulators and their future passengers.

"An unvalidated simulation is not worth anything," he says. "The FAA always asks questions. Their primary focus is safety, as it should be. I believe we can show that physical testing can be replaced with virtual testing, with virtual performance barriers, and still give that same level of safety."

Trusting in digital twins of advanced composite systems

Pasita Pibulchinda (BSAAE '19, MSAAE '21), has been working on one of the facets of building that trust. With Pipes as faculty advisor for her doctoral work, she is glad to be part of the team at CMSC.

"I got into structures through my senior project as an undergraduate. We built a fixed-wing UAV, which got me interested in composites," she says. "I was also an intern and an undergraduate assistant here, and I like I the environment. They mentor me well, and we have a habit of helping each other out."

> "The airplanes we've got today, we'll have to replace them all in less than 30 years, and build even more to meet growing demand for travel. This is an impressive challenge.
>
> *—R. Byron Pipes, director of Purdue's Composite Manufacturing and Simulation Center (CMSC)*

Pibulchinda has been supporting the development of composite models through ADDITIVE3D, a physics-based additive-manufacturing simulation program developed at Purdue within Dassault's digital-twin platform.

"ADDITIVE3D lets us virtually 3D-print the part to predict any residual stress or shape distortion that can happen during manufacture. We can also go back to modify the 3D model or change the 3D printer setting, then run the simulation again and see if the prediction gives a better part," Pibulchinda says.

Her work is in running simulations with many different parameters, like bead sizes, print speeds and nozzle heights, and comparing the simulation results to the structural properties of real-life prints made using those same parameters.

"I am modeling the phenomena that occur during the deposition process, such as deformation and heat transfer of the composites," Pibulchinda says. "This will help users to decide printer settings systematically and scientifically rather than by trial and error, which can result in a waste of time and material."

Pibulchinda's research will apply directly to the Thermwood Large Scale Additive Manufacturing (LSAM) printer at the CMSC – but crucially, her data will also improve the capabilities of the ADDITIVE3D system.

Pipes' team followed a similar path to develop FORM3D, which replicates a composite stamping process and analyzes the virtual product for properties that are important for structural aircraft components. The continuing work on data models will assist with proving out the digital twins of these manufacturing processes.

That, Pipes says, will break the doors open for how these tools can be used.

"Once we've got trust, we can use this with all sorts of applications."

Anup Saha (left) and Karna Patel (center), two mechanical engineering doctoral students advised by Sally Bane, associate professor of aeronautics and astronautics, set up an alignment laser that helps aim a streak camera at the right spot inside the plasma generator.

NANOSECOND PLASMAS

Novel spectroscopy technique informs advancement of plasma-enhanced airfoils and turbines

There's a lot still to learn about plasma. The energized state of matter has illuminated neon signs for more than a century, but precisely how it behaves is still an active area of research. This is especially true of plasmas produced in ultra-short, nanosecond-duration pulses that Purdue researchers have been honing for modern uses, including aerodynamic flow control.

Sally Bane, associate professor of aeronautics and astronautics, is taking a unique approach to getting a deeper understanding of why plasmas behave the way they do. Part of the mystery are the specific temperatures and the chemical composition of the energized gases in these experiments.

By combining multiple visualization technologies, and partnering with a laser-based diagnostics expert at Purdue, Bane is producing results in her fundamental research. The ultimate goal with her work is to provide data models that would pave the way for more precise use of these plasmas, in any situation.

"There's a very broad range of applications of these plasmas. There's the plasma antennas, flow control and combustion control that we're researching here, but they're also used in nanomaterial synthesis, and in some biomedical applications," Bane says.

Better data feeds better computer models

Bane says that current computer models don't have the ability to predict plasma behavior completely accurately. That's the gap she's trying to close.

"Like any of these physical processes, we like to be able to get on a computer and run a model and predict what the plasma is going to do. That way we can effectively design and tailor the plasmas for a particular application," Bane says.

Plasmas produced by nanosecond-duration electrical pulses don't reach equilibrium in that short time. That means measuring the specific gas temperature, vibrational temperature and chemical composition in the tiniest instant is critical to producing better predictive models.

Bane's work will translate her experimental measurements to the chemistry models needed for computer simulations.

“On a baseline level, we don’t completely understand the underlying physics of these plasmas yet, particularly at high pressures, and so we can’t predict them with our numerical models. We are trying to bridge the gap with measurements that have not been done before,” she says.

> “We’re measuring a whole bunch of very important parameters, and we’re measuring them with unprecedented temporal resolution, which you need because these plasmas are so short-lived.”
>
> —*Sally Bane, associate professor of aeronautics and astronautics*

An ultra-fast camera for ultra-fast spectroscopy

Bane’s specialty is optical emission spectroscopy, which involves analyzing the wavelengths present in the plasma’s light output to determine the gas temperature, vibrational temperature and chemical composition changes occurring within them.

“You need very fast, very accurate measurements of multiple quantities in order to create the chemistry models,” Bane says. “On the other hand, if you want to implement plasmas in a large CFD [computational fluid dynamics] simulation, to explore aerodynamic flow control, you would typically model the plasmas as simple heat sources. And so we also need to know what temperature rise the plasmas are inducing, and at what times scales.”

The fastest high-speed cameras available at Purdue’s Zucrow labs can capture an image in a bit less than a microsecond, or 10^{-6} seconds. But even those aren’t sensitive or fast enough for Bane’s needs.

A streak camera, on the other hand, doesn’t take a two-dimensional image you can hang on a wall. Instead, it records the intensity of light over time, which allows it to capture light data in picoseconds — or 10^{-12} seconds.

“With a streak camera, you can get down to a very, very small time resolution. The smallest time step that we’ve done is 25 picoseconds, which is tiny. But you also have to have to capture enough light so that you get a sufficient number of photons on the sensor,” Bane says.

Bane, with support from the doctoral students she advises, feeds the camera output into a spectrometer in order to analyze the wavelengths present in these plasma light pulses. “From each of those spectra, we can learn something about the plasma. For example, we might be able to infer temperatures from that spectra, and then we’ll get a plot of temperature versus time for a single plasma within this time resolution,” Bane says.

“No one’s been able to do that before,” she says — a claim she published in the journal Applied Physics Letters in December 2021.

Widening the scope of spectroscopy – with lasers

One of the limitations of optical emission spectroscopy is that second word: emission. If the samples don’t emit light, you need a different approach.

To get the broader scope of plasma behavior, Bane called for the help of Terrence (Terry) Meyer, a professor of mechanical engineering with a courtesy appointment to AAE.

“Terry is one of the preeminent people in the world on laser

Sally Bane, associate professor of aeronautics and astronautics, is taking a unique approach to getting a deeper understanding of nanosecond-pulse plasmas. Her measurements will help explain why these short-lived plasmas are effective in various aerospace applications.

diagnostics for high-speed, turbulent flow and combustion," Bane says. "He and I are working to adapt some of his methods to this streak camera device that I've been working with."

With laser absorption spectroscopy, the basic approach is to pump energy into the material with a laser and analyze the light that is emitted back, Bane says. Meyer's expertise in this area will allow them to study the plasma just before ionization and during the plasma decay, and measure other important quantities such as electric field and atomic concentrations. These measurements will provide finer resolution to computational models.

Breaking ground, but staying grounded

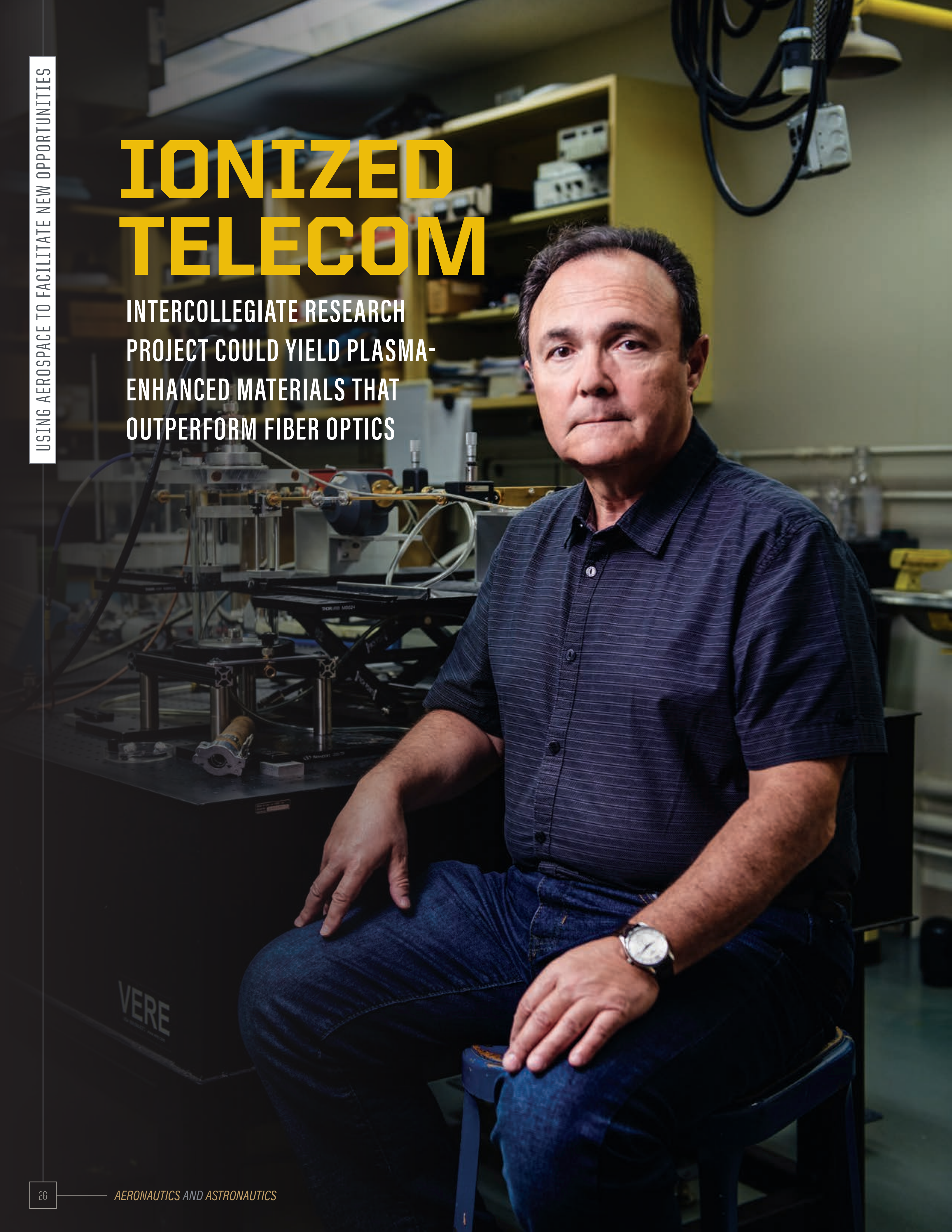
Though the tools individually aren't groundbreaking, combining them to achieve these results certainly is.

"We're measuring a whole bunch of very important parameters, and we're measuring them with unprecedented temporal resolution, which you need because these plasmas are so short-lived," Bane says.

This research, funded by grants from the Department of Energy, has been some of her most fruitful work lately — leading to several conference and journal papers. Together with her co-investigators, including Meyer and AAE Professors Jonathan Poggie and Sergey Macheret, she is working to interpret the many new and interesting findings revealed by the experiments and to implement them in state-of-the-art plasma models.

Still, she approaches her innovations with humility.

"You know, we just took devices that already existed and combined them in a way that people hadn't before. And then we just did a really, really good job of the optics so that we were able to take these really cool measurements."



IONIZED TELECOM

INTERCOLLEGIATE RESEARCH PROJECT COULD YIELD PLASMA-ENHANCED MATERIALS THAT OUTPERFORM FIBER OPTICS

Sergey Macheret lives on the cutting edge. The professor of aeronautics and astronautics isn't satisfied with having pioneered efficient generation principles and some aerospace applications of low-temperature plasmas; the plasma-enhanced metamaterials he's researching today could someday outperform fiber optic cables, drastically reducing the cost and improving performance of global communications.

This work is an extension of the plasma uses he's honed for aerospace applications within the Cold Plasma Research Group at Purdue. That includes instantly-tunable communications antennae and anti-jamming devices, as well as the ability to reduce stall speed by inducing low-temperature plasma on the surface of an airfoil.

Now working together with scholars at MIT, the University of Pennsylvania and in Purdue's School of Electrical and Computer Engineering, Macheret is leveraging his experience with energetic plasmas to explore ways to enhance the capabilities of a new class of materials.

"Metamaterials are called that because they are beyond materials. These are materials that don't exist in nature, but can be engineered," says Macheret. "It's been a rapidly developing, booming field for the last 20 years or so."

Adding plasmas to materials with enduring properties

The metamaterials that Macheret and his colleagues are developing, through funding from the Department of Defense's Multidisciplinary University Research Initiative (MURI), have topological structures that retain their unusual electromagnetic properties even if the structure is damaged.

"In topological structures, these properties do not depend on whether your structure is ideal, or has some defects, or even has an obstacle in the middle of it. No matter what you do, the key features of the materials are still there, undiminished," he says.

Macheret's contribution to MURI is to add tunability to those electromagnetic features through the use of plasmas.

Macheret Earns Plasmadynamics and Lasers Award from AIAA

Macheret has been contributing to the fundamental understanding of plasmas since the 1990s, when he worked to refute some original claims that plasmas behaved in ways that didn't follow the conventional laws of physics.

He was also co-discoverer of a method for efficiently generating plasmas with nanosecond-duration power pulses – sustaining a high average electron density while reducing the power budget by two to three orders of magnitude. This is now the mainstream method for generating cold plasmas.

In 2022, Macheret was elected a fellow of the American Institute of Aeronautics and Astronautics (AIAA) and was presented with the Plasmadynamics and Lasers Award from AIAA. The award recognized his "pioneering work on novel plasma generation and control methods and on aerospace applications of plasmas."

"Something that we're researching are structures that allow electromagnetic wave propagation one direction, but not in the other. Because such structures have plasma elements, we can change those elements — for example, we can change the frequency at which it exhibits one-way propagation properties," he says.

"Since plasmas can be modulated at any frequency, they can potentially be used to create and observe so-called photonic time crystals, a new class of metamaterials surmised by the theoreticians recently, where the periodic structure is created in time rather than in space. This would open new possibilities of control and manipulation of electromagnetic interactions."

He hopes to eventually use metamaterials to expand the capabilities of some of his other recent work, including plasma antennas that can be reconfigured or switched off instantly, or wireless transmitters that can handle high power levels without distortion harmonics.

Applying metamaterials to change telecommunications

Though funding for this research comes from the Department of Defense, Macheret applications for these types of materials outside of the military. Once fully developed, he says plasma-tunable metamaterials could outperform fiber optic cables in bandwidth and reliability.

"If you transmit a signal through an optical fiber, any little rough elements or other defects will scatter the light and weaken the signal. That is why the transatlantic fiber optic cables have repeaters every hundred miles or so," he says.

But if the data were instead transmitted through a topological structure, Macheret says minor or even major defects in the cable wouldn't deteriorate the signal.

"That has the potential not only to eliminate the maintenance costs related to underwater signal repeaters, but eliminate latency introduced by those repeaters. It could transfer the signal over 10,000 miles with no losses whatsoever," Macheret says.

"The things these materials are capable of are nothing short of amazing."

Order from Chaos

A MATHEMATICAL MODEL FOR SATELLITE MANAGEMENT

Space has become critically congested, says David Arnas, assistant professor of aeronautics and astronautics. As a researcher of satellite constellations and their orbits, he believes we are reaching a turning point that will decide whether humans can continue to use space in our future.

"Satellites do not care about national borders, they only care about gravitation," he says. "Space is a common resource of humanity, just like water and air. Even if it seems very vast, it is still limited. It is our responsibility to ensure that future generations will also have fair access to it."

Arnas is creating mathematical models that can be a cornerstone of a future space traffic management system that would address the need of responsible and equitable use of space. These models, Arnas says, could optimize performance and reduce propellant use, enable higher satellite densities and reduce the likelihood of collisions in Low Earth Orbit (LEO).

His work contributes to Purdue's Cislunar Initiative, which conducts a variety of research to enable better use of the space between the Earth and the moon.

Solving the "Wild West" space problem

While working for the European Space Agency, and later as assistant professor at Universidad de Zaragoza, Arnas saw satellite missions that changed their orbits in ways that seemed to block competitors from vying for that space.

"Are they doing these maneuvers to improve the performance of their system, or because they want to prevent competitors from launching or operating their satellites? It is not always possible to know exactly what the reason is, but just the fact that they have that power is disturbing," Arnas says.

Part of the cause of this competitive push is that the current system of satellite placement doesn't allow much density. Currently, satellite systems' orbital shells are separated by altitude, such that the oscillations of the orbits in one shell never enters the range of another. "But even circular orbits can have fluctuations of more than 12 kilometers in altitude," he says. "If you want to bring this distance down to less than 1 kilometer, you need accurate analytical models that are able to predict the maximum boundaries that orbits may experience under orbital perturbations."

One issue is that satellite dynamics don't have analytical solutions, only numerical or analytical approximations — a problem compounded by a large number of satellites. Another issue is that Earth's gravitational pull varies throughout an orbit, depending on the density of what's below. "Earth's gravitational field is less than ideal. Think of it not as a sphere or a spheroid, but more like a big potato," Arnas says.

Calculating these complex orbits numerically and at scale takes a lot of computing power and time. Arnas' mathematical operations would be scalable to many thousands of satellites, and would give each spacecraft its own "slot" separated from others. In addition to allowing denser orbits, this would foster faster response in the event of a solar storm or other major event.

"By following these optimal distributions, we could assure that first, satellites are never going to produce conjunctions between them. This increases safety and reduces the fuel required to maintain missions," Arnas says. "Second, there will be more positions available, which ensures sustainability and fair access to future missions. And third, if an accident happens up there, these mathematical structures enable a quick and safe procedure to reposition satellites that could be in danger."

Creating order from the chaos, he says, is the only way future generations will have access to space.

Building a Better Computational Model

Physics equations drive optimization of complex engineered systems

Computational models allow researchers to analyze and design complex systems, but development can be a slow process. Leifur Leifsson, associate professor and principal investigator of the Computational Design Lab, uses physics equations to optimize engineered systems for aircraft and space systems as well as microwave systems, nondestructive testing systems and food-water-energy systems.

"I've always loved mathematics," Leifsson says. "Taking the mathematical model and converting it into computer code can be really challenging, but I enjoy that challenge. Once you have that implementation, you can use it to analyze really complex systems and understand how they behave."

Leifsson first became interested in advancing fundamental computational methods for surrogate-based modeling and optimization while working on his master's thesis in his home country of Iceland. His research focused on a company that was developing autonomous underwater vehicles.

"I was fascinated by how I could model the fluid flow of the ocean water around the vehicle," Leifsson says. "The same principles apply to modeling propulsion systems. I began reading about computational modeling in aerospace and decided to pursue a PhD in aerospace engineering."

After earning his PhD from Virginia Tech, Leifsson worked in industry at two startups and Airbus UK before joining the faculty at Reykjavik University. Prior to coming to Purdue in 2021, he was an associate professor of aerospace engineering at Iowa State University.

"One of the first conferences I presented at, Bill Crossley chaired that session," Leifsson says. "I was really nervous but Bill was so helpful and supportive and so I always remembered Purdue and Bill Crossley. Purdue is a highly collaborative environment. The opportunity to engage in cross-disciplinary research with other faculty and teach students at one of the best engineering schools in the country was very exciting.

"My research is very collaborative in nature because I'm modeling systems that involve various disciplines. My role is to integrate the effects of these different disciplines which allows me to collaborate with a variety of people, such as one person who focuses on structures and another who focuses on aerodynamics."

With the integrated data, Leifsson can create surrogate models, which are simplified approximations of more complex models. The same methods and techniques used to model an aircraft can be applied to food-water-energy systems. One such project involves an analysis of the nitrogen loads in the Mississippi River basin resulting from high yield agriculture in Iowa. The surplus nitrogen is carried to the Gulf of Mexico, resulting in the generation of a hypoxic zone — an area of low oxygen that can kill fish and marine life near the bottom of the sea — that has a detrimental impact on the environment.

"Much of the nitrogen in the soil comes from the application of fertilizer," Leifsson says. "The water flowing through the state creates an interconnected system. By modeling the plants, energy and flow of water, we can predict how different levels of nitrogen used in Iowa will affect the Gulf of Mexico depending on situational variables such as weather."

Using data to predict outcomes satisfies Leifsson's constant drive for curiosity, a trait he strives to inspire in his students.

"Each student is different and has different interests," he says. "I try to inspire curiosity and encourage them to derive questions because if I'm just telling them what to do, they won't be as engaged. Students need to learn to be autonomous in conducting their own research. It will make them stronger researchers and better engineers in the future."

TRUST BUT VERIFY

How information value can help satellite systems work better in groups

Machines need a lot of information to operate autonomously. But, in the same way that your eyes and ears work together to understand what's around you, multi-sensor systems must be able to combine information into a cohesive picture — and determine which sensor data it can trust.

Keith LeGrand, assistant professor of aeronautics and astronautics, uses mathematical approaches to data and perception challenges. His work in the SCOPE Lab is contributing to research in space domain awareness, multi-object tracking and intelligent sensor control through Purdue's Cislunar Initiative.

From industry to academia

LeGrand heard his calling to research while he was a senior member of the technical staff at Sandia National Laboratories. He also recruited and mentored interns there, which is part of what inspired him to follow that call.

"I found that mentoring was a really rewarding part of the job because it allowed me to sort of broaden my research reach, and I really liked interacting with the students," he says.

After six years at Sandia, LeGrand and his wife agreed to leave Albuquerque in favor of Ithaca, New York, so he could pursue a PhD in aerospace engineering at Cornell University.

"It was a pretty tough decision to give up the really good job, and that security. We sold our car and a lot of our belongings just to kind of prepare for the student salary," he says. "I guess I was pretty driven. I'm very fortunate that my spouse was willing to make the sacrifice also."

Using math to merge data and quash rumors

His work in spacecraft proximity operations at Sandia is what led him to pursue multi-object tracking research. "I was looking at how to autonomously inspect malfunctioning satellites using only local information. I started thinking about a swarm of satellites and estimating their relative trajectories," he says. "At Sandia, there were a million national security applications in mind."

Now running the Sensing, Controls and Probabilistic Estimation (SCOPE) Lab at Purdue, LeGrand is looking at the challenges of proliferated systems that contain hundreds or thousands of small satellites.

"It's unreasonable for a human to task all 1,000 satellites. You need automation. But when you have large systems, how do we meaningfully control them so they're always gathering the best information?" he says.

These satellites need to reference data from many different sensors to arrive at an answer. They must also be able to recognize and ignore bad data, and stop it from perpetually biasing results. These functions run into the limited communications and computation capability in aerospace systems.

One way to improve automation is by estimating what there is to gain from new data. This was part of his doctoral research at Cornell, which involved controlling sensors in multi-object tracking systems.

"We have to be really smart about what information we exchange and when, and how much we trust the information we receive. For a satellite, for example, do I get more information if I look at the same place again and compare, or if I look somewhere else?" he says.

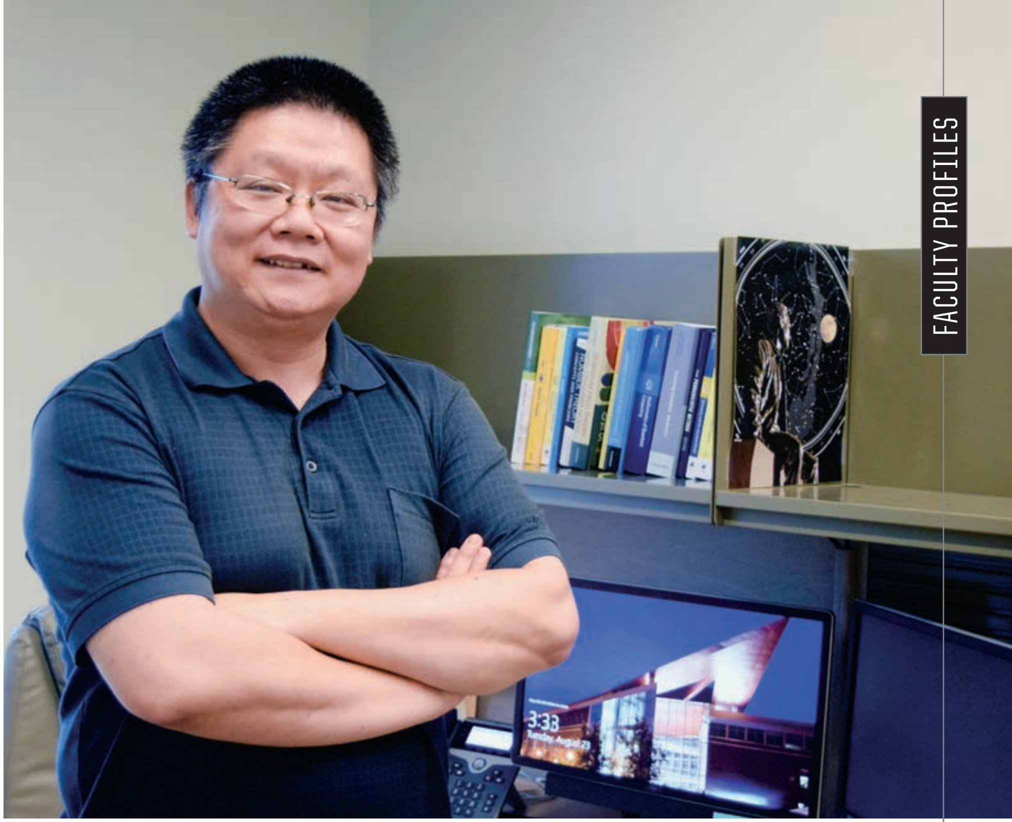
"You can boil down these complicated sensing tasks into what's known as information value, and create an information framework that can autonomously control your air- and spacecraft so you can get the measurements that are most informative."

All these approaches are handled mathematically, informed by statistical models of how each sensor perceives the real world. He believes his approach will be more broadly applicable as well.

"It's a lot of theory," he says, "but always with application in mind. There's always at least a simulation of a real system going into my models."

ENGINEERING FOR 6G

Integrating cell signal and radar will boost location awareness



Aircraft communications and radar have historically been separate systems, each operating in their own frequency bands. With telecommunications companies now spending millions or billions of dollars for exclusive access to narrow frequency bands, autonomous vehicles that transport people or transmit data may find themselves limited with limited bandwidth. Husheng Li, professor of aeronautics and astronautics, is working on a solution.

"Historically, a cellular phone was used for communications, but not radar. You might additionally have radar in an autonomous vehicle," Li says. "Our project is to integrate both: When you send out a signal in forward propagation, you can do communications, and as it bounces back, you can do some sensing."

Funded by three grants from the National Science Foundation, Li is pursuing mathematical methods and physical implementations to combine radar and cellular communications into one signal. Reducing bandwidth in this way could reduce costs for urban air mobility (UAM) operators, and improve drone-based wireless services in remote areas.

Combining wireless systems through mathematical models

Li joined the School of Aeronautics and Astronautics in fall 2022, bringing his experience as a senior engineer at a San Diego-based telecom giant in addition to degrees from Tsinghua University and Princeton University.

"At Qualcomm I designed wireless systems," he says. "Ad-hoc networks with no high base stations, no large towers and access points everywhere. We created simulations and testbeds, and a lot of those ideas went into 5G standards."

Li even has a legacy within the 5G world: Friends in the industry shared that they'd spotted his name in pieces of professional 5G simulation source codes.

For the 15 years after leaving Qualcomm, Li conducted research on cybersecurity of physical systems and wireless communications as a professor at the University of Tennessee. He was motivated to shift into sensing and communications for unmanned aerial vehicles (UAVs) in part because of the implications it has for the upcoming 6G wireless standard.

"One of the major features we'll have is a ubiquitous network. Satellites, airliners, UAVs, boats on the ocean will all be connected," he says. "UAV and airliner communications will become one of the critical parts."

Li says coverage, rather than data throughput, is one of the major concerns of 6G. That's something he has experienced personally in the sparsely populated Great Smoky Mountains: Telecommunications companies are hesitant to invest in base stations to serve a small number of users, he says.

"Most of the coverage in low-density areas will be done using satellites and UAVs. So the study of communications and sensing becomes very important in engineering for 6G," he says.

Li hopes to find solutions in part through his love for mathematics.

"Control and communications for urban air mobility is very dangerous and difficult," he says. "We need robust sensing, agile controls and to integrate these historically separate areas together. With mathematics, we can figure out a unified framework to have all these subsystems in the same system."

That's part of what has drawn him to this project — the integration of theory and practice. When a system becomes too complicated, he says, you can't just rely on math. The challenge is to find an essential problem, then devise a mathematical tool that can analyze that problem and give insight that can be applied back to the practical design for experimentation.

"You sometimes have some theoretical framework that doesn't work in practice, so you have to find some compromise. It's quite challenging to integrate theories and practical design."

SATELLITE RADIO SILENCE

AUTONOMOUS SATELLITE NAVIGATION IS NECESSARY TO EXPAND CISLUNAR SPACE OPERATIONS

Spacecraft are trapped behind human control. When Ken Oguri supported small satellite and deep-space missions at Japan Aerospace Exploration Agency (JAXA), he saw how specific the navigation commands sometimes needed to be.

"I was creating very detailed commands for how many seconds to rotate the satellite body about which axis for how many degrees, then change the direction of rotation for so many seconds, then fire your engine for so many seconds," says Oguri, assistant professor of aeronautics and astronautics.

He though that this was not sustainable if humans intend to explore further into space — a feeling reinforced when he saw similar systems in place while conducting postdoctoral research at NASA's Jet Propulsion Laboratory (JPL).

Since joining Purdue AAE faculty in January 2022, Oguri's research group has been contributing to the Cislunar Initiative by developing solutions that will enable commercial work and science exploration in the area between the Earth and moon and beyond.

Making satellites more self-reliant is one of the main motivating factors in his work.

"It's not only cumbersome, but almost impossible to do continuous interaction with satellites because of the limited number of antennas on the ground. Autonomous operation is necessary in the coming decade if we want to expand our space activity beyond Earth's orbit and into cislunar space," Oguri says.

Oguri's frameworks and algorithms could enable distant spacecraft to independently manage many of their own maneuvers, including orbit and attitude control, rendezvous and docking and sensing capabilities related to these maneuvers.

Safe systems in a chaotic environment

Oguri names three main factors for designing autonomous control algorithms: characterizing and modeling the nonlinear vehicle dynamics; estimating the orbital state of the vehicles as well as the properties of other objects; and planning maneuvers that anticipate vehicle faults.

"We want to make sure that our spacecraft is capable of doing perception and estimation of its relative position and velocity. It must also know how the other object is moving," Oguri says. "If that object is debris, we have to estimate the mass and also the moments of inertia to predict its motion. If we want to dock for servicing, we have to consider translational and rotational motion for both vehicles," Oguri says.

His team is even building in factors that consider the frequently changing lighting conditions in space — a critical piece for a perception system to understand its surroundings. These are the basic elements for planning an autonomous maneuver — but before they'll be accepted, these systems must also expect the unexpected.

"We have to make sure our trajectory is not going to cause hazardous events, even under the circumstances of thrust shutdown," Oguri says. "This aspect is also going to be very important to building trust in autonomous systems in space."

A balancing act for future integration

In a separate but related project, Oguri is working on autonomous guidance algorithms that consider the varying gravitational forces between the Earth and moon. This is necessary for vehicles that will operate in the area of balanced gravity between them.

"There are some chaotic regions where these two forces are competing with each other. If we add small perturbations in one direction, it might go toward the moon or toward the Earth," Oguri says. "This requires more careful implementation of control and navigation."

Oguri hopes to leverage these nonlinear effects in his autonomous vehicle control research.

"Both of them are important for space autonomy. We need to carefully model nonlinear, sensitive, chaotic dynamics in space, and we also want to consider safe, autonomous control of six degrees of freedom vehicle motions," Oguri says. "For now, I'm starting in two different streams of projects, and I want to eventually merge them into one."

ICYMI

UNIVERSITY NEWS

Engineering Dean Chiang selected as next Purdue president

In June 2022, the Purdue Board of Trustees announced its unanimous selection of Mung Chiang as the University's 13th president. Chiang, who was the John A. Edwardson Dean of Engineering and executive vice president for strategic initiatives, succeeds current president Mitch Daniels on Jan. 1, 2023. Daniels has served as Purdue's president since January 2013.

Chiang stepped down as dean of the College of Engineering to focus on his continued role as executive vice president for strategic initiatives and on the transition to his new position. Mark Lundstrom, the Don and Carol Scifres Distinguished Professor of Electrical and Computer Engineering, was named interim dean of the College of Engineering.

The search for a new dean began over the summer. Purdue AAE Professor Dan DeLaurentis serves on the Search Advisory Committee.

"Opportunities and challenges are intensifying for American higher education, from the modality and value of learning to R&D investment by the government and private sector. We are confident that the entire Purdue system, across all campuses and all units, will innovate together and excel together: one brick at a time, toward boundless potential in the Boilermaker future."

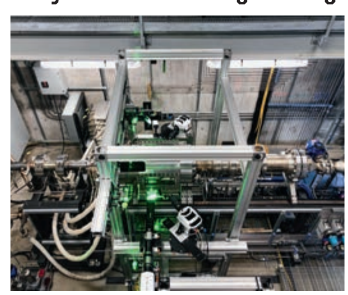
—Mung Chiang, Purdue University president-elect and executive vice president for strategic initiatives

Boeing Lecture brings Rolls-Royce CTO to speak on sustainable aviation

The William E. Boeing Distinguished Lecture Series returned to campus in October 2022 after its hiatus during the COVID-19 pandemic. Grazia Vittadini, chief technology officer for Rolls-Royce, spoke about the challenges facing sustainability in aviation, and the human and business needs to meet those challenges.

Vittadini and Boeing CTO Todd Citron, along with representatives from both companies, also met with students and faculty and toured AAE facilities during their visit.

Purdue receives its largest industry research-testing funding



In April 2022, Purdue and Rolls-Royce signed a research and testing agreement that will bring $75 million over 10 years to the University. This represents Purdue's largest single industry research-testing funding on record.

The testing and research will focus on gas turbine technology and electrical and digital technology. This investment will be focused primarily at Purdue's Zucrow Laboratories — the largest academic propulsion laboratory in the world — for research in sustainable power systems through advanced technology in electrification, turbines, compressors and combustion with sustainable fuels.

The seven-decade relationship between Purdue and Rolls-Royce is highlighted by millions of dollars invested in aerospace testing technology, sponsorship of graduate student research fellowships and more than 600 Purdue graduates among the company's current workforce in Indianapolis.

Full-length stories can be found on AAE's website, purdue.edu/AAE/spotlights

ICYMI

STRAIGHT UP SUCCESS

LAUNCH ENGINEER DAYLE ALEXANDER AMONG VIRGIN ORBIT'S FLIGHT CREW

On the upper deck of a Virgin Orbit 747-400, Dayle Alexander prepared for launch. In the utilitarian cabin stripped of its usual first-class luxuries, she monitored a computer console with rocket and aircraft telemetry. She knew the procedures. She was ready to handle any anomalies.

It was almost four years after she first started at Virgin Orbit, and she was living a dream: Alexander and her fellow launch engineer Sarah Barnes were responsible for the safe and effective deployment of the LauncherOne rocket.

On July 1, 2022, after completing the first cold pass, the aircraft approached the drop point a second time. They initiated the launch sequence. Once the engines were chilled and ready, clamps released it from underneath the 747's left wing, and as the pilots pulled up and banked away, the rocket ignited.

With Alexander on the flight crew, Virgin Orbit's Straight Up mission successfully sent seven United States Space Force satellites into Earth's orbit.

From engines to launches

This job on the flight crew is a departure from Alexander's original plan at Virgin Orbit. After completing her aeronautics and astronautics bachelor's degree in 2016 and her and master's in 2018, she started work doing exactly what she intended: designing rocket engines.

She said that doing her master's thesis research with Stephen Heister, the Raisbeck Engineering Distinguished Professor of Engineering, in Purdue's Maurice J. Zucrow Laboratories gave her an advantage in vying for the position.

"There are several Zucrow alumni at Virgin Orbit. Having Zucrow on my resume, and having people looking at it who knew what Zucrow was, that helped out a lot," she says. "I got to be heavily involved with some combustion device design and analysis and it was really, really cool."

But a different desire lit up in 2020, when she saw Virgin Orbit's first LauncherOne demonstration flight explode just seconds after ignition. Her work in engine design was right in her area of expertise — but in that moment, she felt like something was missing. She was missing.

"I saw the first one, the only failed mission, and I felt a little bit in the background," she said. "I wanted to be in the thick of the action, where all this new stuff was happening."

Alexander asked around about joining the flight crew, and she jumped at the position as soon as it was available.

Rocket launches are like marching band

The pilots and launch engineers are the only four people on the plane, so Alexander had to complete high altitude and water-landing survival training to fly. But the bulk of the work ahead of a launch consists of preparing the instruments and practicing a performance — a performance with explosive contents.

On the ground, Alexander is part of the general launch operations team. She's participating in wet dress rehearsals, preparing software and auto-sequencers, and providing input on sensors and other details the launch sys-

tem may need. There's additional practice on board the 747.

"We have tons of test flights before actual launch. I probably did six or seven training missions for both the pilots and the launch engineers," she said.

While the pilots are practicing the launch release maneuver, Alexander and Barnes are running through procedures, anomalies and mitigation processes. On launch day, the "Terminal Count" auto-sequencer is the critical time: Once completed, the rocket will launch, period.

"The Terminal Count lasts for about 15 minutes before the drop. Those minutes were the most intense of the mission, because that's when the rocket is not just sitting there anymore. It's doing work. Valves are opening, propellant is moving through the system. If something went wrong, that's when it would probably happen," she says.

All that practice, knowing the routine, reminded her of a completely different Purdue experience. While she studied aerospace engineering, she also played the baritone with the "All-American" Marching Band for five seasons, and in indoor and pep bands like Gold and Black Sound, Boiler Brass and the Boiler Box Band.

"It felt a lot like something I had practiced for a bunch of times, and then was finally doing it for an audience," she said.

And though she only plays baritone when she joins the Purdue alumni band, practiced habits are hard to break: "I know I haven't forgotten 'Hail Purdue!'"

Left to right: launch engineer Dayle Alexander (BSAAE '16, MSAAE '18), pilot Mathew "Stanny" Stannard, pilot-in-command Eric "Bip" Bippert, and launch engineer Sarah Barnes made up the entire crew for Virgin Orbit's Straight Up mission.

ICYMI

ALUMNI NEWS

Outstanding Aerospace Engineer Awards

Five AAE graduates received the honor of Outstanding Aerospace Engineer in a ceremony at the Buchanan Club at Ross-Ade Pavilion in April 2022. In the order pictured above: John Dankanich (BSAAE '01, MSAAE'03), Audrey Powers (BSAAE '99), Christie Schroeder Iacomini (BSAAE '93), Kimberly Hicks (BSAAE '06) and Luiz Felipe Valentini (BSAAE '99, MSAAE '01) all received their recognitions in person.

Powers was recognized as a 2021 OAE awardee (see inside front cover). Sirisha Bandla (BSAAE '11), another 2022 awardee, could not receive her award in person due to preparations for a space flight.

Distinguished Engineering Alumni

David D. Thompson

Mark Geyer

David D. Thompson (MSAAE '89) and Mark S. Geyer (BSAAE '82, MSAAE '84) both were celebrated as Distinguished Engineering Alumni in 2022. The honor is reserved for those whose careers and achievements reflect favorably on Purdue University, the engineering profession or society in general.

Thompson is the first vice chief of space operations for the new U.S. Space Force, and holds the rank of general. Geyer served in many aerospace roles during his 31-year career with NASA; his family accepted his honor posthumously (see Page 41).

O'Hara scheduled for space launch on Soyuz

Loral O'Hara (MSAAE '09) became the 26th person in Purdue's Cradle of Astronauts when she completed astronaut training and became eligible for spaceflight in January 2020. At the time of publication, she is scheduled to take her first spaceflight in early 2023, aboard the Soyuz MS-23.

She joined the astronaut program in 2017, after eight years at Woods Hole Oceanographic Institution (WHOI) in Massachusetts. At WHOI, she worked on the engineering and operations of human-occupied and remotely operated underwater research vehicles.

Dave selected as NASA flight director

Ronak Dave (BSAAE '14) was recently selected as a NASA flight director. He will lead missions to the International Space Station and prepare for lunar missions for NASA's Artemis program. Dave was a member of the AAE Young Professionals Advisory Council for the 2019-2020 academic year.

Dave is in rarefied air: NASA has only had 108 flight directors since Christopher C. Kraft Jr. became the agency's first in 1958. Scan the QR code at right to hear the interview with Dave on the "This is Purdue" podcast, or visit stories.purdue.edu/podcast.

Full-length stories can be found on AAE's website, purdue.edu/AAE/spotlights

STUDENT NEWS

ICYMI

Student team tackles power needs in electrified aviation

A team of five engineering students won this year's FAA Smart Connected Aviation student competition by demonstrating how a successful air taxi service will need to manage their electricity needs. Four of the team members are AAE students, including team lead and master's student Nick Gunady (pictured).

The team showed how urban air mobility (UAM) operators could balance on-site renewable energy with the electricity grid to charge their vehicles. They developed sophisticated software that would optimize power cost and demand, winning their category and the overall prize. This is the second time a Purdue team has won this competition.

Construction failure analysis framework concept wins INCOSE Best Paper award

AAE doctoral student Takaharu Igarashi received the Brian Mar Best Student Paper award during the International Council on Systems Engineering (INCOSE) 32nd Annual International Symposium. Igarashi's paper covers the need for a framework in identifying causes in construction failures.

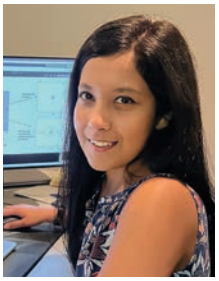
He proposes a system that would improve data collection from construction failures, which would produce better research results and reduce future catastrophic failures in the built environment. He hopes that better research on the ground will result in better-built structures in space.

NASA fellowship funds hypergolic propellant research

Three months into her doctoral research, Stefannie Morales Jiménez was awarded a NASA Space Technology Graduate Research Opportunities fellowship. With guidance from Timotheé Pourpoint, professor of aeronautics and astronautics, she is researching hypergolic propellants that meet or surpass the performance of the state-of-the-art while providing properties that are less toxic for handling, storage and operation.

Morales Jiménez is one of just 49 people to earn this prestigious NASA fellowship this year. The funding covers tuition, conference and travel expenses, supplies and a stipend for up to four years.

Doctoral student receives Amelia Earhart Fellowship to study spacecraft dynamics



Maaninee Gupta was selected to receive the Zonta International Amelia Earhart Fellowship. Gupta is one of 30 women receiving this fellowship in 2022.

With her $10,000 award, Gupta will continue her research in cislunar spacecraft dynamics with Kathleen Howell, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics. Gupta has been working with Howell's Multi-Body Dynamics Research Group since 2018.

Graduating senior wins Purdue Grand Prix

Mere weeks before the spring 2022 graduation, Alex Kardashian (BSAAE '22) stepped out of his go-kart at the Purdue Grand Prix race track and accepted his winner's trophy for the 65th running of the race. He got an early jump into the lead when the green flag waved, and held his lead over 2021 champion Jacob Peddycord until the checkers dropped 150 laps later. Three of Kardashian's teammates were also AAE students.

Two recent graduates recognized by Aviation Week Network

Angie Zhang and Daniel Mayper, who both graduated with bachelor's degrees in spring 2022, were selected from an international pool of candidates as among the top 20 students "on course to change the face of the aerospace and defense industry."

This is the sixth consecutive year that at least two of the Aviation Week 20 Twenties winners were Purdue AAE students. Aviation Week's selections are based on academic performance, an ability to contribute to a broader community and to communicate the value of the design or research they've undertaken.

Full-length stories can be found on AAE's website, purdue.edu/AAE/spotlights

ICYMI

FACULTY NEWS

Purdue hosts NASA conference on safe autonomous systems

The annual stakeholder meeting of NASA's Secured and Safe Assured Autonomy (S2A2) project, held on campus in June 2022, included academic presentations and research poster sessions on autonomous operation of aerial and space vehicles. This project, which is part of NASA's University Leadership Initiative, brings together a diverse, interdisciplinary team of experts from three universities and four industry partner companies. Their goal is to develop new technologies and procedures for a future filled with autonomous aerial vehicles.

Unlocking the potential of next-gen composite materials

Wenbin Yu, professor of aeronautics and astronautics, will be the primary investigator in creating a computer tool to design tailorable composites and hybrid material systems for space applications. NASA has awarded commercial software provider AnalySwift with a 13-month contract for the research.

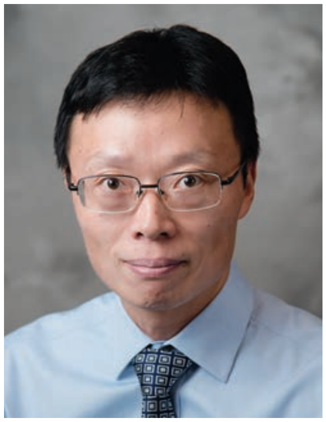
"The final design tool will be broadly applicable to various NASA uses," Yu says. "This contract will bring us to a final, government-endorsed tool quicker than other contracts or investments would support."

AAE head receives university's highest undergraduate teaching honor

Bill Crossley, who has taught more than 3,300 undergraduates in his 27-year career at Purdue, was honored with the Charles B. Murphy Award for Outstanding Undergraduate Teaching in the spring of 2022. It is the university's highest honor for undergraduate teaching. Crossley, who is also the J. William Uhrig and Anastasia Vournas Head of Aeronautics and Astronautics, proudly views the honor as a lifetime achievement award.

Full-length stories can be found on AAE's website, purdue.edu/AAE/spotlights

John P. Sullivan, professor emeritus and former head of the School of Aeronautics and Astronautics, received the J. Leland Atwood Award from the American Society for Engineering Education and American Institute of Aeronautics and Astronautics. It recognizes an aerospace engineering educator for their contributions to the profession.



Dengfeng Sun, professor of aeronautics and astronautics, is the 2022 recipient of the C.T. Sun School of Aeronautics and Astronautics Excellence in Research Award. It is awarded annually for high quality contributions in science and engineering.

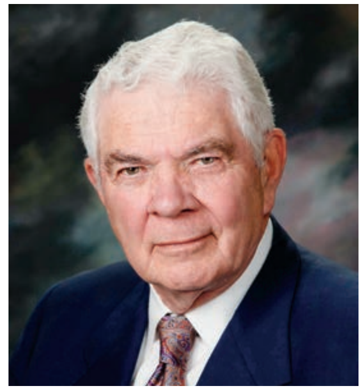
Daniel DeLaurentis, professor of aeronautics and astronautics, was named a senior fellow with the Krach Institute for Tech Diplomacy's diverse and fast-growing team.

Kathleen Howell, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics, is on a team that will be tackling space domain awareness as part of a five-year, $5-million grant from the Air Force Research Laboratory's Office of Scientific Research. The program is tasked with translating academic research into new military technologies for the U.S. Air Force and U.S. Space Force

Cislunar Summit brings together industry leaders to discuss space research arena

Representatives from commercial and government space organizations met at Purdue to brainstorm research needs for the future of space exploration. Kathleen Howell, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics, and Timothée Pourpoint, professor of aeronautics and astronautics, are gauging interest in a large facility that can replicate harsh conditions of space for at-scale experiments. Howell and Pourpoint led this two-day summit to in order to determine needs and set realistic requirements for such an arena.

IN MEMORIAM



James D. Raisbeck (1936-2021)

Through design and philanthropy, and by guiding the next generation of engineers, James Raisbeck contributed to the world of aviation for more than half a century. He came to Purdue in 1954 and, with a break to join the Air Force, graduated in 1961 and began his aerospace career. Working in aerodynamics at Boeing and Robertson Aircraft would lead him to open his own engineering firm in 1973.

Raisbeck himself, and the engineering company bearing his name, are jointly responsible for many contributions to the industry. These include supercritical wings for Rockwell International, performance enhancements on Learjets and Beechcraft, and noise reduction systems for Boeing's 727.

His legacy in aviation goes far beyond those engineering contributions. He supported the School of Aeronautics and Astronautics for decades, through funding for various Design-Build-Test courses and by establishing the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration position.

In Seattle, he established Raisbeck Aviation High School (RAHS) to help attract younger people into the field. Riley Stonesifer, a graduate of RAHS who is attending Purdue on a Raisbeck Engineering Scholarship, said Raisbeck was personally involved with the work there. Stonesifer helped organize a gathering of other RAHS alumni when Raisbeck died on August 31, 2021.

"He would attend our school events, was a friend to much of the staff, and would take the time out of his day to come mentor students personally," Stonesifer says. "He was truly passionate about the field and about encouraging the next generation of pilots, engineers and astronauts to pursue what they are passionate about. He was truly one of a kind: businessman, philanthropist, mentor, father and husband."

Raisbeck received Purdue's Distinguished Engineering Alumni award in 1979, Outstanding Aerospace Engineer award in 1999 and an honorary engineering doctorate in 2005.

Mark Geyer (1958-2021)

Recognized by NASA five times for his exceptional service and outstanding leadership, Mark Geyer spent 31 years living the sort of NASA dream that many aspire to, but very few achieve.

He held several leadership roles with NASA's International Space Station (ISS). As the chair of the Mission Management Team and NASA lead negotiator with Russia, Geyer was responsible for coordinating operations between NASA, the Russian Space Agency and their contractors for the construction of the ISS. His leadership led to the construction of the ISS and its success as the world's first space station. As manager of the ISS Integration Office, he defined the ISS assembly sequence and technical integration of space station elements between the international partners.

Under Geyer's direction, the Orion Program conducted successful tests in space that contributed significantly to NASA's ability to send astronauts to deep-space destinations.

In 2018, Geyer was named director of the Johnson Space Center, home to the nation's astronaut corps and human space flight research and training. In that role, he led a workforce of approximately 11,000 civil servant and contractor employees and an annual budget of more than $5 billion while managing a broad range of human spaceflight activities.

Geyer's work was celebrated by NASA with five awards: In 2000, an Exceptional Service Medal; in 2004, the Space Flight Awareness Leadership Award; in 2006, a Meritorious Executive Rank Award; in 2011 the Distinguished Executive Rank Award; and in 2015, NASA's Distinguished Service Medal.

Geyer graduated from Purdue with his bachelor's in aeronautics and astronautics in 1982, and a master's in 1984. The School of Aeronautics and Astronautics recognized Geyer with the Outstanding Aerospace Engineer Award in 2016. The College of Engineering chose him to be named among their 2022 Distinguished Engineering Alumni; Geyer was notified of the recognition before his death on December 7, 2021.

1940s

David W. Ochiltree (BSAE '43)
Kenneth H. Hummel (BSAE '48)
Marlin D. Reed (BSAE '48)
Harold E. Pryor (BSAE '48)
Ross E. Hamlin (BSAE '49)
Charles F. Kroh (BSAE '49)
Marvin E. Olson (BSAE '49)
Edward G. Dorsey (BSAE '49)
John R. Hunter (BSAE '49)
Elayne M. Brower (BSAE '49)

1950s

James P. Bosscher (BSAE '50)
William W. Penn (MSAE '50)
William H. Ricke (BSAE '51)
Philip A. Fistori (BSAE '51)
Franklin R. Fass (BSAE '51)
Russell G. Welker (BSAE '51)
David L. Millikan (BSAE '52)
Mary L. Stiebling (BSAE '52)
Robert E. Samsen (BSAE '52)
Samuel G. Weir (BSAE '53)
Robert H. Schultz (BSAE '53)
James P. Bigham (BSAE '53)
Wesley D. Balter (BSAE '54)
Lawrence D. Hines (BSAE '55)
John M. Kellam (BSAE '55)
Richard W. Parker (BSAE '55)
Jack L. Keller (BSAE '56)
George H. Nason (BSAE '56)
Robert D. Mayerhofer (BSAE '56)
Robert L. Brandt (BSAE '56)
Richard H. Petersen (BSAE '56)
Robert L. Ringgenberg (BSAE '56)
Robert L. Swaim (BSAE '57)
Edward F. Setmeyer (BSAE '57)
Alan S. Jones (BSAE '57)
Roland V. Connor (BSAE '57)
Ronald D. Drynan (BSAE '57)
Fred R. Glahe (BSAE '57)
James F. Southerland (BSAE '57)
Jack L. Keller (MSAE '57)
James P. Bosscher (MSAE '57)
Dean A. Loomis (BSAE '58)
Floyd E. Moreland (BSAE '58)
Charles G. Burchfield (BSAE '58)
James H. DeWeese (BSAE '58)
Philip B. Reed (BSAE '58)
Richard W. Parker (MSAE '58)
Chuen-Yen . Chow (MSAE '58)
John E. Notestein (BSAE '59)
Jack D. McMillan (BSAE '59)
William S. Kennedy (BSAE '59)
William R. Lahs (BSAE '59)
Laurence E. Simons (BSAE '59)
James E. Meyer (BSAE '59)
Robert L. Swaim (MSAE '59)

1960s

Richard A. Mathias (BSAE '60)
Avon H. Schwab (BSAE '60)
Lawrence B. Haws (BSAE '60)
Gerald L. Spade (BSAE '60)
Troy M. Gaffey (BSAE '60)
Arland T. Stein (BSAE '61)
James D. Raisbeck (BSAE '61)
Lowell K. Davis (BSAE '61)
Lawrence J. Coulter (BSAE '61)
Richard H. Remde (BSAE '61)
James D. Welch (BSAE '61)
Charles O. Ziemer (BSAE '61)
Michael T. Wampler (BSAE '62)
Thomas H. Lindsey (BSAE '62)
Sol M. Feldman (BSAE '62)
David H. Johnson (BSAE '63)
Gilbert R. Eckler (BSAE '64)
William A. Kuczynski (BSAE '64)
Richard A. Navarro (BSAE '64)
David H. Johnson (MSAE '64)
Francis L. Barrett (MSAE '64)
Jerald M. Connan (BSAE '65)
Gilbert R. Eckler (MSAE '65)
Donald G. Lewis (BSAE '69)

1970s

Lynn L. Waite (BSAE '70)
Michael T. Kennedy (BSAE '70)
James F. Sellers (BSAE '70)
Donald G. Lewis (MSAE '70)
Larry J. MacFarlane (BSAE '72, MSAE '73)
Leonard W. Martin (BSAAE '74)
Richard E. Macdonald (MSAAE '76)

1980s

David R. Smith (BSAAE '80)
Michael G. Carpenter (BSAAE '80)
Mark S. Geyer (BSAAE '82)
Keith R. Baylor (BSAAE '84)
Mark S. Geyer (MSAAE '84)

2010s

Dylan Alwine (BSAAE '18)

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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