

AEROGRAM

PURDUE UNIVERSITY SCHOOL OF AERONAUTICS AND ASTRONAUTICS / FALL 2019

A YEAR OF CELEBRATION

2019 marks Purdue's
Sesquicentennial



NEIL ARMSTRONG HALL OF ENGINEERING



BETH MOSES MAKES 25

AAE alumna joins Purdue's CRADLE OF ASTRONAUTS

Alumna Beth Moses joined an elite class in 2019.

Moses (BSAAE '92, MSAAE '94, OAE '18) was one of three crew members in the cabin when Virgin Galactic's spaceplane, the VSS Unity, reached space on a February 2019 flight. The craft reached 89.9 kilometers and qualified Moses, the chief astronaut instructor at Virgin Galactic, for Commercial Astronaut Wings from the Federal Aviation Administration.

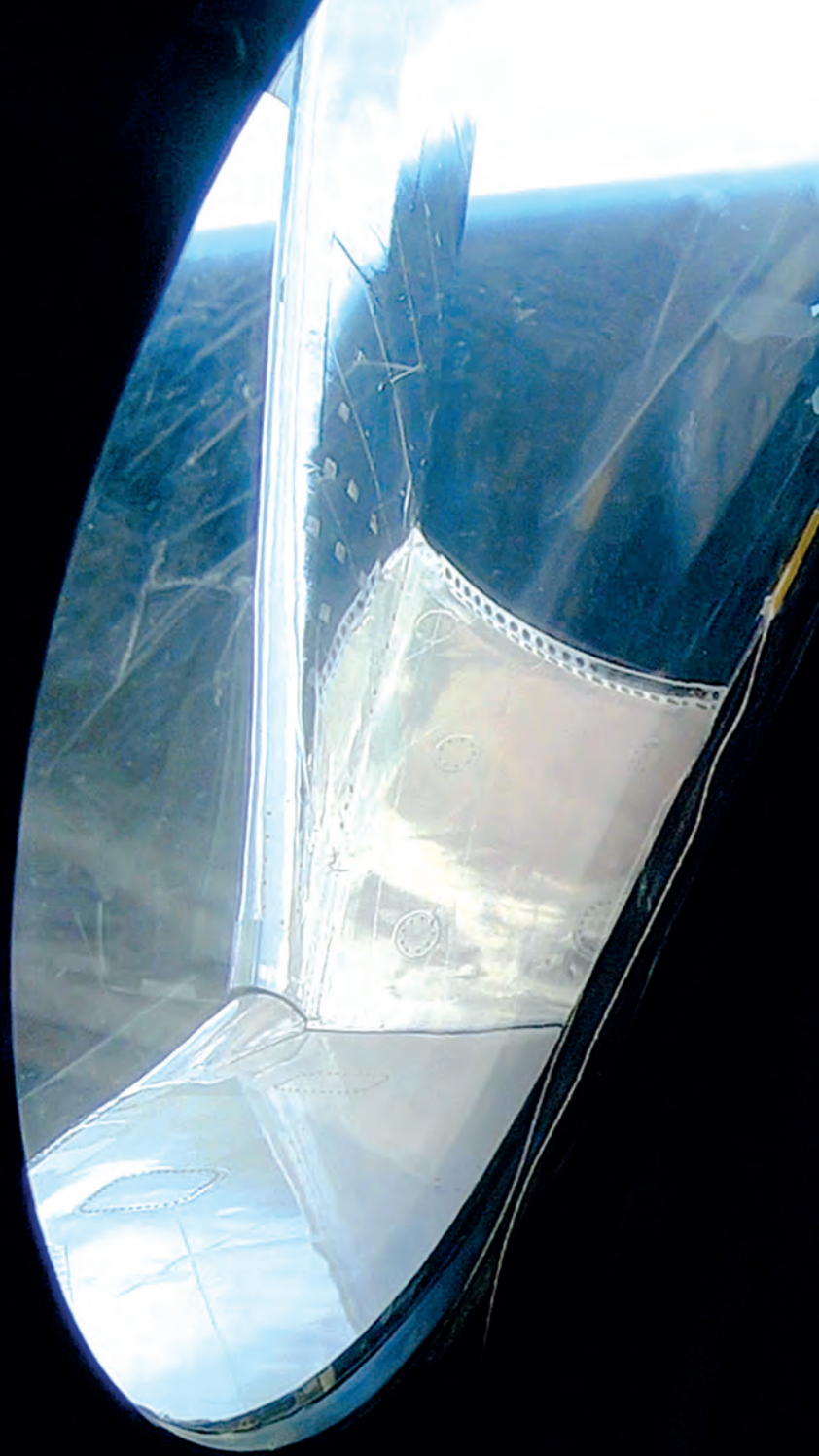
That honor launched her into another special category: She is the 25th member of Purdue's Cradle of Astronauts. Moses is the 571st human to travel into space and the first woman to fly to space onboard a commercial vehicle.

It's a moment Moses will not soon forget.

"I can vividly conjure up the sight, the sensation," she said on a visit to campus in April 2019. "I think the image of Earth from space will be burned into me forever, in a really good way. It's amazing."

More on Moses' historic flight and a special gift to the School of Aeronautics and Astronautics: Page 56.

ABOVE AND RIGHT / Beth Moses became the first woman to fly to space onboard a commercial vehicle in February 2019. PHOTOS: VIRGIN GALACTIC



AEROGRAM

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LAUNCHPAD

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During Purdue University's sesquicentennial year, Neil Armstrong Hall was emblazoned with a Giant Leaps celebration banner.

PHOTO: MARK SIMONS

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TOM I-P. SHIH

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

THIS PAST YEAR, 2018-19, was a very special one for the School of Aeronautics and Astronautics (AAE). This is because it was our University's sesquicentennial and the 50th anniversary of Apollo 11's landing on the moon, when AAE alumnus Neil Armstrong made humankind's first steps on the lunar surface. Also, Ernie (BSAE '60, MSAE '61) and Monica Gambaro endowed and named our graduate program to enable an already exceptional program to reach even greater heights. And, two AAE alums generously gifted an indoor UAS test bed — about 20,000 square feet and 35 feet high — for AAE faculty and students to collaborate with teams from ME, ECE, civil engineering, computer science, and aviation and transportation technology. This test bed will enable research on urban air mobility and UAV flights in swarms and in harsh environments — including those from weather, GPS-denied situations and counter-UAS.

Further, this was the year in which many of our faculty, students and alums were recognized by prestigious accolades and received major research grants. These include Kathleen Howell's Morrill Award; Sally Bane's promotion to associate professor with tenure; and Tim Pourpoint's promotion to full professor — as well as university-wide recognitions that include a MURI award and a NASA center of excellence. For our alums, we had the privilege to honor eight with AAE's Outstanding Aerospace Engineer Award, two with our college's Distinguished Engineering Alumni Award, and one with Purdue's honorary doctorate in aeronautics and astronautics. Further, two were elected fellows by the American Institute of Aeronautics and Astronautics (AIAA).

During this past year, we graduated 162 BS, 104 MS and 20 PhD students; our enrollment grew to more than 800 undergraduate students and 522 graduate students, of whom 210 are PhD students. In addition, we were delighted to have recruited a new faculty member with expertise in hypersonics, Joseph Jewell, who started in Fall 2019. Finally, but not least, Purdue University completed and surpassed its fundraising goal for the Ever True campaign, and I'm pleased to say that AAE led the college in gifts. Our deepest thanks to our alums and friends!

Thus, it was a year with much to celebrate. Our celebrations included the Rolls-Royce Lecture given by Keoki Jackson; the Boeing Lecture given by Dennis Muilenburg; an evening with Bill Nye; a "What IF" panel

on space exploration with Bill Gerstenmaier, Mary Lynne Dittmar and Jonathan Lunine; the launching of AAE's Amelia Earhart Aerospace Summit; the launching of the Midwest Distinguished Lecture Series in Aerospace Engineering with Illinois at Urbana-Champaign, Michigan and Notre Dame — and having Georgia Tech's Professor Vigor Yang as the inaugural speaker; and the launching of the Neil Armstrong Distinguished Fellow and Visiting Professorship, with Paul Bevilacqua as the inaugural distinguished fellow.

One sad note during this past year was the passing of Professor George Palmer, who served AAE from 1947 to 1987. Professor Palmer was known as a committed teacher, a devoted researcher, an innovative mind, an inspiration to countless aerospace engineers and leaders — and a trusted and loyal friend.

As many know, I stepped down as the AAE head at the end of my second term, in July 2019. We held a national search for the next head. We are delighted that our own Professor William Crossley was selected and started on the symbolic date of July 20, 2019 — the 50th anniversary of Neil's walk on the lunar surface. This is an exciting time for AAE, and we look forward to Professor Crossley's leadership in taking us to ever higher levels of excellence and impact in all that we do.

For me, it has been an extreme honor, privilege and pleasure to have served this incredible school during the past decade. I want to convey my deepest thanks to the faculty, staff, students, alums and friends who have worked so hard to make AAE such a great place and for making us all so proud with your excellence and distinguished accomplishments. I also want to thank Dean Leah Jamieson and Dean Mung Chiang for their strong support of AAE throughout the years.

Thus, this has truly been an exceptionally exciting year, and we thank you so much for your support that made everything possible. As always, please keep us informed of developments in your lives so we can share news in future issues of Aerogram, as well as on AAE's website and social media.

Hail Purdue!

TOM SHIH

J. William Uhrig and Anastasia Vournas Head and Professor of Aeronautics and Astronautics

AAE BY THE NUMBERS

#5 BEST UNDERGRADUATE AEROSPACE/AERONAUTICAL/ASTRONAUTICAL ENGINEERING
U.S. NEWS & WORLD REPORT 2019

#5 BEST GRADUATE AEROSPACE/AERONAUTICAL/ASTRONAUTICAL ENGINEERING
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#6 BEST AEROSPACE ENGINEERING
ACADEMIC RANKING OF WORLD UNIVERSITIES/SHANGHAI RANKING CONSULTANCY 2018

OUR FACULTY 2018-19

37 TENURED AND TENURE-TRACK FACULTY MEMBERS:
 • 23 FULL PROFESSORS
 • 7 ASSOCIATE PROFESSORS
 • 7 ASSISTANT PROFESSORS

19 RESEARCH FACULTY, VISITING FACULTY, ADJUNCT FACULTY & LECTURERS

42 FELLOWS OF PROFESSIONAL SOCIETIES

6 MEMBERS OF NATIONAL ACADEMY OF ENGINEERING, NATIONAL ACADEMY OF SCIENCES, AND OTHER ACADEMIES

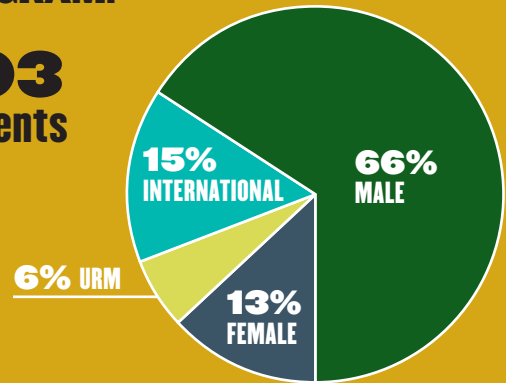
22 NATIONAL SCIENCE FOUNDATION & OTHER YI AWARDS

109 MEMBERSHIPS ON TECHNICAL COMMITTEES, BOARDS, AT INTERNATIONAL AND NATIONAL LEVELS

OUR STUDENTS 2018 FALL ENROLLMENT

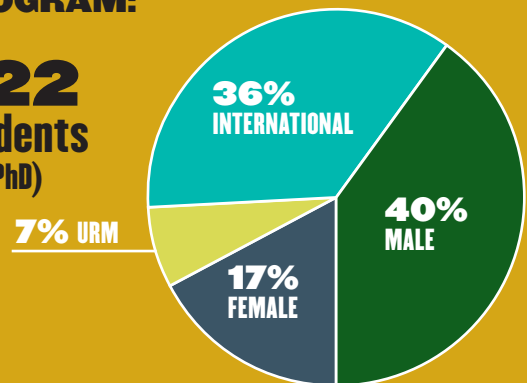
UNDERGRADUATE PROGRAM:

803 students

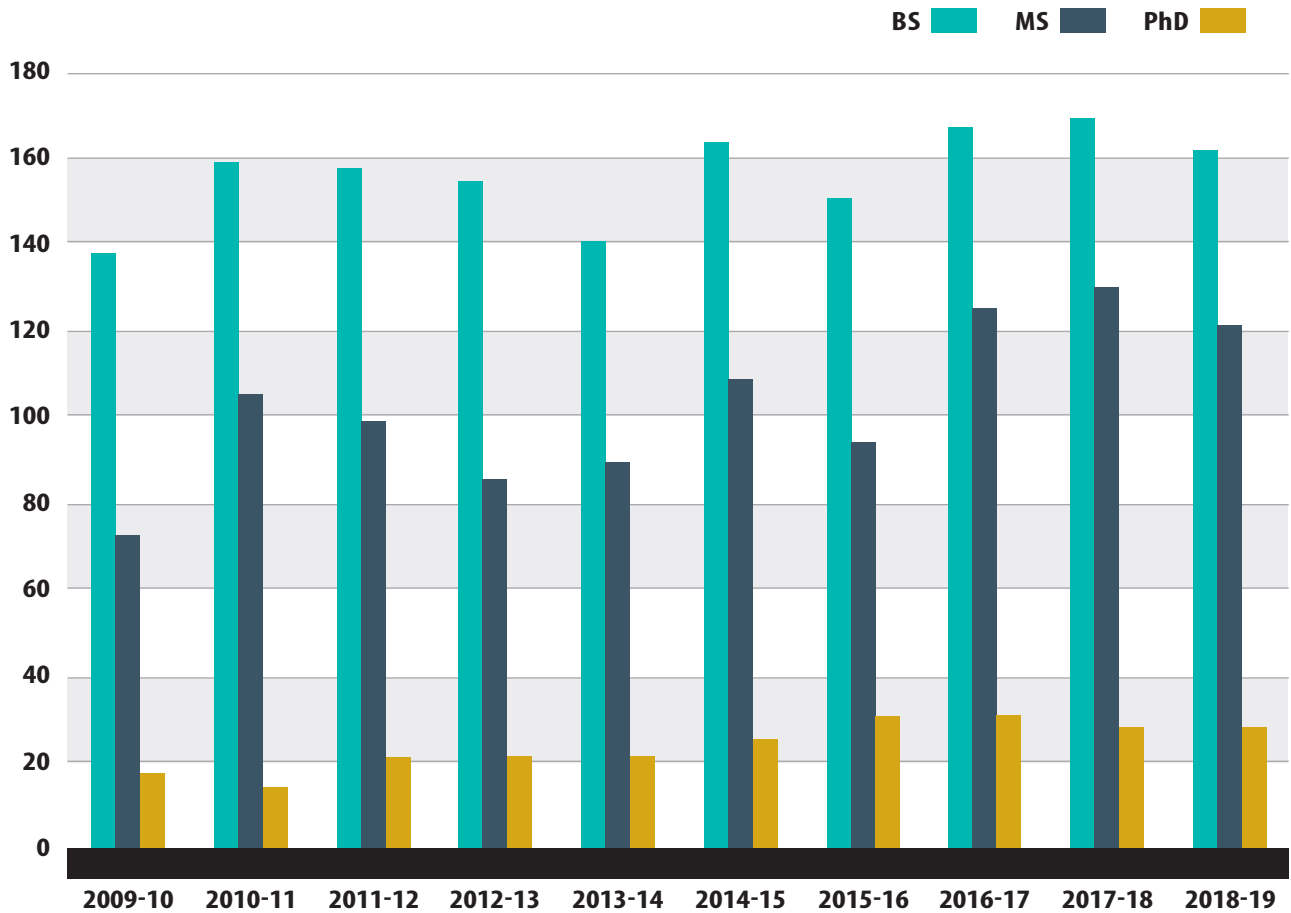


GRADUATE PROGRAM:

522 students (201 PhD)



A DECADE OF GROWTH AAE GRADUATES



CENTERS OF EXCELLENCE DEVELOPED BY FACULTY SINCE 2009

AFOSR

Center of Excellence on Combustion Dynamics
(William Anderson)

ASCENT

FAA Center of Excellence for Alternative Jet Fuels
and Environment (Daniel DeLaurentis)

CITMAV

Center for Integrated Thermal Management of
Aerospace Vehicles (Timothy Fisher/Tom Shih)

IACMI

Institute for Advanced Composites Manufacturing
Innovation (Byron Pipes)

ISA

Center for Integrated Systems in Aerospace
(Daniel DeLaurentis)

I-GSDI

Institute for Global Security and Defense Innovation
(Daniel DeLaurentis)

LYOHUB

Consortium on Lyophilization/Freeze-Drying
(Alina Alexeenko)

NEXTOR II

FAA Consortium on Aviation Operations Research
(Dengfeng Sun)

PEGASAS

FAA Center of Excellence for General Aviation
(William Crossley/Karen Marais)

UTC

Rolls-Royce University Technology Center for
Advanced Thermal Management Systems
(Timothée Pourpoint)

WILLIAM CROSSLEY

PRIMED TO PROPEL AAE INTO FUTURE

William A. Crossley didn't offer much advance notification.

He was onsite at The Boeing Company's Everett, Washington, facility to present a final overview on a project completed by a group of aeronautics and astronautics faculty and their students in collaboration with Boeing and knew it would be a short trip. So his plan was to essentially get in and out, without alerting any former students who were now Boeing employees to his presence.

But before he left, Crossley and the Purdue team were scheduled for a VIP tour of the floor of the factory, one of the largest manufacturing buildings in the world, where Boeing produces thousands of airplanes.

Though Crossley had worked in the aerospace industry for years, he still was somewhat in awe walking the factory floor past all the company's airliners: the 747-8, the 767, the 787 and the 777. Crossley has had an affinity for airplanes since childhood. One of his earliest memories is watching his father, Guy Crossley, take off on a commercial flight from their hometown airport in Cincinnati, Ohio, wondering, "How does that thing work?" Crossley turned that curiosity into an aerospace engineering degree, a job at McDonnell Douglas Helicopter Systems, and then a gig teaching college students exactly how "that thing" works.

So, naturally, Crossley was in a bit of a state of wonder passing the planes that took the place of those his dad, a chemical engineer, once hopped on so frequently. Crossley was knocked out of his reverie when he heard a commotion across the assembly plant floor — then saw three bodies rushing toward him. They were three of Crossley's former students, giddy at not only seeing one of their most influential professors for the first time in years but also eager to show off their handiwork.

That 787-9 plane Crossley was standing in front of? That was *theirs*.

"Professor Crossley, can you get on our airplane?" they asked him.

Crossley was happy to oblige — and he deeply appreciated the moment, realizing it was a manifestation of the impact he'd had on a small group of inquisitive, determined engineers. He calls it one of the most validating moments of his career.

That happened in 2014. Crossley still gets emotional when he tells the story.

"I knew I helped the students on the path they wanted to go on," he says.

That's the heart of what Crossley wants to continue to do, now in a larger role. In May 2019, Crossley was chosen to succeed Tom Shih as the next head of the School of Aeronautics and Astronautics. On July 20, Crossley assumed the position of J. William Uhrig and Anastasia Vournas Head of Aeronautics and Astronautics.

As a member of the faculty since 1995, Crossley has helped shape AAE into one of the world's most respected and highly ranked aerospace engineering programs. As a teacher, he has showcased a passion for nurturing students, piquing their curiosity and challenging their assumptions, molding innovative thinkers into doers and developing impactful engineers. As director of Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS), a Federal Aviation Administration Center of Excellence for General Aviation, Crossley has demonstrated an ability to assemble large teams, both across campus at Purdue and across the multiple universities in PEGASAS, and guide them to remarkable accomplishments. As an innovator and leader in online learning, Crossley was the first AAE faculty member to teach distance-learning courses and has continued to be at the forefront of helping educate nontraditional students by expanding the AAE curriculum and strengthening the program's online reputation beyond campus.

As head, Crossley hopes to expand on new opportunities to challenge how students learn, support pioneering research among faculty and create a more representative identity for the school.



WILLIAM A. CROSSLEY AT A GLANCE

EDUCATION

University of Michigan
BS Aerospace Engineering

Arizona State University
MS, PhD Aerospace Engineering

ACADEMIC APPOINTMENTS

Professor, Purdue University School of Aeronautics and Astronautics (2009-present); Associate Professor, AAE (2001-2009); Assistant Professor, AAE (1995-2001); Director for Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability (PEGASAS), FAA Center of Excellence for General Aviation (Sept. 2012-present); Chair of Aerospace Systems committee area (2010-present) and Design committee area (2001-present)

INDUSTRY EXPERIENCE

McDonnell Douglas Helicopter Systems (1990-1995); Consultant for The Aerospace Corporation (1997); FAAC Incorporated (1998); Institute for Defense Analyses (2002-2009) and NextGen Aeronautics (2003-2005); Visiting scholar at The Boeing Co.'s Phantom Works (2005, 2007); Fellowship programs at Wright Laboratory/Wright-Patterson Air Force Base (1997), NASA Langley Research Center (1998, 2000), and The Boeing Co. (2002)

HONORS AND AWARDS

Purdue University Great Book of Teachers (2013); College of Engineering A.A. Potter Award (2007); AAE's Elmer F. Bruhn Award (2000, 2003, 2006, 2009, 2012); AAE's W.A. Gustafson Award (1998, 1999, 2000); AAE's Outstanding Faculty Mentor Award (2017); American Institute of Aeronautics and Astronautics Associate Fellow (2004)

WILLIAM CROSSLEY

CONTINUED

“The school has helped me succeed, and now it’s my turn to help the school succeed. As the head, I can help,” he says. “I know I can help the faculty on the paths they want to go on. I can’t provide every path for everybody, but I know I can help the school and the people in the school — the students, the staff and the faculty — with a direction forward. I’d like us to have a journey we can share. I want to do that.”

It’s an ideal time for the opportunity, too.

Crossley called it an “incredibly exciting time” for aerospace in myriad areas, ranging from electric vertical takeoff and landing urban air taxis, commercial space in low-Earth orbit, crewed space exploration beyond low-Earth orbit, the renewed interest in supersonic aircraft, advanced manufacturing impacting aerospace, digital twins leveraging data science, electric propulsion, and autonomy in air and space.

He is eager to lead AAE into that exhilarating era by continuing to build on the school’s strengths: Fostering original thinkers and future engineers who will make those ideas reality; and equipping faculty to explore research to answer yet-unknown questions that an evolving industry reveals.

But he’s also excited to see how the school can gain momentum. One way could be by defining themes that unite the school and explicitly showing how the efforts of the school are enabling the future of aerospace: safe, efficient and sustainable air transportation; access to and exploration of space; maintaining defense and security; and using aerospace to facilitate new opportunities.

“Purdue Aeronautics and Astronautics is in the midst of all these themes,” Crossley says. “What the students learn in their class work and research contributes to how aerospace makes the world better. These themes will make our contributions more obvious and uncover additional opportunities for collaboration.”

Part of embracing that, too, is reevaluating the curriculum. As a member of the curriculum committee before being named head, Crossley has been working with faculty to shape a new program for students. While making sure students get the core of what they need to be aerospace engineers, students could be better prepared for the progressing industry if the

curriculum provided undergraduates the opportunity to learn about other areas, to make sure they leave the program as well-rounded aerospace engineers.

“A lot of the evolution in aerospace, the changes we see, have often come because something has happened outside of what we normally think of as aerospace,” Crossley says.

Advancements in electric motors and batteries have been driven by ground transportation, and electric power isn’t taught in AAE’s curriculum because, traditionally, it hasn’t been part of what aerospace engineers needed to know, Crossley says. But those developments could translate into electric airplanes and urban air mobility. That presents an aerospace interest and is one of many examples in which an “aerospace plus” option comes in.

How future courses could be delivered is another element Crossley wants to examine.

AAE already has a large footprint in the Purdue Online Learning program, in part thanks to Crossley’s early willingness to teach his multidisciplinary design optimization course online and to now offering unique courses in remote sensing, space traffic management and electric spacecraft propulsion, among others. As of Summer 2019, AAE has 41 courses available through Purdue Online Learning.

“It lets Purdue reach out to students who aren’t here in West Lafayette and lets them have access to our program. I think the impact we have on the aerospace industry by providing that is really big. It could be bigger,” Crossley says.

With AAE enrollment at an all-time high — nearly 1,500 students for Fall 2019 — perhaps changing how content is delivered could play a major role in providing the growing student population a rewarding experience. Perhaps virtual labs could allow students to get the experience of running a physical experiment without actually running one. Perhaps online content could provide a captivating experience by adapting courses to include more than just faculty delivering material. They are approaches that could benefit on-campus and distance students.

“I think it’s the right time to try to do that. The landscape is such that we can do that,” Crossley says.

Anything he can do to help.

THE FUTURE IN AEROSPACE IS AUTONOMY



New UAS test bed for AAE

The Purdue School of Aeronautics and Astronautics is creating a research and test facility to explore, develop and test unmanned aerial systems (UAS).

The facility will enable faculty and students to work on resilient flights, flights in swarms and urban air mobility in benign and harsh environments. Harsh environments that can be simulated in the facility include those that could occur naturally, such as wind, rain, snow and sand, as well as those created by humans, such as enabling and denying GPS, jamming and other cyberattacks.

The facility will be located at the Purdue Airport within Hangar 4, in a space that's approximately 20,000 square feet in area and 35 feet high. The facility will be equipped with a state-of-the-art, motion-capture system that will be the largest in the world.

"The future in aerospace is autonomy — from package delivery, precision agriculture, infrastructure inspection and surveillance to urban, regional and international air mobility where pilots are not needed," says Tom Shih, J. William Uhrig and Anastasia Vournas Head and Professor of Aeronautics and Astronautics. "This UAS test facility is to educate, nurture and inspire this and the next generation of students to dream what could be and to make those dreams into realities."

Motion-capture technology originated in the movie industry but is finding many applications for UAS and robotics in general. Using infrared light, cameras throughout the facility track the position of reflective markers that can be attached to objects, just as they are attached to actors

A research and test facility that will explore and test unmanned aerial systems is being developed within Hangar 4 at the Purdue Airport, a space that is approximately 20,000 square feet in area and 35 feet high, making it one of the largest university indoor test facilities in the country. PHOTO: JOHN UNDERWOOD

for animated movies. The position and attitude information is similar to GPS, but the error range is significantly less.

The motion-capture system will enable critical research. As UAS learn to use computer-vision and other sensors to navigate indoors or in GPS-denied environments, they can detect the "true" position of the vehicle to track error and improve algorithms. The motion-capture data also can be used for creating virtual reality (VR) or augmented reality (AR) environments. The simulated images from VR/AR can be streamed to UAS or people wearing goggles within the facility. VR/AR can be used to construct environments that would be too dangerous or laborious to build in real life. VR/AR also provides a unique opportunity for training pilots to work with UAS in a safe environment.

The size of the facility will enable unique experiments that could not be accommodated in smaller motion-capture facilities, such as flying fixed-wing aircraft and large swarms.

"We are designing this research and test facility to be state-of-the-art and among the very best indoor UAS facilities in the world," says James Goppert, the acting managing director for the facility and a visiting assistant professor in AAE.

AAE will lead the continuing development of the test facility with a team of leading researchers and educators from mechanical engineering, electrical and computer engineering, civil engineering, aviation and transportation technology, and computer science.

A distinguished AAE alum has provided \$1.25 million that could be matched by others to jump start the development of the facility. So far, \$1.45 million has been generated.



COMING TO PURDUE: FASTER QUIET WIND TUNNEL

Purdue University was awarded a \$5.9 million contract from the Air Force Research Laboratory for risk-reduction and design studies. The contract begins the construction of a Mach-8 quiet wind tunnel for hypersonic research and development.

The Indiana Congressional delegation has supported Purdue's efforts in hypersonic research over the past several appropriation cycles and continues to help build this strength statewide with the Naval Surface Warfare Center Crane Division, Purdue, University of Notre Dame and Indiana University, along with industry partners.

A better understanding of when and how air flow over a surface changes from smooth, or laminar, to turbulent is essential in the successful design of hypersonic vehicles, such as hypersonic aircraft, hypersonic missiles, high-speed interceptor missiles, supersonic transports, many reentry vehicles and trans-atmosphere vehicles. Studying laminar-turbulent transition in wind tunnels is crucial

because it can have a large effect on aeroheating and aerodynamic controls in vehicles that fly at hypersonic speeds, defined as speeds faster than Mach 5 or nearly 4,000 mph.

"Development of these facilities is a research problem in the control of laminar-turbulent transition, but success will enable reduced risk and increased performance in the development of multi-billion-dollar missile programs that are increasingly critical for national defense," said Steven Schneider, a professor in the School of Aeronautics and Astronautics and a principal investigator on the project.

Purdue's would be the first quiet Mach-8 wind tunnel in the world.

The "quiet" piece is significant, Schneider said, because it more closely simulates flight, which yields more accurate data, than conventional hypersonic wind tunnels.

Quiet wind tunnel operation is imperative for recreating the laminar flow of air over the surfaces of aircraft, spacecraft or missiles re-entering the Earth's atmosphere. A quiet



Brandon Chynoweth inspects a model being tested in the Purdue Mach-6 quiet wind tunnel, one of only two working Mach-6 quiet tunnels in the country. A contract from the Air Force Research Laboratory will allow construction to begin on a new Mach-8 quiet wind tunnel. PHOTO: TOD MARTENS PHOTOGRAPHY

operation requires controlling laminar-turbulent transition on the wall of the wind tunnel nozzle in order to study transition on the wind tunnel models. Turbulent flows on the nozzle walls radiate noise onto the test model, interfering with experiments.

Conventional tunnels suffer from high levels of pressure fluctuations radiated from the turbulent boundary layer on the nozzle wall that generate noise levels greater than those measured in flight.

Purdue currently operates the larger of two working Mach-6 quiet wind tunnels in the country. Notre Dame is completing a large Mach-6 quiet tunnel as part of a partnership with Purdue to develop several hypersonic tunnels. As part of the agreement, Purdue will build a Mach-8 quiet tunnel, and Notre Dame will build a Mach-10 quiet tunnel. Another part of the partnership involves the development of a new generation of quiet-tunnel engineers, including Brandon Chynoweth, who will lead the development of Purdue's Mach-8 tunnel.

None of the quiet tunnels will make the other wind tunnels obsolete because as the Mach number goes up, the quiet Reynolds number goes down, Schneider said. The Mach number is the ratio of the speed of a body to the speed of sound in the surrounding medium, and the Reynolds number is used to determine whether a fluid flow is smooth or turbulent. The latter helps predict flow patterns and can be proportional to vehicle size (the bigger the vehicle, the higher the Reynolds number) and altitude (the lower the altitude, the higher the number).

“No single hypersonic tunnel can simulate everything about hypersonic flow,” Schneider said. “Since the quiet Reynolds number is likely to decrease with increasing Mach number, each tunnel will have different strengths and weaknesses, and much depends on our success in building them.”

Schneider's primary area of expertise is high-speed laminar-turbulent instability and transition, focusing on hypersonic boundary-layer instability and transition, construction of quiet-flow wind tunnels, and instrumentation for study of high-speed flows. He has spent three decades planning, designing, constructing, and using quiet-flow facilities.

“We have experience building this, so we have a better idea of what's really needed than most anybody else could. So that makes it less risky, but it's still risky,” Schneider said. “If you can get the thing to work — and we did in 2006 with this one — you can make measurements nobody has ever been able to make before where you see big effects, really big effects, which nobody has ever been able to see before, and they really matter. That's the draw. You could do really cool stuff that really matters, that's really interesting, and nobody has been able to do it before.”

The Mach-8 quiet wind tunnel likely will be built near Maurice J. Zucrow Laboratories in the Aerospace District, a university-affiliated aerospace business hub where companies can collaborate on research and commerce. The process could take five years, Schneider said.

* *The USAF Public Affairs clearance number is 88ABW-2019-3532.*



LEFT / David Spencer, associate professor in AAE, is co-chair of the Cislunar Initiative, along with Kathleen Howell, Hsu Lo Distinguished Professor of Aeronautics and Astronautics. **RIGHT** / The Cislunar Initiative board and members of the AAE faculty. PHOTOS: DAVE MASON, IMAGE SOURCE PHOTOGRAPHIC

The Cislunar Initiative, announced on July 18, enables Purdue to take a leadership role in expanding access to cislunar space by supplying the building blocks for infrastructure; identifying and utilizing space resources; advancing the development of space policy; and providing critical educational opportunities.

“On July 18, 1969, after a journey over 200,000 miles from Earth, Apollo 11 crossed into the Moon’s gravitational sphere of influence, a perfect example of cislunar space. Fifty years later, on the same day, we are proud to launch the Purdue Engineering Initiative in Cislunar Space. From research and commercialization to talent development, our faculty, students and staff will contribute to critical dimensions to the next 50 years of small steps and giant leaps in space,” says Mung Chiang, the John A. Edwardson Dean of the College of Engineering.

Purdue, the “Cradle of Astronauts,” is internationally known for its strengths in propulsion, mission design, habitats in space and systems engineering. The initiative will unite and leverage these capabilities to increase access to the inner solar system.

“It’s time to expand our space infrastructure beyond Earth’s orbit to include the Moon,” says David Spencer, co-chair of the Cislunar Initiative and an associate professor of AAE. “Moving forward, we will need access to space resources in order to achieve our exploration objectives. The Cislunar Initiative is geared toward conceiving and enabling the systems needed to support long-term human and robotic operations in the cislunar environment.”

NASA’s Artemis program aims to return astronauts to the moon by 2024, leading to a projected sustained human presence on the lunar surface by 2028. The space industry already generates \$350 billion annually in revenue and is expected to reach \$3 trillion per year over the next 30 years. Space tourism, followed by suborbital point-to-point business travel, will also bring a new source of revenue.

“If we want to one day use orbits that would make going to Mars more convenient, for example, we’ll need to access the cislunar space and facilitate vehicle movement within the region with a reasonable amount of propellant. Purdue’s strength is in building that transportation system,” says Kathleen Howell, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics and a co-chair of the Cislunar Initiative.

As the orbital economy grows, there will be space traffic to manage and assets to defend. Creating human habitats on the Moon will also require robust methods of protecting people from extreme temperatures and radiation.

This calls for putting new policies and infrastructure in place to ensure that space is free from activities that may produce space debris, which could be catastrophic for both human and robotic systems in the cislunar environment. It also means creating more opportunities to fund and develop the technology needed for establishing a presence on the lunar surface.

The Purdue Cislunar team plans to address these challenges with five near-term objectives:

- An incubator program will spur development of collaborative research centers, small-satellite science and technology missions, and new cislunar infrastructure technologies.
- A consortium on cislunar space development for entrepreneurs, private industry and government agencies will host industry workshops and short courses related to cislunar development and space technologies.
- The CislunarHub platform will provide the global space community with simulation tools and online resources for space system design, analysis and modeling.
- A space policy fellows program will bring together the nation’s leaders in space policy development for seminars, short courses and summer fellowships.
- A cislunar education program will feature K-12 education on space exploration and an online certificate program for students and professionals through Purdue University Online.

“A key part of access is to provide the propulsion devices to take us from Earth to low-Earth orbit to the Moon and beyond. Our capabilities at the Zucrow Laboratories allow us to test rocket engines at highly representative conditions toward these space missions. We can test at high pressures, thousands of PSIs. We can test with real propellants at flow rates that are representative of real conditions.”

TIMOTHÉE POURPOINT
Lead, Cislunar Access

“Facets of policy and interoperability standards are so important for a vibrant cislunar ecosystem to utilize these technologies safely with many different countries playing a role, across many different kinds of systems, rockets, spacecraft, habitats, etc. Robust standards and policies that would allow things to work together, interoperate, is crucial.”

DANIEL DeLAURENTIS
Lead, Cislunar Space Policy



Monica and Ernest Gambaro with President Daniels. PHOTO: GERRY ROBINOS

GAMBAROS' TRANSFORMATIONAL GIFT ENDOWS, NAMES AAE'S GRADUATE PROGRAM

A transformational gift to Purdue University's School of Aeronautics and Astronautics was made by alumnus Ernest Gambaro and his wife Monica to endow and name the school's graduate program. The name — Gambaro Graduate Program of Aeronautics and Astronautics — was approved by Purdue's Board of Trustees on Dec. 7, 2018.

Gambaro (BSAE '60, MSAE '61) and his wife were honored Feb. 16, 2019, in Naples, Florida, for their deep commitment and strong support of AAE and for the huge impact their gift will enable.

"My adult life has been so influenced by what happened to me at Purdue that I wanted to devote as much as we can because I want that experience to be shared by other people," Gambaro says. "It struck me that it was an appropriate thing to do, and I wanted to channel it into the subject matter that I studied, aeronautics, because of the influence it had on me. I also recognized it's a very challenging area to be in. Even when I was going to school

there, the aeronautics school was regarded as the toughest school in the entire University. You didn't go there if you wanted to sleep. It requires a lot of intellect, and it requires a lot of work. Because of that, I think the alumni of the School of Aeronautics and Astronautics have a particular responsibility to keep this thing afloat."

Purdue has the only named aeronautics and astronautics graduate program among the top 10 ranked schools by U.S. News & World Report, and it is the only named aeronautics and astronautics graduate program among Big Ten institutions.

The endowment will allow the graduate program to improve the capability to attract top students by enhancing national visibility and providing financial resources.

"Purdue's School of Aeronautics and Astronautics is incredibly grateful to Ernest and Monica Gambaro for their gift," says Tom Shih, the J. William Uhrig and Anastasia Vournas Head and Professor of Aeronautics

and Astronautics. “This gift will propel our graduate program — already one of the nation’s and the world’s finest — to even higher levels of excellence. It will enable us to recruit highly deserving students and to further enhance the diversity of our program in all forms, including opportunities to work on disruptive and impactful research not yet recognized by the world and to further enhance the diversity of our program in all of its forms.”

Gambaro was born in 1938 in a three-room apartment in Niagara Falls, N.Y. Son of Ralph and Teresa, Italian immigrants who never spent a day in school, Gambaro experienced the devotion and work ethic daily of his parents to support the family during the hardships of the Great Depression. His parents’ work through struggle left an indelible mark. Gambaro says he learned at a young age, “If you don’t work, you don’t survive.”

That’s the approach he brought to Purdue in 1956, and it spurred him to many achievements during his time on campus. He was a member of Tau Beta Pi, an honor society for excellence in engineering, and Sigma Gamma Tau, an honor society for excellence in aeronautical and astronautical engineering. He was founder and first president of the Purdue chapter of Omicron Delta Kappa, a national society that recognizes student leadership.

When he graduated with a bachelor’s degree in 1960 and a master’s in 1961, he did so with honors. In 1961, he was named a Fulbright Scholar by the Institute for International Education and the United States government.

“If I can sum up my background and how it affected my career and my future, it’s that you were in charge of your own destiny, by and large, and there was no substitute for work,” Gambaro says. “The story of my life is availing yourself of the opportunities that were presented and, most importantly, working hard. Because I grew up in an environment where nothing was guaranteed.”

In 1962, Gambaro joined The Aerospace Corporation conceptual design group and oversaw creation and implementation of most Air Force experiments aboard the Gemini spacecraft. He also was part of the payload and mission design for the Manned Orbital Laboratory program for the Air Force. Later, he was assigned to the special projects group where he and a team crafted initial designs for the country’s premier orbital reconnaissance system.

While at The Aerospace Corporation, Gambaro enrolled at Loyola University in Los Angeles to become a lawyer and, in time, transferred to

**“THIS GIFT WILL PROPEL
OUR GRADUATE PROGRAM
— ALREADY ONE OF THE
NATION’S AND THE WORLD’S
FINEST — TO EVEN HIGHER
LEVELS OF EXCELLENCE.”**

TOM SHIH

J. William Uhrig and Anastasia Vournas Head
and Professor of Aeronautics and Astronautics

the company’s corporate law department. In 1980, he became the assistant general counsel of Computer Sciences Corporation (CSC), one of the nation’s leading telecommunications companies. In 1988, he and a partner formed Infonet Services Corporation, which became the largest provider of secure data network services to large and mid-size multinationals. Gambaro retired in 2000.

In 2016, he was honored by Purdue’s School of Aeronautics and Astronautics as an Outstanding Aerospace Engineer. That awards banquet was a special one for Gambaro, not necessarily because he was honored but because he made a special connection with AAE student Robert “Bo” Ilgenfritz.

Gambaro’s encouragement and inspirational story so moved Ilgenfritz that Ilgenfritz referred to Gambaro and incorporated his comments into his own senior speech to fellow members of Purdue’s swimming and diving team at the banquet the following night.

Gambaro says hearing about that moment was touching, and, in a sense, it kindled in him the idea for the transformational gift. “One thing I’ve always believed is that you have an obligation to pass the torch forward,” Gambaro says. “This is our way of trying to give back.”

Gambaro calls Purdue a great institution and credits the aero school for helping him build a foundation for what he’s achieved in life. And he expects the University and the school to continue to offer that transformational opportunity to more students.

“One of the reasons I’m so impressed with Purdue is that it has stayed true to its Indiana roots,” Gambaro says. “I think Purdue still is one of the few universities that I’ve had modern-day experience with, directly or indirectly, that has maintained an attitude where the University tries to impart a sense of purpose in the students — and gives them a foundation to build on.”



EVER 150 YEARS TRUE
THE CAMPAIGN FOR PURDUE UNIVERSITY

SCHOOL OF AERONAUTICS AND ASTRONAUTICS

In 2015, Purdue President Mitch Daniels announced *Ever True: The Campaign for Purdue University* and its goal of raising \$2.019 billion by 2019, the 150th anniversary year of Purdue’s founding and the 50th anniversary year of alumnus Neil Armstrong’s walk on the moon.

Guided by three priorities — Place Students First, Build on Our Strengths, and Champion Research and Innovation — the campaign soared past its goal, raising \$2.529 billion by June 30, 2019, and became the largest fundraising campaign in Purdue history.

In particular, *Ever True* inspired \$501.9 million in student support, tripling Purdue’s previous level of annual student support; \$468.6 million in faculty support, which includes 72 new faculty-related endowments; \$775.1 million for programs; and \$367.7 million for facilities, including the Honors College and Residences and the spectacular Wilmeth Active Learning Center at the heart of campus.

Within the College of Engineering, we have seen generous and loyal support. With a gift on the evening of June 12 from the deanship’s namesake, John A. Edwardson (BSIE ’71, HDR ’06), and his wife Fran, we became the first engineering college in any public university to raise more than \$1 billion in a single campaign. The College of Engineering raised 47% above its target of \$700 million. All of the individual schools surpassed their targets, and dollar goals for students, faculty, facilities, programs, and unrestricted support were exceeded.

Together, we have taken giant leaps in advancing Purdue as a national and global leader that continues to move the world forward. Your generosity has powered Purdue’s vision, drive, and can-do spirit to extend its proud land-grant mission; strengthen its reputation in teaching, in research, and in the transmission to society of the fruits of that research; invest in students and faculty; and foster the breathtaking contributions our graduates extend to all corners of the globe.



PHOTO: GERRY ROBINS

**YOU ARE EVER TRUE,
AND WE ARE EVER GRATEFUL.**

For John Purdue, education was the flame that lit the world — so wrote author Irena Scott, the great-great-grandniece of our University’s founder. On behalf of the School of Aeronautics and Astronautics, thank you for keeping that flame burning brightly.



RITA BAINES
Chief Development Officer



BETH KUWATA
Director of Development



NICOLE MORRIS
Director of Development
Operations and Donor Stewardship

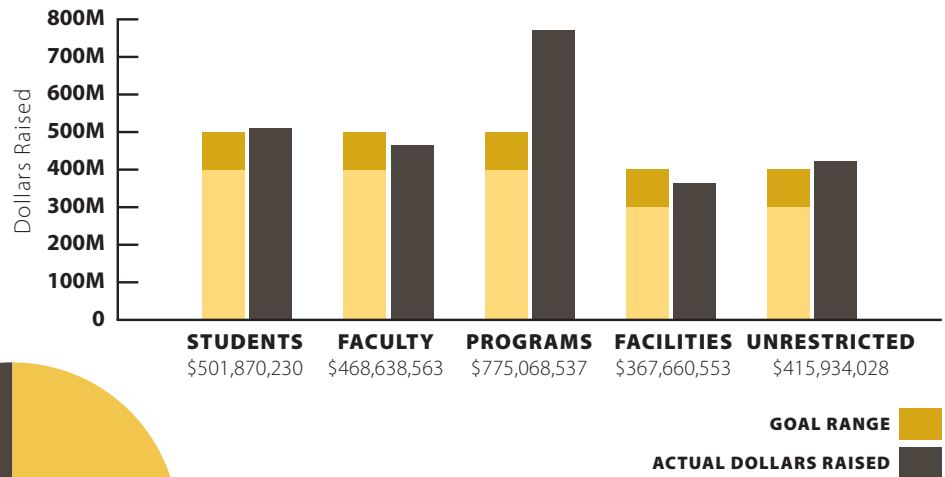
CAMPAIGN AT A GLANCE

- // **209,551** donors contributed to Purdue through *Ever True*.
- // Gifts made on Purdue Day of Giving accounted for **\$146.9 million** of the campaign total.
- // *Ever True* extended across the Purdue University system, including Purdue Northwest, Purdue Fort Wayne, Statewide Technology and Purdue Global.
- // Because of *Ever True*, **student support** (including scholarship funding) has tripled.
- // **94%** of *Ever True* gifts were under \$1,000.
- // Donors made gifts from **113** countries.

\$2.529B

GOAL: **\$2.019B**

GOALS VERSUS DOLLARS RAISED



FIRST-TIME DONORS

49.8%

of donors made their first-ever gift to Purdue through *Ever True*.

150 $\frac{1869}{2019}$ YEARS OF GIANT LEAPS™

From Fall 2018 through Fall 2019, Purdue University commemorated its 150th anniversary. Boilermakers of all stripes recognized the sesquicentennial year with a campus-wide celebration called 150 Years of Giant Leaps.

Here in the School of Aeronautics and Astronautics, there was another milestone to celebrate: the 50th anniversary of the Apollo 11 Lunar landing and AAE alum Neil Armstrong's first steps on the Moon.

Throughout the year, the campus was decked with 150th signs. People donned 150th gear and even tasted a 150th anniversary vintage wine. Multiple events, including the "Ideas Festival" series of speakers, noted the University's storied past and looked ahead to the ideas and challenges that Purdue faculty, students and alumni will be tackling in the future.

This gallery provides a glimpse of Purdue people and places during this sesquicentennial year.





- 1 /** Director David Fairhead and Executive Producer Mark Stewart wore appropriate socks for the debut of their “Armstrong” documentary on July 20.
- 2 /** Dennis Muilenburg, chairman, president and CEO of The Boeing Company, gave the William E. Boeing Distinguished Lecture in March 2019.
- 3 /** A 3D-printed replica of Neil Armstrong’s iconic Apollo 11 spacesuit popped up at a variety of locations during the lunar landing anniversary celebration.
- 4 /** AAE alumni Allison Bolinger and Marcos Flores were part of the “Past, Present, Future NASA Flight Director” panel discussion on July 20.
- 5 /** Chet Janes (middle) joined fellow Purdue alumni Ron Larsen (left) and Tim Harmon (not pictured) for “Industry’s Crucial Role in the Apollo 11 Mission” panel.
- 6 /** Artist Michael Oatman’s artwork was on display in the “Return to Entry” exhibit in the Robert L. Ringel Gallery, March through May 2019.
- 7 /** Lockheed Martin CEO Dana “Keoki” Jackson delivered the Charles Rolls and Henry Royce Memorial Lecture in September 2018.

PHOTOS: AAE, JOHN UNDERWOOD, REBECCA WILCOX



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150 YEARS OF GIANTLEAPS™

8 / Purdue's "All-American" Marching Band performed in 150th regalia. 9 / Astronaut Scott Kelly spoke to a sold-out crowd about the year he spent in space, in March. 10 / Purdue Libraries presented the exhibit "Apollo in the Archives: Selections From the Neil Armstrong Papers." 11 / Purdue alumnus Capt. "Sully" Sullenberger, the "Hero of the Hudson," gave a talk as part of the Giant Leaps Ideas Festival in February.



10



11



12



13



14

12 / Kids enjoyed the STEM activities during the 50th anniversary Apollo celebration. 13 / Popular scientist Bill Nye gave a lecture on campus as part of the Giant Leaps Ideas Festival, in November 2018. 14 / Visitors picked up commemorative stickers at the Apollo 11 celebrations.

PHOTOS: MARK SIMONS, JOHN UNDERWOOD, REBECCA WILCOX

DISTINGUISHED LECTURES 2018-19



Purdue Engineering Distinguished Lecture Series

Jacqueline Chen, distinguished member of technical staff at the Combustion Research Facility at Sandia National Laboratories. She spoke on "DNS of Turbulent Combustion in Complex Flows."



Midwest Distinguished Lecture in Aerospace Engineering

Vigor Yang, professor of aerospace engineering and industrial and systems engineering at Georgia Tech. His topic was "High-Fidelity Engineering Design Innovation for Aerospace Systems."



AAE Distinguished Lecture

Andrew Alleyne, Ralph and Catherine Fisher Professor, Director of Power Optimization of Electro-Thermal Systems, University of Illinois at Urbana-Champaign. His topic was "A Systems Approach to Management of Transient Thermal Systems for Mobile Electrification."

PURDUE DELIVERS ON INDUSTRY COLLABORATIONS

In 2015, his first year as a professor in Purdue's School of Aeronautics and Astronautics, Carson Slabaugh attended a kickoff meeting to coordinate a project selected for the University Turbine Systems Research Program, funded by the Department of Energy.

At the event, Slabaugh connected with AAE alumnus Scott Claflin, the director of an advanced concepts R&D group at Aerojet Rocketdyne. Claflin, who was at the event because his company had a Phase I project that was sponsored by the same group, casually asked Slabaugh about his areas of research. When Slabaugh shared them, Claflin said, "We have an immediate need for this kind of testing." Slabaugh wasn't quite sure his group could accomplish the task at that point, but said yes anyway.



CARSON SLABAUGH

"You're just hungry at that point, trying to get things off the ground," Slabaugh says of the opportunity, "so I took it."

Ultimately, Slabaugh and Stephen Heister, the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration, wrote a Phase II proposal with Aerojet Rocketdyne that became a \$1.2 million contract over two years. The partnership on the project concluded in May 2019, with great results, in literal testing and for future endeavors.

"It worked out beautifully," Slabaugh says of the partnership.

That's only one in a significant list of industry collaborations Slabaugh and other

AAE faculty are engaged in. From 2013 through 2017, AAE averaged \$1.2 million per year in industry research expenditures, according to AAE Professor Alina Alexeenko. She analyzed sponsored-research data for Purdue's College of Engineering as part of a project to scale up industry collaborations in the college.

Slabaugh has been one of the school leaders in industry expenditures since joining AAE's faculty. Nicole Key, a professor in mechanical engineering who holds a courtesy role in AAE, has been the College of Engineering's most fruitful professor in producing sponsored industry research from 2013 to 2017.

The benefits and importance of building such relationships is significant, Slabaugh and Key say.

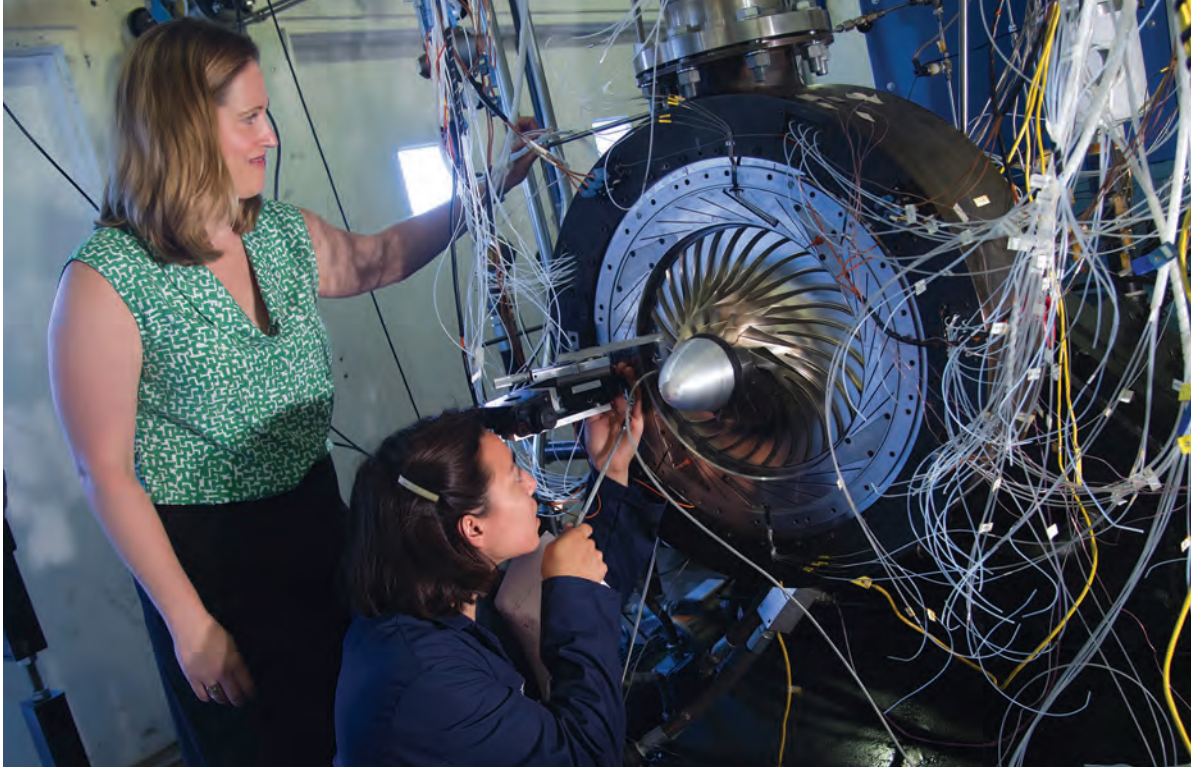
"It's important that the research we do at Purdue is relevant and can have impact," says Key, who received her bachelor's, master's and PhD from Purdue before joining ME faculty in 2007. "A lot of important problems come about from things that happen in the field that I would never know about had I not had a connection with industry. It's also important for our students not just to go through the motions of getting a degree but to understand the wider impact of these issues and to understand the industry and the market they will be working in."

Industry is very much about tracking progress and milestones, and if a milestone isn't met, there could be a risk of not getting follow-up work. But "when it's done well, it can be really fruitful," Slabaugh says.

"It's about being able to meet their need. Our colleagues in industry are working against profit margins, so it's precious money that they've earned. You must have something that's going to be valuable to them or it's not going to last very long," says Slabaugh, whose doctorate is from

TOP AAE INDUSTRY SPONSORS (2013-2017)*





Nicole Key (left), a professor in mechanical engineering who holds a courtesy role in AAE, has three compressors in her lab that were designed and funded by industry partners Rolls-Royce and Honeywell Aerospace. PHOTO: MARK SIMONS

Purdue. “It’s not just convincing them that you have a good idea. It’s even more important to deliver when they do fund your work.

“I get feedback from industry partners who say: ‘We come to Purdue because you guys deliver.’ That’s just what we do.”

Ideal collaborations are mutually beneficial. They allow industry to tap into advanced scientific fundamental understanding as well as faculty and students’ skill sets; Purdue faculty and students gain perspective on the industry experience and context for things they work on.

Both Slabaugh and Key have experienced those circumstances.

Key currently has three compressors in her lab that were designed and funded by industry partners: The single-stage centrifugal compressor (SSCC) is with Honeywell Aerospace. The centrifugal stage for aerodynamic research (CSTAR) compressor and the 3-stage axial compressor with small core technology blading are with Rolls-Royce. She’s had funding from Rolls-Royce since 2008.

Honeywell’s rigs group supports the Purdue team to ensure the most complicated rig in Key’s group is successful. Honeywell has introduced her group to equipment such as slip rings and tip clearance control systems, but her students also have introduced Honeywell to new data acquisition and data processing strategies.

“It’s not a one-way street where they give us money and we give them data,” she says. “It ends up being a neat back-and-forth exchange of ideas and understanding.”

Industry has downturns, certainly, and research can be cut when a company is trying to weather those storms. But, in Key’s experience,

many industry partners value the relationship with faculty and students and want to protect that and their reputation. So it’s a situation that is well-communicated and worked through.

One reason Slabaugh and Key know they’ve been able to attract industry partnerships — and expect to continue doing so — is due to the unique facility in which they work: Maurice J. Zucrow Laboratories. It is not only about Zucrow’s capabilities — the high-pressure propellant systems, flow capabilities, high-pressure combustion research and relevant test conditions (velocities and Mach numbers) — but it is the skill set of the people inside the buildings who can provide advanced measurements that industry simply can’t.

“When it comes to combustion, there are very few places in the world that they can go, at least as far as universities are concerned, to answer the questions that they have, and find people who are brave enough to attempt the things that they need us to do,” Slabaugh says.

When Key started at Purdue, she directed her experimental efforts at a higher technology readiness level. The facilities she runs aren’t exactly what one would find in a jet engine, but they’re close, and that’s enticing to industry partners.

“I made a conscious decision that even though this is hard to do, we’re going to do it and we’re going to do it well,” says Key, whose research interests include turbomachinery. “So any company that has a research or a technology development need on this kind of application, on high-speed compressors, Purdue is on the short list of places they could go to do that research. Zucrow and the facilities here have enabled us to do that kind of work. That’s been huge.”

SOLAR SAIL SUCCESS

For the first time, a spacecraft demonstrated solar sailing as a method of propulsion for CubeSats, increasing orbital energy by controlling the sail orientation relative to the sun.

David Spencer, AAE associate professor, was the project manager for LightSail 2, the historic citizen-funded project from The Planetary Society.

“Through demonstration of controlled solar sailing, LightSail 2 provides an important advancement toward the realization of solar sailing’s potential for space science applications,” Spencer says. He has been involved with the LightSail program since



DAVID SPENCER

2010 and was the mission manager for LightSail 1.

There are a handful of long-term, visionary applications of solar sailing.

A fleet of solar sail-propelled spacecraft could monitor the space between the sun and the Earth to provide Earth an early warning for solar storms. A solar science mission could attempt to get into a polar orbit around the sun. Also, solar photons could be harnessed to provide constant acceleration to reach extremely high velocities, allowing accessibility to the outer solar system and beyond.

“Solar sailing technology can enable missions to the extreme limits of our solar system with flight times of 25 years or less,” Spencer says.

LightSail 2 was part of the Air Force’s Space Test Program-2 (STP-2) payload launched on the SpaceX Falcon Heavy rocket on June 25.

LightSail 2 was enclosed within Prox-1, a spacecraft about the size of a mini-refrigerator that included a spring-loaded deployer. Spencer led the development of the Prox-1 spacecraft while at Georgia Institute of

Technology. Prox-1 detached from Falcon Heavy into an orbit with an altitude of 720 kilometers (about 450 miles) before deploying LightSail 2 one week after launch. Following a spacecraft checkout period, LightSail 2 deployed its solar panels and then unfurled four triangular solar sail segments, which combined to form a square sail geometry. Cameras mounted in the solar panels imaged the sail deployment event.

The solar sail rotated edge-on and face-on to the sun each orbit, giving the craft thrust to raise its orbit by about half-a-kilometer per day during the early portion of the mission. The result was to increase the orbital energy about Earth, stretching the initial near-circular orbit into an ellipse.

Atmosphere drag was expected to overcome the ability to increase orbital energy using solar pressure about one month after LightSail 2 was deployed. The craft likely will burn up in the atmosphere six months to one year after sail deployment.

Spencer led mission operations after launch, and his research team was responsible for tracking LightSail 2, receiving the signal from the spacecraft as well as commanding the spacecraft during operations from the Space Flight Projects Lab at the Purdue Technology Center. Justin Mansell, one of Spencer’s graduate students, worked on modeling and simulation of the mission, including the sail control algorithm, to compare that with actual flight data and evaluate the overall performance of the system.

Funding for the project has been through both the Planetary Society’s members and private donors.

“The LightSail program was citizen-funded and implemented by a team composed of small companies and universities,” Spencer says. “The program demonstrates a new way of conducting space exploration, without relying on government agencies for funding.”

RIGHT / This image was taken during the LightSail 2 sail deployment sequence on July 23, 2019. Baja California and Mexico are visible in the background. LightSail 2’s dual 185-degree fisheye camera lenses can each capture more than half of the sail. PHOTO: THE PLANETARY SOCIETY



NOVEL CONCEPT TO DEVELOP FERTILIZER

uses only air and water as raw materials

A group of Purdue researchers may help save Africans from famine — by using plasma.

Sergey Macheret, a professor in the School of Aeronautics and Astronautics, is part of a team of researchers who have designed a plasma device that produces nitrogen oxides from the air then dilutes them in water to make a liquid nitrate fertilizer.

That fertilizer could be an efficient, cost-effective way to address food security and plant nutrition in Sub-Saharan Africa, where corn is a major part of the diet. Currently, fertilizer is too expensive for African farmers. About 70% of the corn grown in Eastern and Southern Africa is grown without fertilizer.



SERGEY MACHERET

The Purdue researchers' novel concept would eliminate the need for massive centralized production of nitrate fertilizers and instead produce nitrates "on the spot" from air and irrigation or rain water. Unlike current fertilizer options, Macheret's process would not use added chemicals nor would it produce side products, such as carbon dioxide and carbon monoxide.

The key technology for the concept is based on low-temperature plasma (LTP). Because plasma is made using electric power, the fertilizer production could be powered by renewable energy sources, eliminating the need for commercial fertilizers and associated pollution.

"What if we use 'free' electricity, which is wind or solar? So, then, after an initial investment in the plasma facility, we would not have to spend anything running the system and making fertilizer," Macheret says. "What are the raw materials we use? Air and water and nothing else. So we use solar power, air and water. And what do we make? A fertilizer to grow plants. That is an overall vision."

The team — which includes Tony Vyn, a professor in agronomy, Andrei Khomenko, a postdoctoral researcher, as well as graduate students from AAE and a research associate in agronomy — tested the concept over the summer, using seed money from the Strengthening Interdisciplinary Collaborations Between the colleges of Agriculture and

Engineering competition. The team was limited in how much liquid nitrate fertilizer it could produce based on laboratory-size equipment, but it produced enough liquid fertilizer for the agronomy partners to test on plots of corn during growing season.

The test had three plots: one control plot without fertilizer, one using plasma-produced fertilizer and one using commercial fertilizer.

"The key results are encouraging," Macheret says. "We proved that the plasma fertilizer clearly acts as well as the commercial fertilizer if the same number of kilograms of nitrogen per hectare is applied. Whether you use the commercial fertilizer or the liquid plasma-produced fertilizer, the corn growth is the same. That's the key result."

The plasma-produced fertilizer helped corn plants achieve the same final plant height and ear weight as the conventional fertilizer did. Purdue's product also enabled corn leaves to maintain intermediate leaf chlorophyll contents, which improved potential photosynthesis in June and July, results consistently above the controlled plots. The field tests also showed that plasma-produced fertilizer was effective even though about half of it was applied after the flowering has occurred.

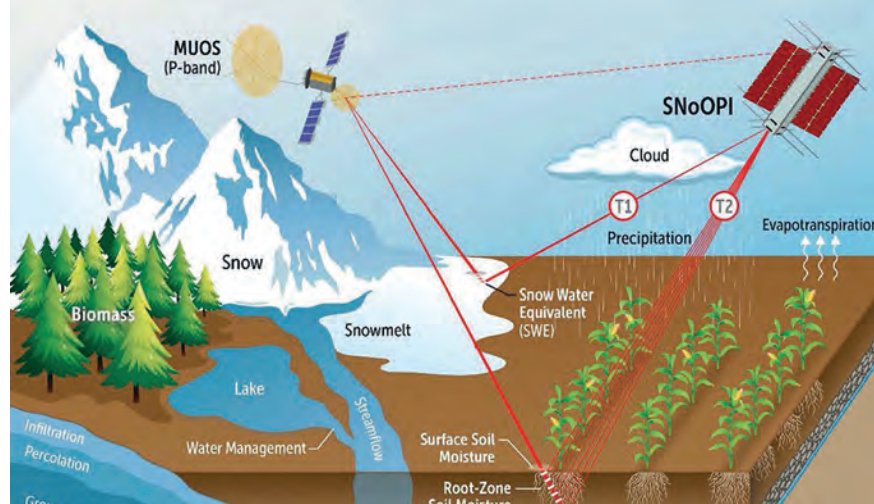
"There are some other interesting results that we're still trying to make sense of, but all of them are good. There is not a single bad result," Macheret says. "So that's an interesting proof of principle that, indeed, it works. This product can be used as a fertilizer, and it's definitely at least as good as — and in some respects maybe even better than — a commercial fertilizer. So, that is an important aspect of developing the concept."

Purdue's team still needs to improve the energy efficiency and to better organize the process. The team also would like to scale up the operation. Currently, it uses a kilowatt scale system, and farms would realistically be 2.5 acres or so. For that, Purdue would need a system with hundreds of kilowatts or a megawatt of power.

Even at the current process efficiency, the concept is promising.

"To supply all the nitrogen needs of a corn-growing farm in Kenya, for instance, we would only need to cover 1.5% of the area of this farm with solar panels. That is a very encouraging projection," Macheret says.

SNoOPI SELECTED TO FLY AS AUXILIARY PAYLOAD ABOARD FUTURE SPACE MISSION



SigNals of Opportunity P-Band Investigation (SNoOPI) is a scientific investigation mission to demonstrate the essential new techniques for globally mapping soil moisture and snow over various land surface conditions. IMAGE: AAE

A Purdue professor will test an instrument in orbit that could demonstrate a new technique for globally measuring soil and snow variables critical to water management and food production on Earth.

A small-satellite mission led by James Garrison, a professor in AAE, was one of only three projects selected for funding by NASA's Science Mission Directorate for the In-Space Validation of Earth Science Technologies (InVEST) program in support of the Earth Science Division.

In March 2019, Garrison's project, SigNals of Opportunity: P-band Investigation (SNoOPI), was also one of 16 selected by NASA's CubeSat Launch Initiative to fly as an auxiliary payload aboard space missions planned to launch in 2020, 2021 and 2022. NASA's Goddard Space Flight Center and Jet Propulsion Laboratory will build the satellite and prototype instrument under Garrison's lead. David Spencer, an associate professor in AAE, will lead the Science Operations Center to be established at Purdue. Purdue will receive a total of \$1.2 million in funding released by NASA for the agency's part of the project.

SNoOPI is a scientific investigation mission to demonstrate measurement of the complex reflection coefficient over various land surface conditions for use in future Earth observation constellations. These experiments are a necessary precursor to show the feasibility of measuring snow and soil moisture, globally, from orbit.

Water within the top meter of the soil, known as "root-zone soil moisture," is critical to forecasting food production and predicting floods and droughts. Similarly, knowledge of the net amount of water stored in snow, the "snow water equivalent," will improve water management for agriculture, hydroelectric power and the

drinking supply. Neither variable is directly measured accurately with current technology.

"In the general area of weather forecast, the water contained in the soil and snow is a big unknown, and improved data on these variables could greatly improve weather forecasting in general," Garrison says.

Use of long wavelength "P-band" electromagnetic waves that can penetrate through vegetation and into the soil is the key to making these measurements. Conventional methods of active or passive remote sensing using P-band have been studied for two decades but have generally been considered infeasible for use in space, due to large antennas required and susceptibility to interference from communication transmission within this band.

But Garrison's "Signals of Opportunity" (SoOp) in P-band is a new remote sensing technique with the capability of estimating both essential variables. The novelty is that it reuses signals from existing telecommunications satellites that would be a source of interference to other systems and observes changes in the signal strength and properties as it reflects from the land surface. This technique also does not require a transmitter, in contrast to radars, enabling its use on small platforms.

Garrison's research has advanced the P-band SoOp technique and prototype instrumentation through model development, airborne tests and field experiments. Further advancement of the technique requires in-space demonstration, which is the goal of the InVEST grant.

"It was selected to demonstrate that our method for using P-band 'signals of opportunity' for remote sensing of soil moisture and snow works from orbit," Garrison says. "We have identified some specific technical questions that can only be evaluated from orbit."

NASA PICKS PURDUE FOR NEW INSTITUTE TO RESEARCH SPACE HABITATS

In April, a Purdue-led proposal was one of two selected by NASA for a new Space Technology Research Institute to advance space habitat designs using resilient and autonomous systems.

Shirley Dyke, a professor of mechanical and civil engineering at Purdue, is the principal investigator for the Resilient ExtraTerrestrial Habitats Institute (RETHi), a multidisciplinary team in partnership with the University of Connecticut, Harvard University and the University of Texas at San Antonio. Karen Marais, an associate professor in AAE, will lead one “thrust” of Purdue’s proposal: smart design, growth and architecture for resilience.

RETHi seeks to design and operate resilient deep space habitats that can adapt, absorb and rapidly recover from expected and unexpected disruptions. The institute plans to create a cyber-physical prototype test bed of physical and virtual models to develop, deploy and validate different capabilities.

RETHi will receive as much as \$15 million over a five-year period from NASA’s Space Technology Mission Directorate.

Objectives for the “smart design, growth and architecture for resilience” piece of the institute, led by Marais, are to establish a new approach to resilience for autonomous habitat systems, develop the control-oriented dynamic computational

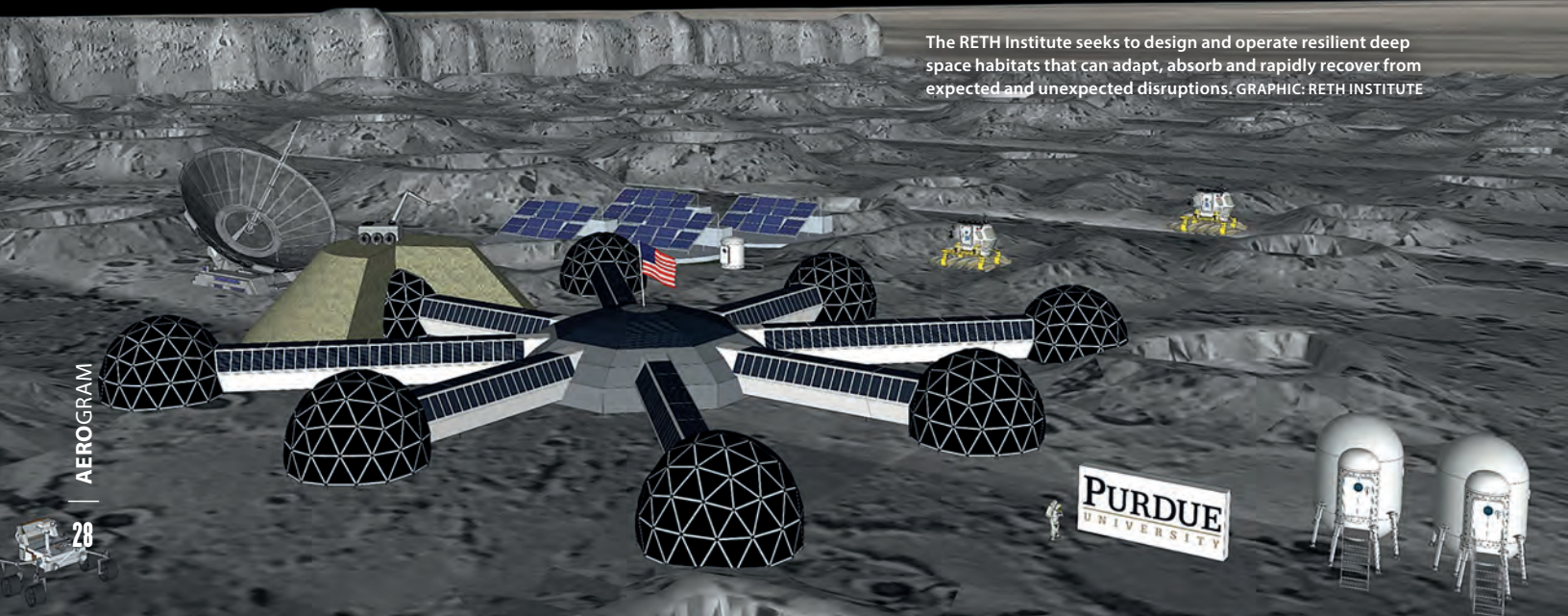
modeling platform, and validate and refine assumptions, interdependencies, models, system architectures and, more importantly, the resilience approach using cyber-physical testing.

Essentially, Marais will help assess and manage risk in a complex engineering system. That’s always difficult, she says, whether it’s an aircraft or a large chemical plant, but this project is especially challenging considering it is for deep space habitats.

“We’ve just made it orders of magnitude more difficult to do,” Marais says. “It is a cool problem to work on, but also one that’s essential. If we want to be able to colonize space, then we have to be able to figure out how to keep people safe, healthy and productive. We might have this habitat uninhabited for periods of time. We need to make sure that it keeps functioning. When people come in and they want to open the door and go back in again, they can turn the lights on. That’s essentially what I’m doing, trying to come up with ways of designing for resilience and managing risk in a complex system that is far away. We can’t just go to the local hardware store and buy spare parts.”



The RETH Institute seeks to design and operate resilient deep space habitats that can adapt, absorb and rapidly recover from expected and unexpected disruptions. GRAPHIC: RETH INSTITUTE





The science of PREDICTING SPACE COLLISIONS

AAE researcher employs machine learning techniques

More than 20,000 spacecraft larger than a meter in the geosynchronous orbit region and larger than about 10 centimeters in the low Earth orbit region are currently catalogued.

Another 100,000 smaller objects — down to the centimeter level — join them.

All of that makes for a considerable amount of traffic in space. That congestion presents a potential threat to space's infrastructure along with a crucial question: How does one prevent collisions, whether it's multimillion-dollar satellites colliding or random space debris smashing into smaller objects?

Carolyn Frueh, an assistant professor in AAE, worked with NASA's Goddard Space Flight Center to prevent such accidents by learning to predict collisions through reliable and fast computation.

Typically, "probability of collision" is computed. But there's no fast way of computing that exactly, Frueh says. There are simplifying assumptions that go into the computing, which makes it inaccurate. So Frueh and her team looked at alternative measures, such as information measures, to move away from probability of collision methods.

Frueh used machine learning algorithms to see if historic data on near approaches can be used to learn to predict new collisions.

"A lot of the research was actually what are good things to use for the machine learning, what are useful measures to learn from, basically. We tried to do that, not throw all the data in and see what comes out, but how can we infuse physics-based information that we know from the problem?" she says. "Satellites are not that agile

compared to drones or cars or anything. They cannot change direction that rapidly, so how can we get the physics that is dominating the problem compared to other problems where we use machine learning? How can we get that into it?"

NASA's Conjunction Assessment Risk Analysis (CARA) team is responsible for protecting NASA missions. CARA provides identification of close approaches, screens to determine the risk posed by a given event, and plans and executes any risk-mitigation strategies. The latter is where Frueh's collision prediction and avoidance comes into play.

Because orbits have uncertainties, and not every object in space is known, it can be difficult to predict potential collisions. But any kind of advance notice can be helpful, so Frueh's method potentially will provide details to make well-informed choices. If her information can offer an alert on timing (days in advance, for example), then an adjustment could be made to maneuver away from the debris. If her information can show that an object would pass by — and how closely it would pass — then one could opt to hold steady and not adjust.

"That's the information we'd like to provide. That's not what we're having at the moment," Frueh says of current methods. "At the moment, NASA says there's a 10^{-6} chance (a one-in-one million chance) we're going to collide in three days. That's a small chance, but when you have multimillion dollars up there, you're like, 'What are we going to do now?' You want to have as secure a knowledge as possible, as early as possible."

‘SELF-DRIVING’ PHARMACEUTICAL LYOPHILIZERS COULD ENABLE COST-EFFICIENT MANUFACTURING

Many pharmaceutical products would not be commercially viable without lyophilization, also called freeze-drying. But lyophilization is an expensive and time-consuming process in pharmaceutical manufacturing.

A group of Purdue researchers is hoping to change that by accelerating the transition to automated lyophilization and enabling “self-driving” pharmaceutical lyophilizers, which will enable more cost-efficient manufacturing. The proposed project was chosen in September 2018 by the National Science Foundation for a \$750,000 grant to develop real-time sensor technologies, computational modeling and bioanalytical tools for closed-loop lyophilization.

“We are very excited about this project being supported by the NSF Partnership for Innovation program, which helps transition research from the lab into the market for societal benefit,” says Alina Alexeenko, a professor in AAE, founding co-director of Purdue’s Advanced Lyophilization Technology Hub (LyoHub) and the principal investigator on the project.

Co-principal investigators include Timothy Peoples, managing director of the Purdue Foundry; Dimitrios Peroulis, the Reilly Professor of Electrical and Computer Engineering and the associate dean for

external affairs in the college; and Elizabeth Topp, founding co-director of LyoHub and professor of industrial and physical pharmacy. On this project, Purdue partnered with Millrock Technology, a third-generation manufacturer of freeze-drying equipment located in Kingston, New York.

AAE graduate students Gayathri Shivkumar and Andrew Strongrich have been heavily involved in the research; Shivkumar’s models and Strongrich’s sensor designs are being used in the project.

Lyophilization is a stabilizing process that is used to preserve the long-term safety, strength and quality of pharmaceutical products. It’s accomplished by using a sterile vacuum environment to remove water while maintaining chemical or biological function of products. The rarefied fluid dynamics and heat transfer conditions encountered at the low pressures used in lyophilizers are very similar to the high-altitude aerodynamics problems Alexeenko’s research group specializes in solving.

Current lyophilization methods don’t have real-time control and real-time measurements, Shivkumar says. All inputs are fixed at a constant value using open-loop control.

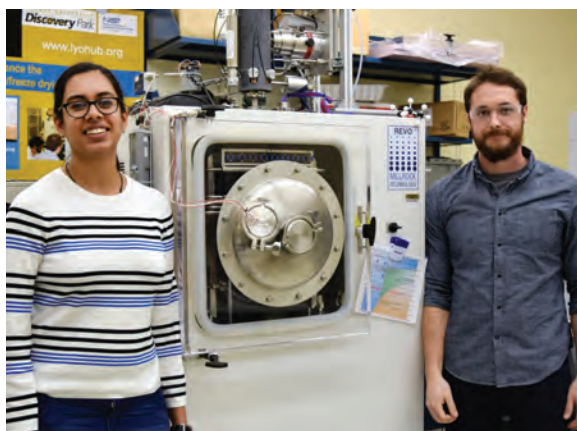
“That’s how it’s freezing. That’s how it’s drying. They have a set recipe that’s tried

and tested over time, but that's not necessarily the most optimal cycle," Shivkumar says. "So, if you're able to get real-time measurements, you can optimize it. Not just to the most optimal, single-point value, but maintain the conditions at their most optimal value based on real-time measurements. The heat transfer model we wrote shows how you'll be able to dry everything much faster — if you're able to constantly change the conditions, depending on what you're measuring."

Faster and more optimal drying could mean considerable time and cost savings.

A typical production lyophilization cycle usually takes a minimum of a few days to as long as two weeks. The process is lengthy because of overly conservative cycles due to lack of in-process product monitoring and closed-loop control.

Some technologies are moving toward closed-loop control of the lyophilization process, but it still is not widely applied, Strongrich says. But that's the idea behind Purdue's project, spurred by its sensors and modeling. By closing the loop, taking measurements of the product state during its drying, and feeding that back to a controller, it is, essentially, an autopilot system.



Graduate students Gayathri Shivkumar and Andrew Strongrich have been heavily involved in research that could enable "self-driving" pharmaceutical lyophilizers. Shivkumar's models and Strongrich's sensor designs are being used. PHOTO: AAE



Alina Alexeenko. PHOTO: REBECCA WILCOX

"Right now, we have a model that shows if we were to do closed-loop, then we would save a lot of time. But it hasn't actually been implemented yet. That's what this grant is for," Shivkumar says. "The biggest roadblock is getting that real-time measurement at every instant of time at each location and being able to integrate that all into one code to get the optimal single-point at each instant of time. That's where, once our sensors are working perfectly and they're able to beam out this information, we'll have to take all of that, consolidate into one code and control it using that code."

When freeze-drying, each formulation has its own "speed limit," Strongrich says. For this research, that speed limit is defined in terms of product temperature. Each formulation has a critical temperature it can't exceed or it will undergo what's referred to as collapse. The point of lyophilization is to freeze-dry the liquid product so it can remain viable for months or even years. If it collapses, that doesn't happen.

That's where the sensors come in. They're inserted among product vials to measure local pressure and temperature. This information can be used to directly compute what the sublimation rate is by using fundamental fluid mechanics.

"It can determine then how to adjust the dryer such that we're right on the brink of that collapse temperature but never exceeding it. Because the warmer we go, the faster we dry. That's what it comes down to," Strongrich says.

PURDUE, AAE PLAY KEY RESEARCH ROLE IN MURI GRANT FOCUSED ON ENERGETIC MATERIALS AND MACHINE LEARNING

In collaboration with six universities, Purdue received a Multidisciplinary University Research Initiative (MURI) award from the Department of Defense (DoD) in April 2019. The grant seeks to enable scientists to predict the behavior of energetic materials using advanced machine learning tools, which cover a wide range of applications including military munitions, propellants, pyrotechnics, and industrial explosives.

The University of Missouri is the principal investigator on the project, which includes researchers from Purdue, the University of Illinois, the University of Iowa, the University of Illinois at Chicago, Columbia University, and the Rensselaer Polytechnic Institute in New York.

The team will receive \$1.5 million per year for up to five years from the Air Force Office of Scientific Research. Only 24 research teams won MURI grants, which pursue basic research spanning multiple scientific disciplines.

AAE Professor Vikas Tomar says the project, called Integrating Multiscale Modeling and Experiments to Develop a Meso-Informed Predictive Capability for Explosives Safety and Performance, will address a long-standing problem that has never been addressed.

“So far, a significant focus of energetic materials research has been on material processing. However, microstructures for

such materials have random character, making them unsuitable for systematic microstructural characterization tools available for other materials such as metals or ceramics,” Tomar says. “This characteristic makes these materials also suitable for data science tools incorporating machine learning, a focus of the proposed work. Purdue’s Interfacial Multiphysics Lab has unique capabilities to perform high throughput experimental measurements of thermal and mechanical properties in energetic materials at nanometers to micrometers length scales with picosecond time resolution, a key requirement for models needed for the proposed work.”

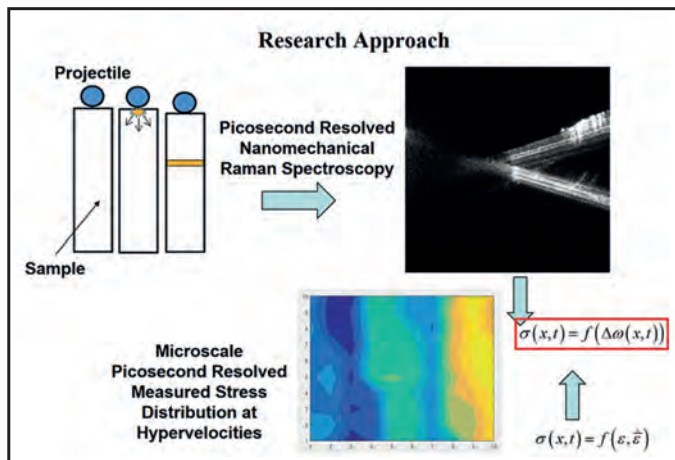
Tommy Sewell, a professor at Missouri who is the principal investigator on the project, says the team will use artificial intelligence or machine learning to sift through mountains of experimental and simulated data and to identify correlations in the data that scientists might miss. But he also says machine learning will take his team only so far.

“If all that you seek is knowledge, maybe that is good enough for some purposes, but it’s not good enough for us,” Sewell says. “What we seek is understanding, and that comes from ‘carbon-based’ computing (human thought and physical models), not silicon-based computing. A long-term goal is to minimize the amount of experimentation and the assorted costs and do most of the work in computer simulations, and then use experimentation to validate the results. If we’re successful, we will end up with a framework that can be adapted to treating the initiation phenomenon for a wide variety of explosives.”

Another goal is to reduce accidents involving energetic materials, Sewell says. If rocket propellant transitions from a stable burn over to a detonation, it can result in catastrophic consequences.

“What we are trying to do ... is to develop a theoretical framework that will allow us to derive the next generation of reactive burn models that are far more predictive than models currently in use,” Sewell says. “The goal is to reduce accidents, to improve safety and to design energetic formulations that would have a much more tightly tailored performance.”

AAE Professor Vikas Tomar and Purdue are part of a group chosen to receive a Multidisciplinary University Research Initiative (MURI) award from the Department of Defense. IMAGE: AAE





FUELING THE FUTURE OF SPACE EXPLORATION

New hybrid energy method uses graphene foams to increase burn rates of solid fuel

Graphene, a material with applications in biomedical technology, electronics, optics, composites, energy and sensors, soon may help send rockets to space.

A new propellant formulation method using graphene foams to power spacecraft is being developed in Purdue University's Maurice J. Zucrow Laboratories, the largest academic propulsion lab in the world. The research is showing success at increasing burn rate of solid propellants that are used to fuel rockets and spacecraft.

"Our propulsion and physics researchers came together to focus on a material that has not previously been used in rocket propulsion, and it is demonstrating strong results," says Li Qiao, associate professor in AAE.

The research team, led by Qiao, developed methods of making and using compositions with solid fuel loaded on highly conductive, highly porous graphene foams for enhanced burn rates for the loaded solid fuel. They wanted to maximize the catalytic effect of metal oxide additives commonly used in solid propellant to enhance decomposition.

The graphene foam structures are also thermally stable, even at high temperatures,

and can be reused. The developed compositions provide a significantly improved burn rate and reusability.

Qiao says the graphene foam works well for solid propellants because it is super lightweight and highly porous, which means it has many holes into which scientists can pour fuel to help ignite a rocket launch.

The graphene foam has a 3D, interconnected structure to allow a more efficient thermal transport pathway for heat to spread quickly and ignite the propellant.

"Our patented technology provides higher performance that is especially important when looking at areas such as hypersonics," Qiao says. "Our tests showed a burn rate enhancement of nine times the normal, using functionalized graphene foam structures."

Qiao says the Purdue graphene foam discovery has applications for energy conversion devices and missile defense systems, along with other areas where tailoring nanomaterials for specific outcomes may be useful.

Qiao and the team have worked with the Purdue Research Foundation Office of Technology Commercialization to patent their technologies. They are looking for partners to license them.

A new propellant formulation method to use porous graphene foams to power spacecraft is being developed at Purdue.
PHOTO: AAE

DRONE SEARCH AND RESCUE



AI research offers more eyes and ears for search and rescue missions

Rescue teams descended on the destruction left by Hurricane Michael in October 2018, frantically searching for survivors. But a week later, more than 1,000 people were still unaccounted for, leaving families to wait and hope.

Currently, drone surveillance in natural disaster response is inadequate and presents a number of hurdles. But new research led by Purdue University professors is using artificial intelligence and learning algorithms to create a platform that allows multiple drones to communicate and adapt as mission factors change.

Shaoshuai Mou, associate professor in AAE, and Daniel DeLaurentis, professor in AAE, are leading the research, which received three-year funding from Northrop Grumman Corp. as part of the Real Applications of Learning Machine consortium.

“For the system, we focused on a multi-agent network of vehicles, which are diverse

and can coordinate with each other,” Mou says. “Such local coordination will allow them to work as a cohesive whole to accomplish complicated missions such as search and rescue.

“There are challenges in this area. The environment may be dynamic, for example, with the weather changing. The drones have to be adaptive and must be capable of real-time environment perception and online autonomous decision-making.”

Distributed control, human-machine mixed autonomy, lifelong learning and artificial intelligence will be key enablers to the proposed research, Mou says.

In this research, AI and machine learning techniques will assist the system in many ways, such as in object recognition and human-machine communication as well as in improving the system performance over time. In particular, the system assisted by AI will allow for input from a human commander into the mission parameters and let the drones provide feedback and even suggestions in natural language.

“For complex situations, we still need to involve humans in the loop and try to do mixed autonomy consisting of machines and humans,” Mou says.

In the project’s mission scenarios, a ground-based powerful-processing vehicle will communicate with air, ground or aquatic drones that can cover a wide area.

“The utilization of heterogenous vehicles could be key to solving many complicated problems,” Mou says.

Mou and DeLaurentis are joined on the project by faculty from the University of Illinois at Chicago and the University of Massachusetts at Amherst.

A team of researchers, led by Purdue, with Northrop Grumman support, will use AI to create a way for land/air drones to communicate and adapt during search and rescue missions. IMAGE: AAE



DETECTING AND PREVENTING CATASTROPHIC FAILURES

Department of Defense-funded research could prevent catastrophic events in extreme environments

Could new technology from Purdue University researchers have helped save the Titanic?

Purdue engineers have developed technology to help prevent catastrophic failures involving nuclear, energetic and other materials in extreme environments.

“Our advancements in temperature measuring and stress sensing can potentially save lives and significantly reduce costs,” says Vikas Tomar, professor in AAE and research team leader. “Our Nanomechanical Raman Spectroscopy technology will allow for safer structures by enabling simultaneous time-dependent measurements of chemical, thermal, and mechanical changes in structures and materials undergoing mechanical loading in extreme environments.”

The Purdue analytical technology is unique in its approach to detecting changes in materials in environments with very high temperatures or in other potentially dangerous environments.

The Purdue approach focuses on detecting stress as a predictor of failure, rather than relying on damage detection to try to predict potentially catastrophic failures of these materials in sometimes extreme and dangerous situations.

The new technology uses advanced sensors, along with data science and machine learning elements, to detect and predict failures within the materials. Purdue’s technology could be used for nuclear materials, lithium-ion batteries, metals, and biological and energetic materials, all of which are used in situations with extreme temperatures and shock velocities.

“Current practices in damage tolerance are fine if damage is widely distributed,” Tomar says. “If the damage is localized and not widely distributed, such as the hairline crack in the Titanic, you must have technology like ours that uses stress sensing to predict if damage is going to be catastrophic. The situation is even more complicated for materials in extreme environments.”

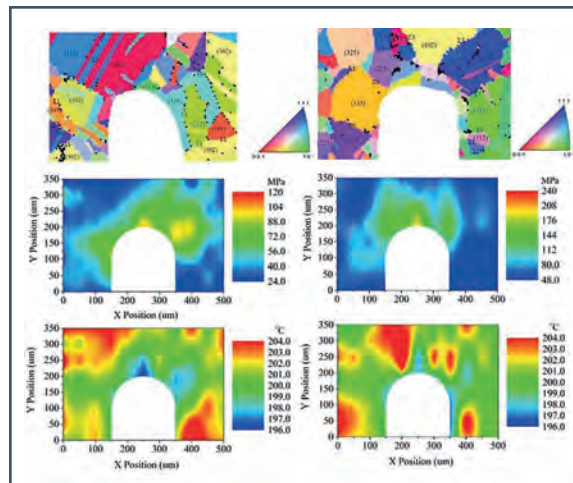
The work aligns with Purdue’s 150th anniversary and the Giant Leaps celebration,

acknowledging the University’s advancements in space exploration. Space exploration is one of the four themes of the yearlong celebration’s Ideas Festival, designed to showcase Purdue as an intellectual center solving real-world issues.

“Our technology changes the paradigm from damage-sensing to stress-sensing,” Tomar says. “Such a paradigm shift will enable safer structures, especially the ones that are operating in extreme environments. I see our technology as an enabler for opening up a new multibillion-dollar industry.”

The Department of Defense recently awarded the team a \$508,000 United States government competitive Defense University Research Instrumentation Program grant mechanism to make this technology more accessible to extreme environment measurements such as shock loading, nuclear irradiation and rechargeable battery explosions.

Tomar and his team worked with the Purdue Office of Technology Commercialization to patent the technology. They are looking for partners to continue developing their system and to license it.



NMRS measurements of stress and temperature fields in a superalloy. New Purdue University aerospace detection technology uses advanced sensors, along with data science and machine learning elements, to detect and predict failures within certain materials. IMAGE: AAE



PURDUE ENGINEERS TO PARTICIPATE IN NEWEST DEPARTMENT OF DEFENSE PROGRAM

A team of engineers from Purdue's School of Aeronautics and Astronautics will work as part of a new U.S. Department of Defense program intended to accelerate basic research innovations with defense relevance into the marketplace.

The team is led by Vikas Tomar, professor of AAE, and will collaborate with Mike Dodd, director of business development for the Indiana Innovation Institute (IN3), as part of the inaugural I-Corps @ DoD program.

The collaboration will develop business plans for new Purdue technology that uses advanced sensors, along with data science and machine learning elements, to detect and predict failures within certain materials.

"Current practices in damage tolerance are fine, if damage is widely distributed," Tomar says. "If the damage is localized and not widely distributed, such as a hairline crack, you must have technology like ours that uses stress sensing to predict if damage is going to be catastrophic. The situation is even more complicated for materials in extreme environments."

Tomar and graduate research assistant Ayotomi Olokun are leading the research for Purdue, with mentorship in the

program from Dodd, who also serves as the deputy lead for Governmental Advocacy with the Defense Entrepreneurs Forum. IN3 is an applied research institute that brings together top leaders from government, military, industry and research universities in collaboration with the Naval Surface Warfare Center, Crane Division (NSWC Crane).

"The I-Corps @ DoD program is an excellent vehicle for all university researchers to transition their work into the marketplace so that it can directly impact the warfighters mission and create job growth in Indiana," Dodd says.

The Purdue research focuses on detecting stress as a predictor of failure, rather than relying on damage detection to try to predict potentially catastrophic failures of these materials in sometimes extreme and dangerous situations.

The technology is being developed by Tomar in Purdue's Interfacial Multiphysics Lab and could be used for nuclear materials, lithium-ion batteries, metals and biological and energy materials, all of which are used in situations with extreme temperatures and shock velocities.

ABOVE / Graduate research assistant Ayotomi Olokun holds a piece of energetic material used in explosives and rocket propellant. Professor Vikas Tomar and Olokun's research using impact tests on such materials to observe their responses will be part of a new program through the U.S. Department of Defense. PHOTO: SHAYAN BAWANEY

HOWELL HONORED with Morrill Award

Kathleen Howell, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics, was accorded the highest honor that Purdue confers upon a member of its faculty.

Howell received the Morrill Award, intended for faculty at the rank of full professor who most strongly exemplify the spirit of the land-grant university. She was honored for demonstrating a synergy among all dimensions of her profession: teaching, research and engagement.

Each year, the Office of the Provost selects up to three Morrill Award recipients who receive a \$30,000 cash prize. Jay Akridge, provost and executive vice president for academic affairs and diversity, presented the award during a May 7 ceremony.

"I am extremely honored by the Morrill Award," Howell says. "I am also humbled to be joining such an illustrious group of colleagues as the past recipients. It is notable to me that we achieve success only with the support of others; I sincerely appreciate my mentors, collaborators and students along the way."

Howell has made pioneering contributions in celestial mechanics and astrodynamics, and her research has had



PHOTO: JOHN UNDERWOOD

a major impact on numerous past and ongoing NASA and international space flight missions in the Earth-Moon and Earth-Sun systems, including Artemis, Genesis, Triana and Cassini.

Her accomplishments have been widely recognized through many awards, including the Dirk Brouwer Award from the American Astronautical Society and Purdue's 2018 C.T. Sun Excellence in Research Award. She is a member of the International Academy of Astronautics, the National Academy of Engineering, and the American Academy of Arts and Sciences. She is a fellow of the AIAA and the American Astronautical Society.

AAE ADDS TO FACULTY

Joseph Jewell joined AAE faculty as an assistant professor in hypersonic aerodynamics, effective Fall 2019.

Jewell's research interests are primarily in experimental fluid dynamics, especially hypersonic aerothermodynamics. He will take over the existing Boeing/AFOSR Mach-6 Quiet Tunnel and will be involved with the development of the Large Mach-8 Quiet Ludwig Tube.

Prior to Purdue, Jewell was a research scientist in the Hypersonics Branch at the U.S. Air Force Research Laboratory on Wright-Patterson Air Force Base where he worked through Spectral Energies LLC. Previously, he held a National Research Council postdoctoral fellowship. He serves on the AIAA Aerodynamic Measurement Technology Technical Committee as well as on the NATO Working Group on Hypersonic Boundary Layer Transition Prediction.

Jewell earned a PhD in aeronautics from California Institute of Technology, after completing two master's degrees (aerospace engineering at the University of Michigan; hypersonics at the University of Oxford as a Rhodes Scholar) and receiving a bachelor's with a double major (aeronautics and medieval history) at Caltech.



JOSEPH JEWELL

MORE FACULTY HONORS



STEVEN COLLICOTT PROFESSOR

Patti Grace Smith STEM Award, Commercial Spaceflight Federation (For leadership as an educator committed to scientific excellence and expansion of knowledge for next generation of commercial space pioneers)



KAREN MARAIS ASSOCIATE PROFESSOR

American Institute of Aeronautics and Astronautics Associate Fellow



TIMOTHÉE POURPOINT

Promoted to full professor



SALLY BANE

Promoted to associate professor



KATHLEEN HOWELL PROFESSOR

Purdue Innovators Hall of Fame (Purdue Research Foundation Office of Technology Commercialization)



SHAOSHUAI MOU ASSISTANT PROFESSOR

Outstanding Faculty Mentor (AAE award to recognize outstanding work in mentoring graduate students)



WATERLOO TSUTSUI CONTINUING LECTURER

W.A. Gustafson Award (Outstanding teacher in AAE, selected by juniors and seniors in student body)



GREG BLAISDELL PROFESSOR

Purdue's Book of Teachers (Honors best Purdue educators, underscoring commitment to teaching excellence)



INSEOK HWANG PROFESSOR

C.T. Sun School of Aeronautics and Astronautics Excellence in Research Award (AAE award that recognizes high-quality contributions in science and engineering)

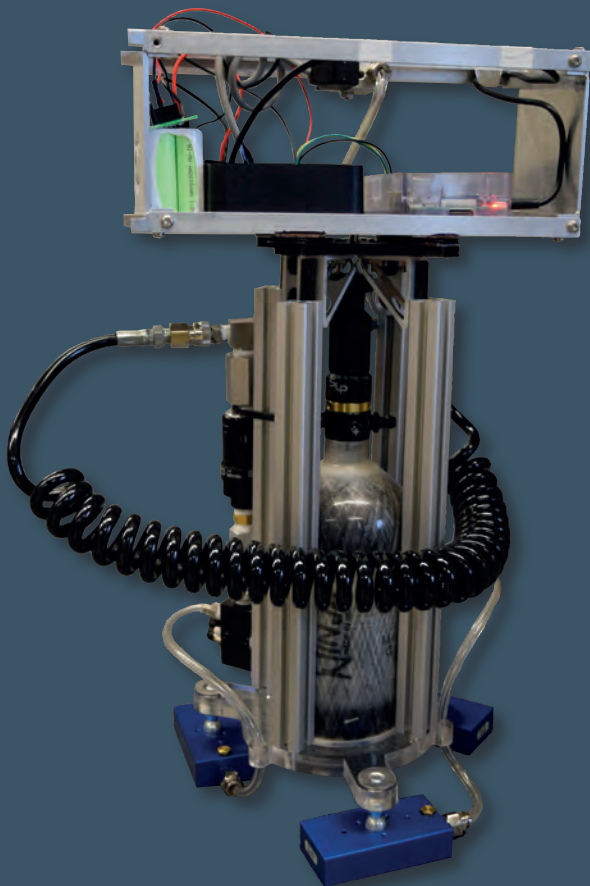


JONATHAN POGGIE ASSOCIATE PROFESSOR

Elmer F. Bruhn Award (Outstanding teacher in AAE, selected by undergraduate student body)

DESIGN BUILD TEST

TracSat project provides
undergraduates with
hands-on experience



One AAE course produced unique project-based learning opportunities for undergraduate students while also creating a testing bed that will aid the school in future small satellite projects.

With the help of an AAE alumnus, what started in Fall 2018 as an option in AAE 59000 Space Flight Projects was its own course offering the following spring. The AAE 59000 TracSat Design Project was taught by Alexey Shashurin, an assistant professor in AAE.

Alumnus Mike Dreessen (BSAAE '83), the executive director of Missile Defense and Space Systems Engineering at General Atomics Electromagnetic Systems (GA-EMS), wanted to establish a program for undergraduate students to get hands-on experience creating and testing small satellite systems and subsystems. That led to conversations with Tom Shih, and ultimately with Professor Shashurin. The latter discussion produced the TracSat program, an opportunity for students to work with every subsystem that exists in an aerospace vehicle.

The course proved to be a special experience for undergraduate students Benjamin James Davis, Leonardo Facchini, Pol Francesch, Joe Kezon, Adam Patel, Glynn Smith and Peter Waller. Graduate student mentors McClain Goggin and Aaron Pikus also were impressed.

“Some of the undergrads have had experience on some of these projects before, and some haven’t, so it’s a big learning experience, and that’s a good thing,” says Pikus, who completed his master’s work in May 2018. “That’s one thing I really think more students should do — these sorts of projects, with more real-world aspects.”

TracSat is a levitation base that provides a low-friction test bed for small satellites to do 2D maneuver testing and demonstration. A 2U CubeSat is uncoupled from the levitation base and houses all components for autonomous maneuvers.

In Fall 2018, students accomplished a set of goals: building a prototype, being able to translate on a low-friction surface and having something that can actuate, such as magnetically latching valves for propelling the platform. The spring semester was focused more on coding, Smith says, by getting into the controls, being able to move it a certain way and target tracking maneuvers across a table.



ABOVE / From left, Alexey Shashurin, AAE assistant professor; graduate student Aaron Pikus; student Peter Waller; alumnus Mike Dreessen; student Pol Francesch; student Adam Patel; student Glynn Smith; and graduate student McClain Goggin. Not pictured: students Benjamin James Davis, Leonardo Facchini and Joe Kezon.



AT LEFT / Alumnus Dreessen visits the AAE 59000 class to discuss TracSat, a program funded by General Atomics Electromagnetic Systems. Dreessen is the executive director of Missile Defense and Space Systems Engineering at GA-EMS. PHOTOS: AAE

But not just any “table.” The testing for TracSat is being done on a 6,500-pound, 4-by-8 foot, fine-polished granite slab inside the Structural Dynamics Lab in the Neil Armstrong Hall of Engineering. The table provides a large-area surface that uses air bearings to allow the satellite to float without friction over the surface.

“The whole idea with TracSat is to build a satellite that can be tested on the ground, and using the table, be able to control how it moves, much like it would in a space rendezvous mission,” Dreessen says. “While it can’t be moved up and down, the satellite can be moved to educate students on propulsion, guidance, navigation and control. While in a laboratory environment, students need to set up tests to tackle issues and start doing some remote sensing — all of the things you would do if the satellite was actually in space.”

The step beyond theoretical textbook learning is crucial, but the course offered another element that served students well: Dreessen’s involvement.

The program is funded by GA-EMS, and Dreessen was an active participant. He suggested developing the system and formulated the direction, Shashurin says. It was Dreessen’s idea to go for target acquisition maneuver for testing and demonstration of propulsion, sensors and control algorithms on the low-friction surface test bed.

“It’s always nice to have a project driven by industrial needs,” Shashurin says.

Dreessen was present on-site as often as possible. He made several trips to campus

during the fall and spring semesters to check on students’ progress.

“He is giving far more than we would ever hope for, and there’s no comparison for that in any project,” Smith says. “It’s awesome having GA-EMS and him.”

Dreessen enjoys the interactions perhaps as much as the students. When he was a student at Purdue, design, build, test courses didn’t exist. Dreessen understands the value of the hands-on experience and remains intent on pushing forward with TracSat.

“With over 35 years of experience, I want to challenge students by not giving them the answers, but instead by giving them more questions to ask,” Dreessen says. “I’ve learned there’s more than one way to do something, and my way may not be the best way. I want to make sure they’re thinking about all the things that could go wrong, what has been overlooked, what hasn’t been accounted for. If you build a multimillion-dollar missile that should fly for 40 minutes but is obliterated after flying for only 30 seconds, leaving you with nothing, what do you do? I want them to ask questions and think beyond the lab environment to tackle real-world issues.”

Dreessen is hoping Pikus, who joined GA-EMS in May 2018, will be the future connection with Purdue, though Dreessen certainly expects to be involved in some way.

FIRST INSTRUMENT FOR ORBITAL SPACECRAFT BUILT BY AAE STUDENTS LAUNCHED

On April 17, the S.S. Roger Chaffee, Northrop Grumman's renamed NG-11 Cygnus spacecraft, launched atop an Antares rocket to deliver supplies and scientific experiments to the International Space Station.

Part of the scientific payload on the resupply mission was built by students from Chaffee's alma mater, Purdue.

A team of undergraduate students in AAE developed an advanced pressure sensor to show the density of the atmosphere at reentry for a 3U CubeSat called the Student Aerothermal Spectrometer of Illinois and Indiana, known as SASSI2. SASSI2 was developed with students from the University of Illinois Urbana-Champaign through NASA's Undergraduate Spacecraft Instrument Program.

Purdue's sensor platform was built to take advantage of the natural reentry experienced by all CubeSats by measuring bulk-flow properties as well

as ambient conditions. Once combined with chemical species information from onboard spectrometers, the data could enable scientists and engineers to determine the chemical reaction rates needed to validate their models.

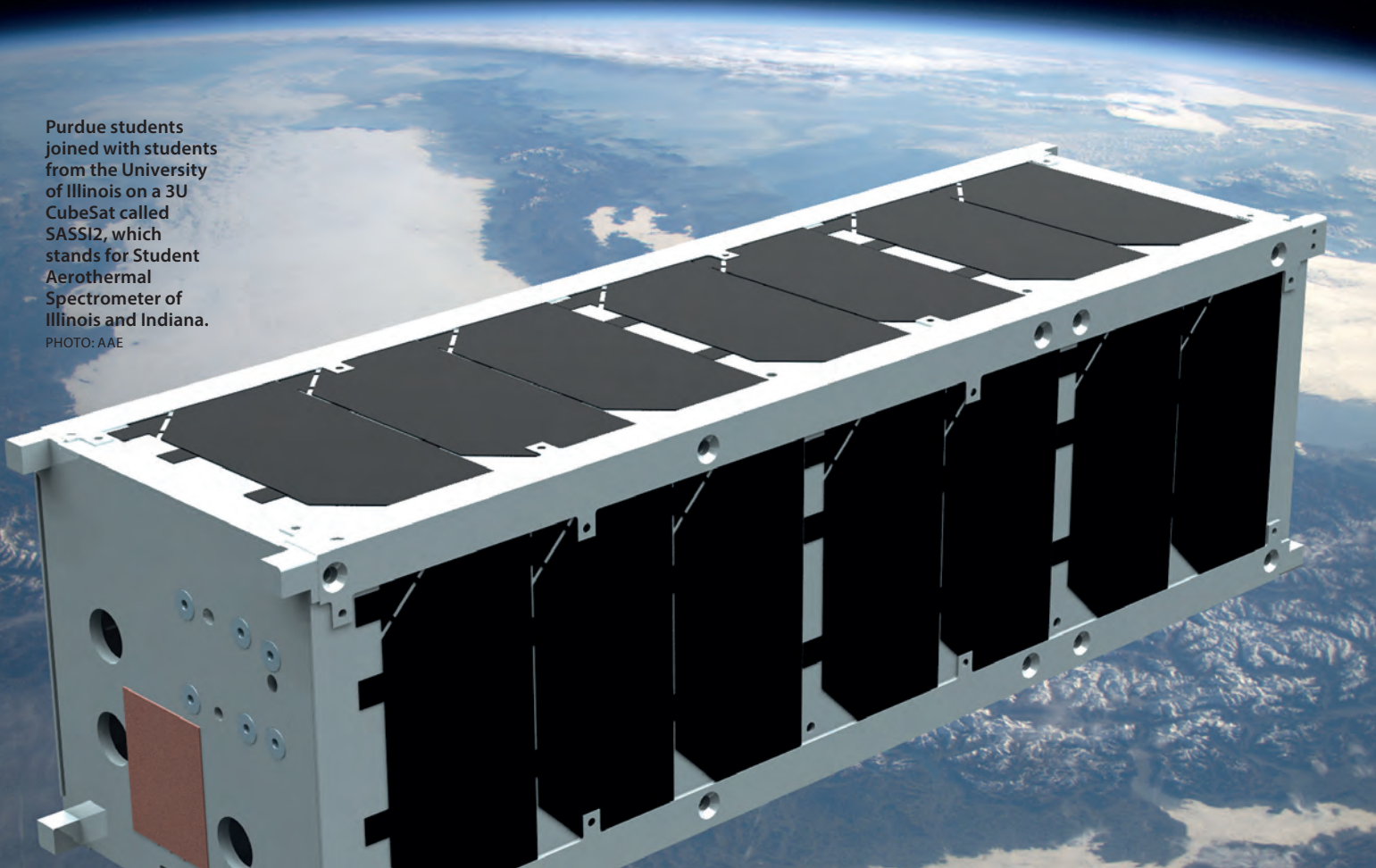
Alina Alexeenko, a professor in AAE, is the principal investigator for the Purdue science instruments. David Spencer, an associate professor in AAE, is co-investigator. Zach Putnam, an assistant professor at the University of Illinois, is the principal investigator for SASSI2, and Deborah Levin, professor at Illinois, is the co-principal investigator.

"For the Purdue team, it's especially meaningful that the S.S. Roger Chaffee will lift the SASSI2 instrument into space. It's the first instrument for an orbital spacecraft that was built by AAE students," Alexeenko says.

The SASSI2 project was implemented through a multi-semester AAE 45000/49000 CubeSat design, build and fly course that included more than 40 students, starting in Summer 2016 through Spring 2019.

Purdue students joined with students from the University of Illinois on a 3U CubeSat called SASSI2, which stands for Student Aerothermal Spectrometer of Illinois and Indiana.

PHOTO: AAE





More than 100 people attended the first Amelia Earhart Aerospace Summit. PHOTO: AAE

AMELIA EARHART AEROSPACE SUMMIT INSPIRES STUDENTS IN AEROSPACE ENGINEERING

The goal of the inaugural Amelia Earhart Aerospace Summit was to empower students within the aerospace engineering field. By most accounts, the daylong event in October 2018 overwhelmingly accomplished that.

Students from Purdue and visiting universities, as well as the Purdue professors and industry professionals who attended, say they left the event feeling heartened, inspired and armed with knowledge.

“The summit was nothing short of extraordinary in my eyes,” says Maisie Linker, one of the event organizers and president of Women in Aerospace, a student organization in AAE. “The reason I know it was successful is that I had so many people come up and thank me for the event.”

Four keynote speakers provided more than perspective on careers in academia, government and industry. They also delivered inspirational and encouraging messages to the 115 students who attended. A mentoring session and career success panel allowed students to network and interact with members of AAE’s Industry Advisory Council, alumni who are leaders in aerospace engineering fields. A poster competition presented an opportunity for students to get feedback on research. A graduate

school information session that included a six-member panel of current AAE graduate students offered insight into steps toward making a decision about grad school.

Anna-Maria Rivas McGowan (BSAAE ’92) and Tamaira Ross (BSAAE ’96, MSAAE ’98), whose keynote talks were some of the day’s most heavily attended, say it was important for them to be involved in the event because of its mission.

“I think this event is great,” says Ross, a configuration design engineer at Blue Origin. “Focusing on similarities rather than differences is important, but it is also important for women to have a cohort in which they can socialize and feel like they’re not alone.”

McGowan, NASA’s senior engineer for Complex Systems Design, charged students to embrace diversity in many ways, not just demographically but also in exploring diversity of opportunities available in the aerospace profession and in defining success in their own way. Her encouraging message was perfectly aligned with the summit’s goals.

“The students took some of the vision, the passion, the energy that Amelia Earhart had, brought it forward for the 21st century and tried to capture that to inspire students going forward,” McGowan says.

BURNING MAN

**Student project added flare
— via flamethrower —
to Burning Man event**

Burning Man is every bit a spectacle.

The weeklong event is hosted in the desert, within a pop-up “city” constructed by its visitors, with the purpose of cultivating a community of creative thinkers. Attendees celebrate artistic self-expression and provide experiences in “grand, awe-inspiring and joyful ways that lift the human spirit, address social problems and inspire a sense of culture, community and personal engagement.”

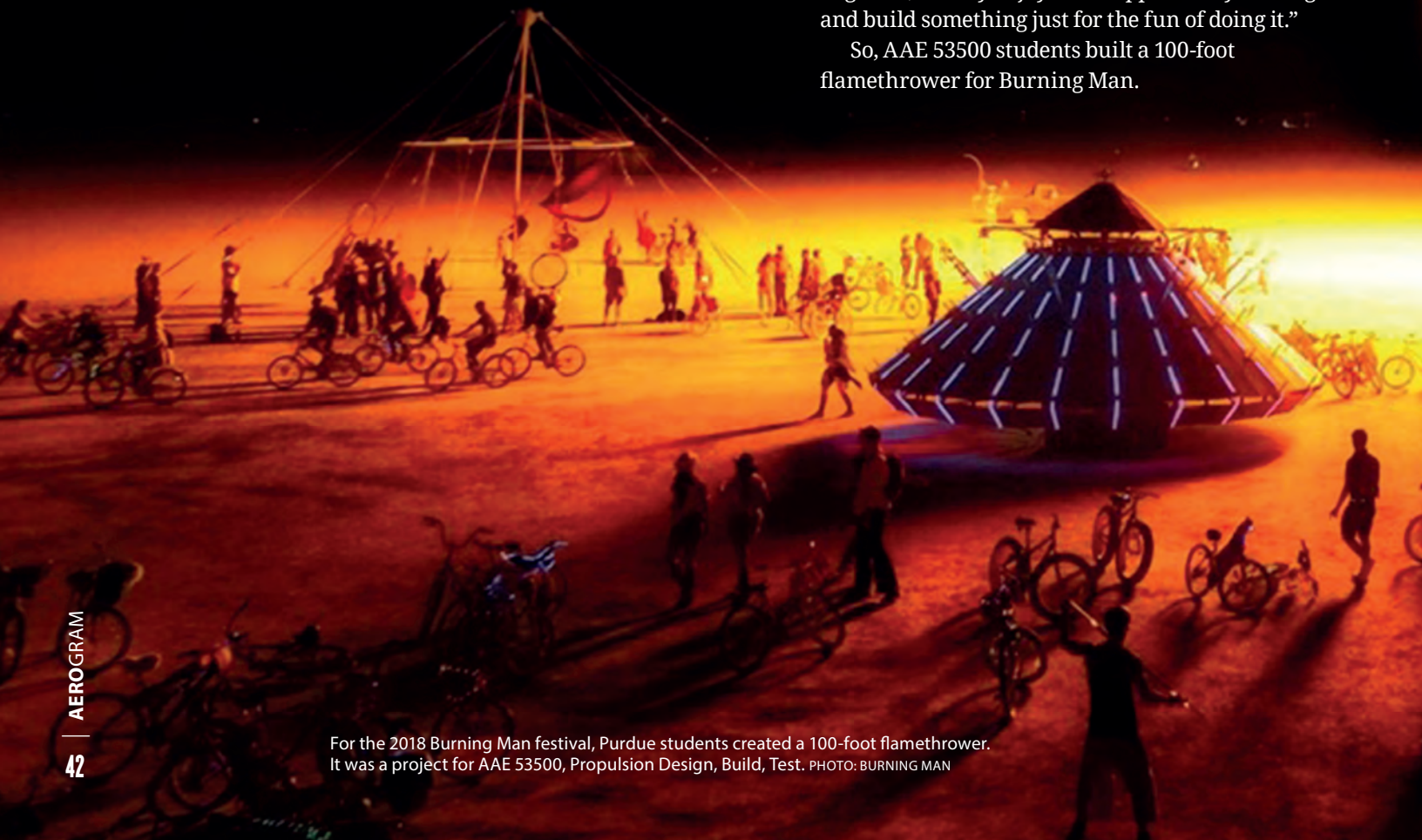
So a 100-foot flamethrower attached to a fire truck called “Heathen” certainly belonged. That’s exactly what a group of AAE students were tasked to provide for the August 2018 event.

The “Big Friendly Flame” was one project in AAE 53500, Propulsion Design, Build, Test, in Spring 2018 with the intent to develop, assemble, integrate and test a large, artistic flame device. The 10-member team delivered the project to Walter Productions, the company that sponsored the project, about a month before the event. Some team members attended Burning Man in Nevada’s Black Rock Desert midweek to help get the project integrated.

By the end of the week, it was center stage.

“I was interested in doing a Burning Man project because most of the work we do is very targeted, very focused on some specific research objective. We want to learn some specific thing,” says Carson Slabaugh, an assistant professor who taught the course for the first time in the spring. “As an engineer, I really enjoyed the opportunity to design and build something just for the fun of doing it.”

So, AAE 53500 students built a 100-foot flamethrower for Burning Man.



The directives for the 2018 project were general, in a way. “They wanted a really, really big flame,” Slabaugh says. But there were restrictions. For one, the team would not be allowed to use liquid fuel.

“Unfortunately, any fuel that is ejected but doesn’t burn comes back down, so you have to maintain a safety perimeter. That just isn’t possible at a festival

like Burning Man, where this flame effect is going to be mounted on a truck and driving through crowds of people,” Slabaugh says. “So we had to use propane, which is a gas at atmospheric conditions. That makes it really, really hard, actually, to get very large-scale flames like this. Liquid fuel flamethrowers can reach distances of 40-60 feet, but we were stuck with a gaseous fuel and needed to reach flame heights that are twice as large as known liquid systems. That was the technical challenge.”

Philip Piper, the team leader on the project and a graduate research assistant, says Maurice J. Zucrow Laboratories, the nation’s largest university propulsion lab,

was used to develop and build a prototype of the concept.

“Zucrow is amazing because they really have all the expertise, all the components, all the facilities that were needed,” he says.

Piper was joined on the project by project mentor Rohan Gejji, a postdoctoral research associate in Slabaugh’s research group, as well as AAE students Hasan Celebi, Blair Francis, Tristan Hagerman, Mark Hurt, Naveen Joel, Steven Pugia, Angel Rodriguez and Brandon Smail.

The completed system had three combustion devices: a pilot system that stayed lit at all times, a torch ignitor and an ejector. The team also built an “accumulator,” or a tanking system, to transfer liquid propane into it and eject the propane as liquid. It flashes to vapor quickly. Using an accumulator system, as well as ejecting the liquid, allowed the team to bring the pressure to about 500 PSI. A typical propane tank has pressure about 100-150 PSI.

“We created a nitrogen pressurization system that let us not only eject the propane in a liquid phase but also push it up to much higher pressures,” Slabaugh says.

A liquid propane test with 480 PSI and 16.4 pounds of mass flow produced a 103-foot flame height — as well as a vortex ring and a massive, lingering smoke ring. In testing, Slabaugh says the flame reached nearly 130 feet. But at 100, there still is plenty of awe factor.

“That’s kind of a cool part: You see it, but you also feel it, you hear it,” Piper says. “It’s kind of a full experience.”



MARTIAN MAKERS

Purdue team led Mars simulation facility

The air may be breathable and the location is on planet Earth, but for two weeks a multidisciplinary team of Purdue students and alumni ate, slept, worked and lived like they were on Mars.

For the second consecutive year, a Purdue team went on a mission to the Mars Desert Research Station facility in Utah, conducting a number of experiments and living life as though stationed on the fourth planet from the sun.

Cesare Guariniello, crew geologist on last year's Boilers2Mars team, was team

commander in 2019 and is an aspiring astronaut. He said improving technical expertise and knowledge is only part of the preparation for traveling to the red planet.

"It is much more difficult to test oneself in the psychological and social aspects," says Guariniello, a 2016 AAE doctoral program alumnus and current research associate.



ABOVE / Cesare Guariniello (AAE), Ellen Czaplinski (EAPS) and Alexandra Dukes (AAE) stand at the edge of an area called "The Moon" during an extravehicular activity. PHOTO: AAE



Dukes, crew journalist on the Mars simulation and AAE master's student, takes a rest during the last extravehicular activity (EVA) of Crew 202 with the MDRS habitat in the background. This EVA involved climbing up 500 feet to gather geological samples. PHOTO: AAE

“Participation at the Mars Desert Research Station gives the team a chance to get as close as possible to an actual mission in space, with a good amount of realism.”

The six-member team was selected by Purdue MARS, the Mars Activities and Research Society, to take part in the simulation mission. The team, called MartianMakers, took control of the research station the evening of Dec. 30 and passed it on to the next team on Jan. 12.

In addition to Guariniello, the team consisted of Alexandra Dukes, crew journalist and AAE master's student; Denys Bulikhov, executive officer and doctoral student in industrial engineering; Kasey Hilton, crew engineer and senior chemistry major; Ellen Czaplinski, crew geologist and 2016 Department of Earth, Atmospheric, and Planetary Sciences alumna; and Jake Qiu, health and safety officer and senior agricultural and biological engineering student.

Overall, the mission team represented five different areas in the colleges of Science and Engineering.

The simulation included a variety of aspects that combined to make the experience as real as possible. The team could not break simulation during the mission and donned a flight suit and a heavy air pack with helmet every time they performed extravehicular activities.

Guariniello says accurate protocols must be followed for radio communications, including a large number of daily reports during a two-hour communication window with the volunteers at the Mars Desert Research Station Mission Control Center. Highly structured daily schedules were used, and the team worked with extremely limited amounts of water, power and communication.

Guariniello says the team members had a number of experiments and research projects to work on during the two weeks. Among the tasks were analysis and mapping of radiation in the station area, monitoring crew reaction to stressful situations, the study of germs and contamination of plants/crew in the habitat, and analysis of waste produced in the habitat. Some of the work was computer-based, while other duties were executed directly at the habitat, such as bacteria collection and sequencing, and waste analysis.

Built near Hanksville, Utah, by the Mars Society in 2001, the desert research station includes a small two-story habitat, an astronomical observatory and a scientific laboratory and greenhouse. The Mars Desert Research Station is one of only a few Mars simulation environments in the world.



BASE 11 SPACE CHALLENGE OFFERS \$1 MILLION PRIZE

A team of Purdue students will attempt to build a rocket that can reach space — and win a \$1 million prize.

The Base 11 Space Challenge is presenting the task for a student-led university team to design, build and launch a liquid-propelled, single-stage rocket to an altitude of 100 kilometers by Dec. 30, 2021.

Purdue was approached to participate in the competition based on the reputation built by its Students for the Exploration and Development of Space (SEDS) chapter. The work that the Purdue Space Programs (PSP) Liquids team (part of SEDS) accomplished on its “Boomie Zoomie” rocket drew attention. PSP built the first liquid-liquid rocket designed entirely by Purdue students for a competition with a goal of reaching 45,000 feet.

But that feat is not quite like reaching the Karman line, the altitude at the edge of space, 328,000-plus feet away. That’s exactly what

Base 11 is spurring teams to do, using prizes over the course of a three-phase challenge to mark milestone achievements in the process, including design of the rocket, static testing of the engine and smaller pop-up innovation challenges.

Few doubt how ambitious the competition’s goal is: Only one student team is known to have built a rocket that has reached the Karman line. But that stiff task has only sharpened the resolve for the group of 63 Purdue students, as of summer 2019, who are involved in the estimated \$600,000 project.

“There’s tremendous enthusiasm for it,” says Scott Meyer, the managing director at the Maurice J. Zucrow Laboratories, which hosted one of three safety sessions in October 2018 for teams interested in participating in the competition.

“It’s extremely ambitious. Whether we hit the altitude goal or not, the opportunity to

ABOVE / Much of the Purdue team that will compete in the Base 11 Space Challenge is on the Purdue Space Liquids team, shown with the “Boomie Zoomie” rocket. PHOTO: AAE

get hands-on learning experience to test these high-pressure, high-flow systems is incredibly valuable,” says former SEDS president Chris Nilsen, now a design, build, test propulsion engineer at Purdue and the student interface on the project. “Boomie Zoomie really did help, at least with the sizing and understanding what needs to be done for this one. We may not have the highest-flying rocket; we’re going to have the best-performing engine, though.”

Stephen Heister, the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration, is the principal investigator on the project and is teaching a senior capstone design course in Fall 2019. The course will aim toward designing the Base 11 rocket, with industry mentors in each specific area of design — propulsion (engine, igniter), avionics, controls, and feed systems — to offer additional insight and guidance to students. The PSP group would be responsible for structures, recovery,

ground support and testing support.

Advisors on the project include Meyer; Li Qiao, associate professor in AAE; Scott Sudhoff, the Michael and Katherine Birck Professor of Electrical and Computer Engineering; James Goppert, visiting assistant professor in AAE; and Mark Grubelich, a distinguished member of the technical staff at Sandia National Labs.

“We think it is important for Purdue to support this competition due to our reputation in propulsion and the great learning opportunities it provides our students,” Heister says.

Base 11 is a nonprofit workforce and entrepreneur-development company with a mission to “dramatically increase STEM talent in the U.S. with greater representation and inclusion of women and minorities,” according to its website. Part of the competition includes an outreach component, and Purdue’s team anticipates collaborating with a high school on potential payload, among other things.

STUDENT TEAM WINS TECHNICAL PROJECT OF THE YEAR

Christopher Nilsen looked down and saw people sitting, legs crossed, on the floor. Saw others clogging the aisles. Others, standing outside the doorway, contorting bodies, doing their best to hear.

Nilsen couldn’t quite believe it. But he also kind of could.

The Purdue Space Program Liquids team, part of Purdue’s Students for the Exploration and Development of Space (SEDS), had generated considerable attention over the past year-plus with its work on a liquid oxygen-liquid methane rocket. Nilsen, the president of SEDS, says Purdue’s team is one of only five college teams in the world that has a functioning liquid rocket.

But Purdue’s rocket is the only one with dual cryogenics. And the only liquid-liquid rocket designed entirely by students. And, perhaps, the first one to actually complete a successful launch and flight, hopefully in March.

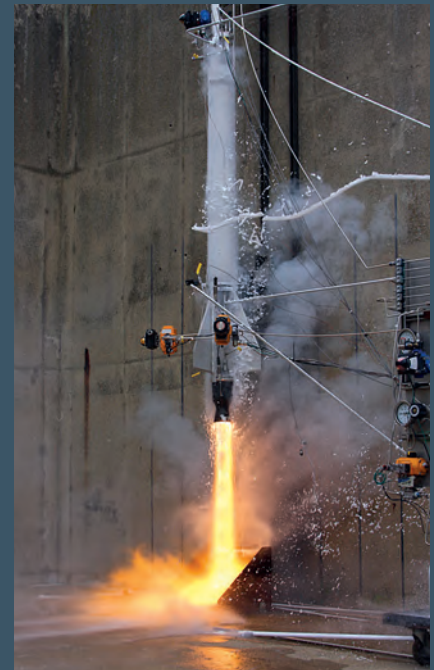
It’s *how* PSP Liquids has been able to design, build and test its “Boomie Zoomie” rocket that had so many people packed into a room in November at SpaceVision, the national SEDS conference. After giving a presentation on the rocket, Nilsen was approached

by a gentleman who praised the project as one of the most impressive he’d seen by a student group. The next day, Nilsen saw the man giving a keynote talk at the conference: He was Roger Simpson, the program manager for NASA’s Rocket Propulsion Test Program Office.

That same day, Nilsen and his PSP Liquids team were awarded the “Technical Project of the Year” by the national SEDS organization. The team consisted of 61% AAE students.

Considering the turnout for the presentation, Nilsen wasn’t exactly surprised by the award. But still, no less proud of the team’s accomplishment.

“It was very cool,” says Nilsen, a senior in multidisciplinary engineering who also gave a presentation on the project at AIAA’s Science and Technology Forum and Exposition in January 2019. “We had a following. People were actually asking us questions. They knew who we were before we got there. They knew the rocket before they got there. Students from Arizona State said, ‘We saw your rocket. Now, we’re building one, too, because it’s so cool.’ We’ve kind of spurred a little movement, I guess, that people want to do the same thing.”



The Purdue Space Program Liquids team, part of Purdue’s Students for the Exploration and Development of Space (SEDS), has generated considerable attention over the past year-plus with its work on a liquid oxygen-liquid methane rocket. PHOTO: AAE



'LAUNCHBOXES'

SEND K-12 SCHOOL EXPERIMENTS INTO SPACE

Standing less than a foot tall and weighing a few ounces, the rectangular box doesn't seem like much. But at Purdue's School of Aeronautics and Astronautics, there is hope that the "Launchbox" represents the first step for K-12 schools across the country that want to conduct zero-gravity experiments in space.

A few aluminum Launchboxes already were shipped out this summer, and more interest is expected as students return to school this fall, says Steven Collicott, AAE professor.

Collicott says the Launchboxes allow schools to focus on the experiments they want to send up on private suborbital rockets and also expose students and teachers to Purdue Engineering.

"Teachers should be thinking and working with students about what's going inside the box and the purpose of their experiment, not how to house it on the rocket," Collicott says. "We are enabling more schools to fly their own original experiments to space by providing this mundane, low-tech tool for teachers."

In December 2018, Collicott and his students finished a two-year project working with second-

graders from Cumberland Elementary School in West Lafayette to send up an experiment aboard a Blue Origin rocket launch to determine whether fireflies could light up in space.

Compliments from Blue Origin officials about the box used for the firefly experiment led Collicott to look into possible production. His findings: Launchboxes were so inexpensive that they could be given away to interested schools and other organizations.

"We email the schools some computer files for 3D printing the plastic end caps," he says. "Then we ship them the preformed aluminum for the box plus the fasteners and instructions for assembly.

"It's a simple solution that stayed simple."

Once completed, the boxes are 8 inches by 4 inches and allow schools to work within the 1-pound payload limit. The boxes are strong enough to support a 15-pound weight, which is sufficient for the stresses of the launch to space.

The Blue Origin New Shepard rocket reaches space at a height of 60 miles in the air, much higher than any balloon or aircraft.

"That flight opportunity is now available to schools all over the world at roughly half the cost of high school football uniforms," Collicott says. "Any school district in the country that plays football can now afford space flight.

"Just like their athletic booster clubs, schools can finance these flights with a 'Rocket Booster Club,' he adds.

PURDUE SCHOOL LAUNCHBOX

- 8 inches by 4 inches
- 1-pound payload limit
- Strong enough to support a 15-pound weight





LEFT / “PETE,” the Purdue Engineering Tool for EVA, performed well in tests conducted by divers at NASA’s Neutral Buoyancy Lab, says David Liu, the team’s project manager (pictured). **RIGHT** / For the fifth time, a team from AAE’s Zero-Gravity Flight Experiment class was selected to test a tool they designed as part of the NASA Micro-g Neutral Buoyancy Experiment Design Team challenge. PHOTOS: NASA

TEAM TESTED TOOL AT NASA AS PART OF MICRO-g NEXt COMPETITION

A team of AAE students was selected by NASA for the 2019 Micro-g Neutral Buoyancy Experiment Design Teams (NEXt) challenge and tested a tool they designed and built at Purdue in the Neutral Buoyancy Lab in Houston.

It was the fifth year of the Micro-g NEXt competition, and a team proposal from the AAE 41800 Zero-Gravity Flight Experiment class has been selected every year.

The 2019 challenge asked undergraduate students to design, build and test a tool or device that addressed International Space Station spacewalking needs. There were three challenges to choose from: sharp-edge detection and removal/covering, EVA camera attachment mechanism, and mini-arm end-effector. The Purdue students chose the spacewalk camera attachment tool design challenge and built one device that mounted to three different types of hand rails that astronauts encounter outside the ISS during spacewalks.

“The students created a practical design that meets all of the requirements imposed by NASA, and it is also quite simple to actuate by a gloved hand to attach to the three different rails,” says Steven Collicott, professor in AAE.

“I am reminded each year how cool it is that our Purdue aerospace engineering students are taught by Professor David Wolf, who performed many successful spacewalks on the space shuttle, Mir and the International Space Station.”

In May, the student team visited NASA’s Neutral Buoyancy Lab, which has a 6.2-million-gallon pool to train astronauts for spacewalks, to test their tool with professional NBL divers. The students coached and directed the divers from the Test Conductor Room of the NBL facility.

Purdue’s tool was called “PETE,” which stands for Purdue Engineering Tool for EVA.

“The tool performed exceptionally well,” says AAE student David Liu, the leader on the project. “Despite some issues with tolerancing, we managed to clamp securely to two of the three surfaces. The divers were really happy with how our tool functioned and how easy it was to use. Giving ourselves the extra requirement of having to be used single-handed resulted in a tool that was not only objective-focused but also user-focused, which definitely lent itself to how much the divers liked it.”



TWENTIES AWARDS

TOMORROW'S LEADERS

Three AAE students — Aaron Blacker, Alexis Harroun and Adam Patel — were selected as Tomorrow's Leaders: The 20 Twenties by Aviation Week Network, in collaboration with the American Institute of Aeronautics and Astronautics (AIAA).

Blacker, Harroun and Patel were identified as top aerospace-bound students by an international field of highly qualified candidates. The final selection was based not only on academic performance but also on an ability to contribute to a broader community and to communicate the value of their research or design project.

The program brings together students, faculty and hiring managers to recognize what's needed for business and academic success. Students build a network composed of the technical experts who have built the industry; universities gain visibility for high-quality educational opportunities provided to students; and hiring managers gain knowledge about the best of the best in the next generation of aerospace talent.

"This year's 20 Twenties winners reflect the passion, ingenuity and remarkable talent found within the aerospace community," AIAA Executive Director Dan Dumbacher said in a news release.

AARON BLACKER is a second-year master's student working with AAE professor Bill Anderson to study lifted flames in a traverse-unstable rocket engine combustor. The goal of Blacker's thesis research is to develop nonvisual indicators of flame position in rocket engines that may ultimately enable design and performance improvements in orbit-class engines.



"I have read Aviation Week and Space Technology since high school, and the bios of each year's 20 Twenties have inspired me in my own quests to impact the future of aerospace," Blacker says. "I am truly honored and excited to be named one this year and to represent a legacy of Purdue

aerospace research in rocket propulsion and space exploration, more broadly. I would like to thank my family, friends and past professors for their endless support, as well as Dr. Anderson for nominating me for this award."

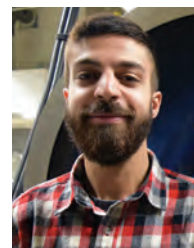
ALEXIS HARROUN is a second-year master's student working with Stephen Heister,



the Raisbeck Engineering Distinguished Professor in the School of Aeronautics and Astronautics. Her thesis research focuses on designing aerospoke nozzles to improve the performance of rocket rotating detonation engines, a promising alternative type of rocket propulsion technology.

"I am really excited and honored to be chosen for the Aviation Week's 20 Twenties award," Harroun says. "I would like to thank all the people who continue to support me, including my parents, all of my professors and my advising professor, Dr. Heister, for nominating me."

ADAM PATEL, a senior, is specializing in propulsion and aerodynamics. His focus



is on electric propulsion, specifically on developing a novel low-energy surface flashover igniter subsystem for pulsed plasma accelerators in the Applied Plasma Science Lab under Alexey Shashurin, assistant professor in AAE.

"I am beyond honored to receive this prestigious distinction," Patel says. "I would not be in this position without Professor Shashurin and Waterloo Tsutsui [AAE continuing lecturer], and I am incredibly grateful for their guidance."

This is the third consecutive year that AAE has had at least two students selected. Before this year's trio were Kate Fowee and Kim Rink in 2018, and Geoffrey Andrews, Julia Crowley Farenga and Emily Zimovan in 2017.

AAE students participate in CONGRESSIONAL VISITS DAY

Melanie Grande couldn't wait to tell fellow AAE students.

After attending Congressional Visits Day in 2018 in Washington, D.C., solely because she learned about it while on co-op at NASA Langley Research Center, Grande came back to Purdue in Fall 2019 on a mission.

"I'd never heard of Purdue students going, but I was like, 'We can go. Let's do it,'" Grande says.

She held an initial callout meeting and eventually raised funding for a 2019 trip. She figured she'd be fortunate to have 10 people show interest. There were nearly 40. So, Grande expanded her fundraising to AAE's student organizations. Ultimately, 20 students were selected and, for the first time, a large group of AAE students attended Congressional Visits Day on March 20, 2019.

Congressional Visits Day is organized by the American Institute of Aeronautics and Astronautics (AIAA), which has sent members to Washington every year since 1999 for a day of advocacy and awareness with national decision-makers. Students and professionals participate in meetings with state representatives and congressional staffers to discuss issues in the aerospace and defense industry. The AIAA outlined three key issues to present in Washington: funding stability and competitiveness, research and development and innovation, and workforce development and enhancement.

Purdue's group attended 71 meetings and spoke to representatives of 12 states. Of the 20 students who attended, 11 had a chance to speak with representatives from Indiana.

Graduate students Grande and Tracy El Khoury already were interested in policy before attending, but participating in Congressional Visits Day gave them a new perspective.

"It makes you want to do more because you realize you can make a difference. And you can see how much room for improvement there is," El Khoury says. "Really the point of this was, as an aerospace engineer, you can't just be an engineer locked in your office and not be aware

of the outside world. You have to be aware of what's happening. You can be a great engineer but with the wrong policy and the wrong timing, you just don't get anywhere."

Grande is on the AIAA's public policy committee, and she says the organization spends the year working on the three key issues and developing papers on smaller issues, so she's been ingrained in policy matters for some time. Congressional Visits Day only intensified her passion.

"You just realize how many people can make a difference. That really energizes me," she says. "On the other hand, when you go there and you start learning more about it and start thinking more about our political system, maybe you do get a little down and frustrated, a little disheartened. But being there to do something about it counteracts that."

The two-day trip was sponsored by AAE, AIAA and AIAA's Indiana Section — as well as by student organizations, including the AIAA Purdue chapter, AAE SAC, Aero Assist, Purdue SEDS, Sigma Gamma Tau and Women in Aerospace.

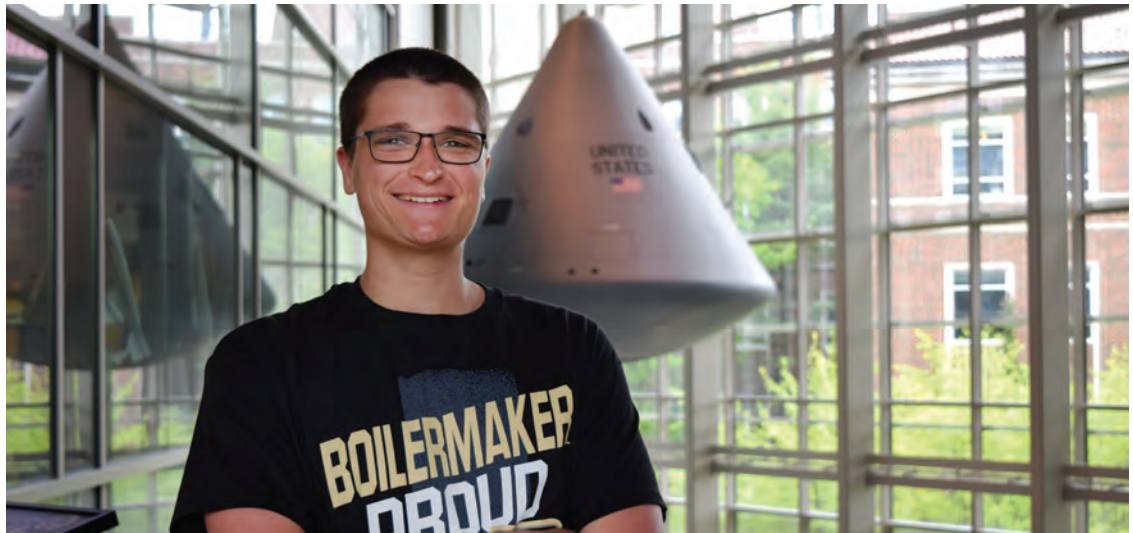


A group of students spent a full day meeting with staffers in Washington, D.C., for the AIAA's Congressional Visits Day.

PHOTO: AAE



AAE students selected for PRESTIGIOUS FELLOWSHIPS



Graduate student Jay Evans will work in the Department of Defense's Naval Air Warfare Center Weapons Division in China Lake, Calif., for the same number of years he's in the Science Mathematics and Research for Transformation (SMART) Scholarship-for-Service Program. He also will intern at that facility every summer, starting in 2020, until he graduates. PHOTO: AAE

Science Mathematics and Research for Transformation (SMART) SCHOLARSHIP-FOR-SERVICE PROGRAM

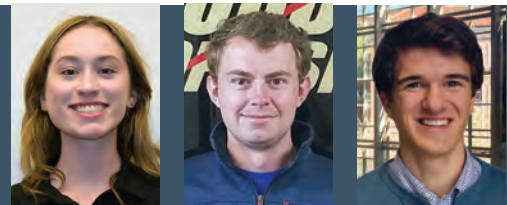
Graduate student Jay Evans was selected for the program, established as a concentrated effort to enhance the Department of Defense workforce with talented, innovative and brilliant scientists, engineers and researchers.

The SMART program funds the total cost of full-time tuition and provides a cash stipend ranging from \$25,000-\$38,000 (depending on degree being pursued), health insurance, book allowances and

summer internships that range from 8-12 weeks. The scholars also are guaranteed civilian employment with the DoD upon degree completion, the program's website says.

Evans' master's and doctoral research will be focused on detailing the complex, coupled combustion physics in solid-fueled ramjets (SFRJs) through experiment. He's a master's student under Carson Slabaugh, an assistant professor in AAE.

NATIONAL SCIENCE FOUNDATION Graduate Research Fellowship Program



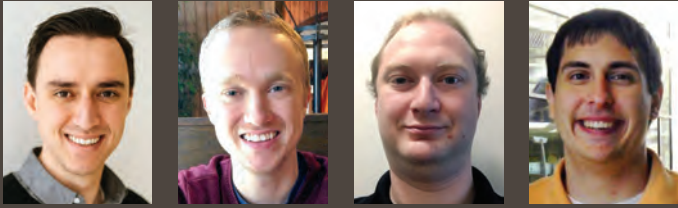
FROM LEFT / Sydney Dolan, Ethan Plaehn and Stephen Scheuerle

Sydney Dolan, Ethan Plaehn and Stephen Scheuerle were chosen for the NSF GRFP, which recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering and mathematics disciplines who are pursuing research-based master's and doctoral degrees at accredited United States institutions.

Each fellowship consists of three years of support during a five-year fellowship period. Currently, NSF provides a stipend of \$34,000 to the

fellow and a cost-of-education allowance of \$12,000 to the graduate degree-granting institution for each fellow who uses the support in a fellowship year.

Dolan earned her bachelor's degree from Purdue in December 2018 and will attend MIT for graduate school. Plaehn's main focus during graduate school at Purdue will be research and development of rotating detonation engines under Carson Slabaugh, an assistant professor in AAE. Scheuerle, a master's student under Kathleen Howell, is focusing on astrodynamics.



FROM LEFT / Nick LaFarge, Jeremy Marcum, Michael Orth and Jeffrey Pekosh

NASA SPACE TECHNOLOGY Research Fellowship

Graduate students Nick LaFarge, Jeremy Marcum, Michael Orth and Jeffrey Pekosh earned the esteemed honor of being named fellows.

NSTRF awards are made initially for one year and may be renewed, with satisfactory progress, for up to three additional years. Fellows receive a student stipend (\$36,000), faculty advisor allowance (\$11,000), visiting technologist experience allowance (\$10,000), health insurance allowance (\$2,500), and tuition and fees allowance (\$20,500).

NASA Space Technology fellows will perform innovative, space technology research at their respective campuses and at NASA centers and/or at nonprofit U.S. Research and Development (R&D) laboratories.

A master's student under AAE Professor Kathleen Howell, LaFarge is focused on applying modern advancements in machine learning toward automated spacecraft trajectory design in a multibody regime. Marcum's research is focused on better understanding storable propellant combustion behavior to improve the performance and reliability of hypergolic rocket engines, under Timothée Pourpoint. PhD student Orth's NSTRF fellowship proposal focused on engine design and propellant chemistry for a novel deep-throttling rocket engine under advisor Pourpoint. A PhD student under James Longuski, Pekosh focuses on missed-thrust for low-thrust spacecraft.

NATIONAL DEFENSE SCIENCE AND ENGINEERING Graduate Fellowship

Alexis Harroun and Utkarsh Pandey were selected to receive the fellowship, given by the Department of Defense.

NDSEG Fellowships last for a period of up to three years and cover full tuition and mandatory fees. Fellows also receive a monthly stipend of \$3,200 and up to \$1,200 a year in medical insurance. The NDSEG Fellowship is sponsored by the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research under the Office of the Assistant Secretary of Defense for Research and Engineering.



ALEXIS HARROUN

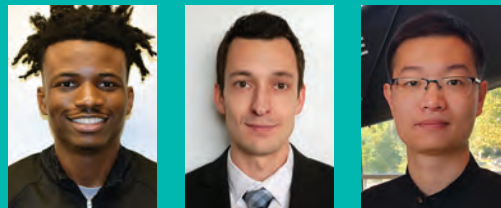


UTKARSH PANDEY

Harroun earned her master's degree from AAE in May 2019. Her proposed doctoral research is to investigate the use of condensed phase propellants for application on rocket rotating detonation engines. Stephen Heister, the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration, will remain her advisor.

Pandey, a first-year master's student working at Maurice J. Zucrow Labs under Timothée Pourpoint, is helping senior students with experiments on hypergolic propellants for rocket engines and solid-fuel ramjets for high-speed propulsion.

BILSLAND DISSERTATION Fellowship



FROM LEFT / Kolawole Ogunsina, Sylvain Renevey and Xuan Wang

PhD students Kolawole Ogunsina, Sylvain Renevey and Xuan Wang were selected to the program, which provides support for outstanding PhD candidates in their final year of doctoral degree completion. The goal of the fellowship, awarded by the Dean of Purdue's Graduate School, is to allow exceptional candidates to focus exclusively on finishing their dissertation.

Each will receive a stipend for 2019-20 of \$20,000 (\$1,666.66 per month). The fellowship includes a graduate tuition scholarship, medical insurance supplement and coverage of most fees.

Ogunsina's primary research areas are in aerospace systems, under the advisement of Professors Daniel DeLaurentis and William Crossley. Renevey is a third-year PhD

student of David Spencer, an associate professor in AAE. Renevey's research is focused on spacecraft formation flying, specifically on the development of a control algorithm based on relative orbital elements and artificial potential functions. Wang's research topic is the distributed control of multi-agent network under Shaoshuai Mou, an assistant professor in AAE, in the area of Dynamics and Control.

MOSES GIFTS PENNANT THAT FLEW TO SPACE TO AAE

Beth Moses needed a rush order.

She didn't find out until days before she was going to fly on Virgin Galactic's VSS Unity that she'd be allowed to stow items for the trip to space. And she had to have Purdue memorabilia in the ballast case, so she emailed Tom Shih, the J. William Uhrig and Anastasia Vournas Head and Professor of Aeronautics and Astronautics.

But Moses couldn't tell Shih why she desperately wanted two Purdue items ASAP.

Few people knew in advance that Moses was scheduled to be on the flight crew for the company's second test flight, on Feb. 22. It meant she'd become the first woman to fly to space on a commercial vehicle. She wanted to make

the trip even more memorable by representing the university she credits with launching her aerospace engineering career, first at NASA and now at Virgin Galactic.

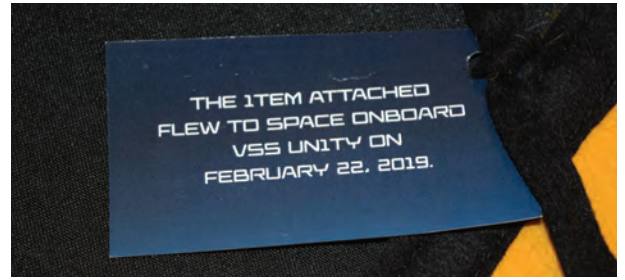
So she sent the rush request to Shih. A staff member from the School of Aeronautics and Astronautics was dispatched and located a pair of pennants — one gold, one black — at University Book Store and they were shipped overnight.

Just in time for Moses to pack them on SpaceShipTwo for the suborbital flight.

"Purdue has such a space heritage and is so much a part of what I am, it just felt like something I wanted to honor," Moses says. "I would not have been able to do that job and launch into my career if I didn't have the education that Purdue gave me. I don't think

I would have been on that ship if Purdue hadn't been in my background. So, it just seemed like I needed to honor that legacy."





LEFT / Beth Moses presented Tom Shih with a commemorative gift in April 2019: A pennant that flew to space with her on Virgin Galactic's VSS Unity in February.

ABOVE / A special tag marks the pennant. PHOTOS: AAE

But the idea wasn't simply to fly pennants to space and keep them: Moses always planned on giving them to Purdue.

Moses followed through on that intention on April 2, when she was back on campus to attend meetings with AAE's Industrial Advisory Council, a group she's belonged to since 2016. Just after a lunch break April 2, she gave a quick recap of the experience to the council and then presented the gold pennant to Shih. He'd told her to keep one for herself. So a black pennant will stay with Moses, who also wore her Purdue class ring on the flight.

The gold pennant will be displayed inside Neil Armstrong Hall of Engineering.

"We're so proud of Beth Moses' accomplishments and are grateful to her for sharing a piece of this exciting history with us," Shih says. "For this event to happen at the 50th anniversary of the Apollo 11 Moon Landing makes it even more special, since our alum, Neil Armstrong, is the first human to walk on the Moon, and Beth, also our alum, is the first female commercial astronaut. What a wonderful new entry to Purdue's Cradle of Astronauts to begin a new age of space travel and exploration."

The world learned that Moses (BSAAE '92, MSAAE '94) was on board only moments after the flight took off. It didn't take long for people to become enamored with her, especially once the photo was released of her reaction to seeing Earth — an open-mouthed moment of awe.

About two months after the historic flight, Moses still can't quite grasp the magnitude of the moment, the scope of its meaning.

Really, on the flight, she was just doing her job as Galactic's chief astronaut instructor,

performing a cabin flight test to train future commercial customers. She had sensors strapped to her body to measure heart rate, vibration, and acceleration, among other things, and had 11 cameras focused on her. She had a timeline to keep, evaluating specific engineering tests. She unstrapped from the seat and floated around the cabin to evaluate that experience as well.

That other aspect, though, the "first" part? That's proving a bit more elusive to grasp.

Moses never had any ambition to be the first female commercial astronaut — she would have been happy to be "second or third or 10th or 5,000,000th" in space, she says. She wants everyone to have the opportunity to visit, and that's what Virgin Galactic is working toward for its customers.

But now that she is the first? That is only slowly dawning on her, though she doesn't plan on getting consumed by it. For now, she's trying to stay grounded in what she knows: It was a successful test and an exhilarating experience.

"It's the culmination of a personal lifelong ambition plus the start of something phenomenal for humanity," she says. "I feel both honored and humbled, and there's a whole new era and whole new bit of exciting work to come. That flight is sort of like an anointment of the commercial space industry, as well as the beginning of an exciting time."

There may be only one label Moses actually does care about.

Moses was enthralled with space as a kid, her bedroom covered in posters of the Space Shuttle. Nearby, her brother Chuck had posters of jets. Their mom jokes it was sibling rivalry — "Mine



LEFT / Moses receiving her Commercial Astronaut Wings from the FAA. **RIGHT** / Moses, Chief Astronaut Instructor, floats in the cabin of VSS Unity as Chief Pilot David Mackay and Co-Pilot Michael “Sooch” Masucci pilot the spaceship. PHOTOS: VIRGIN GALACTIC

MOSES GIFTS PENNANT

CONTINUED

goes way faster than yours,” Beth would tell him — but Beth offers a firm “no” to such motivation. Space always fascinated her.

It wasn’t until the first week of high school at Glenbrook North in the Chicago suburbs that she was able to identify her calling. She picked up a brochure in the science department that listed NASA astronauts. It showed their head shots and had short bios. At the bottom, there was a description of the astronaut corps, mentioning how there were pilots and researchers among the group and, also, aerospace engineers.

“As soon as I laid eyes on that phrase, I said, ‘Oh, that is what I want to be. I know that’s me,’” she says. “Of course, I always wanted to be an astronaut, who doesn’t? But I definitely wanted to engineer and fly spacecraft. I always was an aerospace engineer and hopeful astronaut.”

Then she set a goal of attending Purdue and then working for NASA. Purdue certainly aided in the latter. During undergrad and graduate school at Purdue, Moses had nine co-op rotations at NASA’s Johnson Space Center in Houston. When she finished her master’s degree in AAE in 1994, NASA snapped her up.

Counting her co-op time, she was in NASA for 24 years, including as extravehicular activity system manager for the International Space Station. She worked on the ISS from drawing board to assembly complete. Once the ISS was finished, Moses joined the private sector with

Virgin Galactic in 2013. Moses was named Outstanding Aeronautical Engineer by AAE in 2018.

At Galactic, she’ll continue to train professional staff to evaluate the cabin, just like she did on the recent flight. There will be more cabin tests for VSS Unity, but once all is verified and ready to go, she’ll start training Richard Branson and all the company’s customers. There are more than 600 ticketholders at this point.

Moses certainly will have a unique perspective to offer — and a shiny accoutrement on her flight suit when she does.

Galactic’s Feb. 22 flight climbed to a height of nearly 56 miles, which qualified Moses and the two pilots onboard for Commercial Astronaut Wings from the Federal Aviation Administration. She received those wings April 9 during a presentation at the Space Federation’s Space Symposium in Colorado Springs, Colorado.

The designation means Moses is Purdue’s 25th astronaut, 16 of whom are AAE graduates. She’s been invited to — and plans to attend — Purdue’s astronaut reunion in October.

“That come-to-the-reunion invite was like, ‘Oh my god, I’m part of this group.’ That was a real moment,” she says. “I realized, ‘I’m not only an astronaut, I’m a Purdue astronaut.’ That means a lot. Those were my heroes. Those were my colleagues at NASA. I learned from that chain of people.”

GERSTENMAIER RECEIVES HONORARY DOCTORATE

Notable alum's Purdue career comes full circle

At Purdue, William Gerstenmaier ran out of time.

In 1992, Gerstenmaier received a fellowship from NASA, his employer, to pursue a doctorate at Purdue. It was 15 years after earning his bachelor's degree in aeronautical and astronautical engineering from the University and more than 10 after receiving his master's from the University of Toledo. Gerstenmaier, admittedly, was rusty.

"A lot of skills had atrophied, and I didn't realize how much I didn't know. So it was a really humbling experience to come back to school," he says. "I had to pull out old textbooks and reteach myself."

With the provision that he'd be on leave from his NASA duties for only one year, Gerstenmaier packed all of the coursework into 1992-93. Then he learned he could stay another year while the agency was in the middle of the International Space Station redesign. So Gerstenmaier got in another year of light coursework and prepared for qualifiers.

But then it was time to return to NASA. And Gerstenmaier didn't have his PhD.

His major professor wanted him to write and publish papers, but instead, Gerstenmaier returned to a management job at Johnson Space Center in Houston. His time spent building software for the control center was very different from his research in dynamics and controls at Purdue. As a result, he never finished the dissertation and research.

"I don't regret it at all," he says. "I got retooled at Purdue. I got to learn what things were like. It really helped me when I went back to JSC because I could do things my employees couldn't even do in terms of some coding and algorithms. So it was excellent."

Gerstenmaier got everything out of the experience except the degree.

Purdue remedied that in May.

At the 2019 spring commencement ceremony, Gerstenmaier received an honorary doctorate presented by President Mitch Daniels for his accomplishments as one of NASA's most influential leaders and administrators. Gerstenmaier is the associate administrator for the Human Exploration and Operations Mission Directorate at NASA Headquarters, and he's been at the agency for more than 40 years.

Gerstenmaier started at NASA in 1977, performing aeronautical research at the Cleveland facility. He headed to JSC in 1980 and worked on the first 18 space shuttle flights as a propulsion flight controller. In 1988, he was asked to lead the Orbital Maneuvering Vehicle Operations Office. Then he moved to the Space Shuttle/Space Station Freedom Assembly Operations Office before serving as



At the spring 2019 commencement, William Gerstenmaier was presented an honorary doctorate by President Mitch Daniels for his accomplishments as one of NASA's most influential leaders and administrators. PHOTO: MARK SIMONS

Shuttle/Mir Program operations manager. In 1998, he was named manager of Space Shuttle Program Integration. In 2000, he was named deputy manager of the ISS Program. Two years later, he became manager. In 2005, he moved into his role as associate administrator for the Space Operations Directorate.

Gerstenmaier called the honorary degree a tremendous honor.

"I feel really privileged to be honored in this way," he says. "I think the business that I'm in, human spaceflight and spaceflight in general, is really hard and really complicated, and it's not really any one individual that makes it work. It's really a team. I have a tremendous team behind me that supports me every day in a variety of different ways. It's nice that I get recognized, but I also think of all the folks who have really helped along the way. Even back to Purdue, some of the professors I had. Some of the folks even back in junior high and high school, teachers I've had that have really shaped where I am today.

"So when I think about this, I'm honored that I'm recognized, but then I think about all the others who have helped me to get this recognition."

A LOOK BACK AT ENGINEERING SCIENCES: An analytical approach



Tom Brandon was a mechanical engineering student at Purdue in the late 1950s when he heard the University had added a new engineering program.

On a trip home to South Bend, Tom made sure to not only mention it to younger sister Nancy but also to offer a bit of a challenge.

“They’ve never had a girl graduate from it,” he said, prodding the sister who always loved math but was intrigued by engineering.

Tom’s urging wasn’t necessarily why Nancy chose that new program, Engineering Sciences — one she called “perfect” because it was a more analytical approach to engineering instead of hands-on — but proving a point didn’t hurt.

Nancy certainly did that.

She became the first female graduate of Engineering Sciences in 1961, just one year after it merged with the School of Aeronautical Engineering. The merger lasted until 1972, after which the school changed its name to the School of Aeronautics and Astronautics. Ultimately, Nancy Brandon Anderson retired as Director of Technical Operations for Hughes Space and Communications Group after 21 years with the company. She served on the AAE Industrial Advisory Council until her retirement. In 2007, she was selected as an Outstanding Aerospace Engineer, a distinction given to the most illustrious graduates of the school.

Anderson was only one of many accomplished alumni in Engineering Sciences.

Five graduates have been selected as Distinguished Engineering Alumni: Jack Daugherty in 1977, Robert Hostetler in 1982,

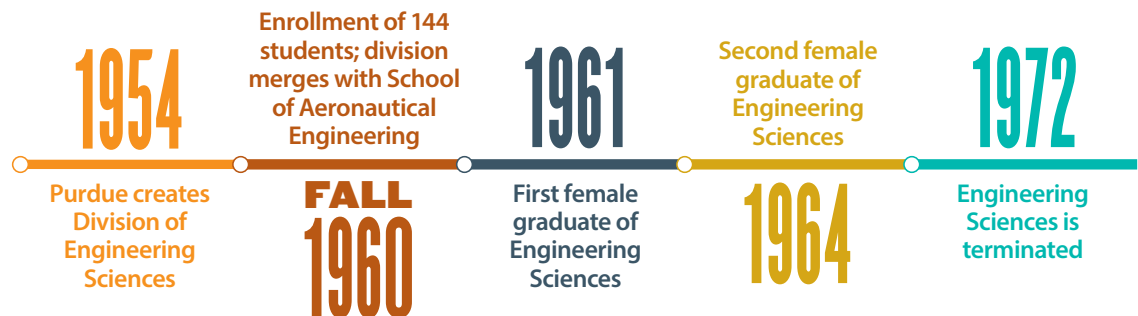
Ronald Kerber in 1988, Chris Whipple in 2004 and Janice Voss in 2012.

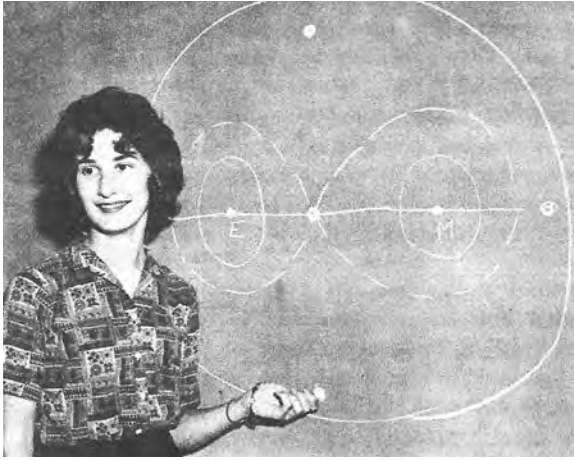
Ten have been named Outstanding Aerospace Engineers. Daugherty, Hostetler, Kerber, and Voss all were in the 1999 Class of OAEs. Steve Lamberson was selected as an OAE in 2002; Whipple in 2004; William Schmitendorf in 2005; and Jerry McElwee in 2006. Michael Hyer joined Anderson in the Class of 2007.

Engineering Sciences was aimed at providing students with a deep and broad grounding in both engineering skills and basic sciences. Graduates went on to wide-ranging professional careers, whether it be president and CEO of a manufacturer of electronic components and subsystems (Robert Hostetler); vice president of advanced systems and technology for McDonnell Douglas Corporation (Ronald Kerber); an astronaut who flew in space five times and traveled 18.8 million miles (Janice Voss); an innovator in theoretical and experimental research and development in plasma physics, high-voltage electron devices, gas discharge physics, lasers, and laser kinetics (Jack Daugherty); risk assessment and environmental analyses gauging risks associated with energy production, fuel emissions and radioactive wastes (Chris Whipple); or many others.

“It had the reputation on campus as being the hardest school, so maybe that was the attraction,” says Lolitia Beaty Bache, a 1964 graduate who started her career with the National Security Agency as an analyst, switched to programming, and retired in 2011 as a senior software engineer.

Regardless of vocation, the rigorous Engineering Sciences curriculum served its purpose.





Nancy Anderson, the first female graduate of Engineering Sciences. PHOTO: PURDUE UNIVERSITY ARCHIVES

“It prepared me very well,” Anderson says. “The reason I stayed to get a master’s is I was young when I started college, and when I graduated, I did not feel ready to face the big, bad world. So I went to summer school and started an extra year really specializing in what I wanted to do. I felt like conquering the world then, and I ended up in California in the aerospace industry.”

Engineering Sciences had 144 students enrolled in Fall 1960, the first academic year it merged with aero, compared to 193 in aeronautical engineering. The programs had separate heads until 1967, when Hsu Lo became the sole head over both programs.

A common curriculum was difficult to achieve because of the disparity in objectives of the two programs, and, ultimately, that’s what led to the termination of the engineering sciences program in 1972. Students who remained in the Engineering Sciences curriculum continued until graduation, and the difficulty of the coursework never lessened. Students needed at least 132 hours to graduate, depending on academic year.

Almost all of the classes were dual-level undergraduate-graduate classes, too, says Anderson, who received her master’s in 1962, one year after her bachelor’s.

“It was a killer,” Anderson says with a laugh. “It’s one of the reasons I was able to get my master’s degree so quickly, because I had enough other graduate classes. We were all very busy. It was tough. I had better than a B average, and I was in the lower half of my class. Does that give a clue of how competitive it was?”

The coursework didn’t only test Anderson, though — it also piqued her interests. Her major professor in graduate school was Lo, whose specialty was in orbit mechanics, and she was happy to take any courses related to space, she says. Ultimately, she spent the entirety of her career involved in satellites with The Aerospace Corporation, Rockwell International (now part of The Boeing Company) and Hughes (also now part of Boeing).

There were plenty of other courses that proved challenging.

Frank Siepker, a 1961 graduate, says he had eight semesters of math as an undergrad, including advanced courses that included master’s math students. In some semesters, he took 21 credit hours. He

remembers another with six three-hour courses and a two-hour lab. He had a couple courses in mechanical engineering, thermodynamics, electrical engineering, aerodynamics, an introduction to digital computers, and internal combustion engines, among others.

“It was very rigorous,” says Siepker, who opted for law school after receiving his bachelor’s and was an attorney for more than 40 years in Illinois. “The courses were difficult. The theory was complex. It was 90% theory, no hands-on application, except the lab we had. It developed those analytical thinking skills.”

Bache, who married a fellow Engineering Sciences student, initially came to Purdue with the intention of becoming a math teacher. She was in the same sorority as Anderson and switched from math to Engineering Sciences as a junior.

She worked hard in the program, appreciated the quality of teaching and especially liked the smallness of the major, which allowed her to get to know her classmates well.

“I got a really good education,” says Bache, one of only two women in the Engineering Sciences Class of 1964. “The diversity of the Engineering Sciences program served me well. Scientific programming, which I eventually did after I left the NSA, was very dependent on math. Part of my concept of ESE and my attraction to it was that it was essentially ‘applied math.’ It also allowed for a lot of flexibility in my working career.

“My Purdue experience prepared me well for later in life. I always worked in a field where there were way more men than women, and most of the time I was the only woman on the team. My experience at Purdue gave me confidence that I could hold my own in all those situations.”

Like Bache, Anderson says she never experienced discrimination by faculty and always felt “part of the group.” Anderson did notice, though, one advisory professor whose enthusiasm increased once she reached junior year, perhaps an indication that he knew she was around to stay, she says.

“It was an excellent time, good people, good classmates,” Anderson says.

DISTINGUISHED ENGINEERING ALUMNI

1977	Jack Daugherty
1982	Robert Hostetler
1988	Ronald Kerber
2004	Christopher Whipple
2012	Janice Voss

OUTSTANDING AEROSPACE ENGINEERS

1999	Jack Daugherty Robert Hostetler Ronald Kerber Janice Voss
2002	Steven Lamberson
2004	Christopher Whipple
2005	William Schmitendorf
2006	Jerry McElwee
2007	Nancy Anderson Michael Hyer

PURDUE HONORS PAIR OF AAE GRADS AS DISTINGUISHED ENGINEERING ALUMNI

Two AAE graduates were honored as Distinguished Engineering Alumni, an honor presented to men and women who have distinguished themselves in any field in ways that reflect favorably on Purdue University, the engineering profession, or society in general.

Timothy Cahill (BSAAE '86, MSAAE '88) and Kenneth Sanger (BSAAE '81, MSAAE '83) were recognized at a banquet in February.



Timothy Cahill

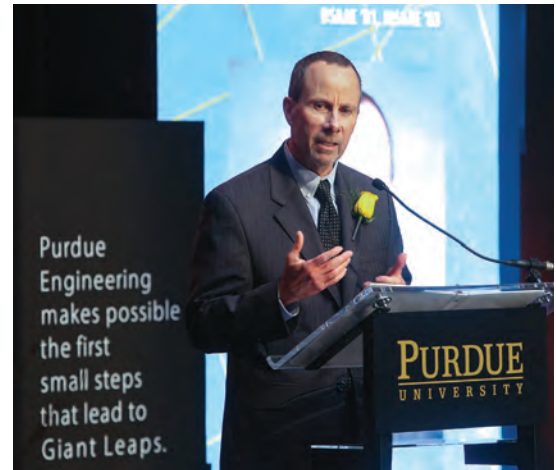
At Lockheed Martin since 1995, Cahill has used his Purdue education to excel in several positions with increasing responsibility. He began as an engineer in its Space Systems' Special Programs and today is vice president of Integrated Air and Missile Defense Systems for Lockheed Martin Missiles and Fire Control.

Cahill says his Purdue degree carried a lot of weight when he entered the working world decades ago — and still does.

"Purdue has a tremendous reputation in industry. When people know you are a Purdue Engineering graduate, they have high expectations and are willing to give you stretch assignments to prove yourself, even when you are junior in your career," he says.

Cahill still appreciates how Purdue taught him — pushed him — to think, rather than merely memorize.

"There was always discussion about why something was important, about its direct applicability in industry, and how each discipline balanced with the others," he says.



PHOTOS: COLLEGE OF ENGINEERING

Kenneth Sanger

Before Sanger's 2018 retirement from Boeing, he was responsible for the design, development, production and certification management — including profit and loss — of the all-new Boeing 787-10 Dreamliner.

Sanger assumed his first executive leadership role with Boeing in 2004 and took on increasing leadership and technical responsibility in each subsequent position. In his final role as vice president and general manager for Boeing's 787 commercial airplane development, Sanger led a global team composed of internal staff and suppliers throughout North America, Asia, Europe, Russia and the Middle East.

Sanger says that among the valuable benefits he derived from his years at Purdue, learning the importance of planning and preparation was key.

"Purdue's engineering curriculum and faculty challenged me to show up for every class, do every assignment and every test, which translated into my detailed preparedness throughout my professional career," he adds.

Sanger says he is grateful for the engineering faculty who took the time to invest in their students despite the demands that leadership in their research fields placed on them. He adds that the Purdue Engineering faculty "made my time at Purdue some of the best years of my life."

AAE honors 2019 Class of OUTSTANDING AEROSPACE ENGINEERS

The School of Aeronautics and Astronautics honored eight graduates with Outstanding Aerospace Engineer awards.

The awards are presented to alumni who distinguished themselves by demonstrating excellence in industry, academia, government service or other endeavors that reflect the value of a Purdue aerospace engineering degree. The 203 OAE recipients represent just over 2% of the more than 8,500 alumni of the school.

JULIE ARNDT

Director of Commercial
Managed Programs
Boeing Global Services
BSAAE 1991

CHRISTOPHER AZZANO

Commander
Air Force Test Center,
Edwards Air Force Base
BSAAE 1987

DOUG BEAL

Vice commander
U.S. Naval Forces Central
Command/U.S. 5th Fleet
BSAAE 1986

MIKE DRESSEN

Executive director
Missile Defense and Space
Systems Engineering,
General Atomics
Electromagnetic Systems Group
BSAAE 1983



FROM LEFT / Lindsay Millard, Julie Arndt, Scott Meyer, Mike Dreesen, Doug Beal, Chris Azzano and Tony Gingiss. David Thompson was unable to attend. PHOTO: REBECCA WILCOX

TONY GINGISS

Chief executive officer
OneWeb Satellites
BSAAE 1990

SCOTT MEYER

Managing director
Maurice J. Zucrow Laboratories,
Purdue University
BSAAE 1990, MSAAE 1992

LINDSAY MILLARD

Program manager
Tactical Technology Office,
DARPA
PhD AAE 2008

DAVID THOMPSON

Vice commander
Air Force Space Command
MSAAE 1989

Neil Armstrong Distinguished Visiting Fellow BEVILAQUA MAXIMIZES VISIT

As part of the inaugural Neil Armstrong Distinguished Visiting Fellows program, AAE alumnus Paul Bevilaqua gave a three-day short course, Introduction to V/STOL Theory and Practice, participated in the Industrial Advisory Council's ethics panel, and met with faculty and students.

Bevilaqua (MSAAE '68, PhD AAE '73) spent about two weeks on campus from late March into early April.

"It was a good experience. I enjoyed it," Bevilaqua says. "I'm a Purdue graduate, and I feel like I ought to be giving back."

The Neil Armstrong Distinguished Visiting Fellows (NAVDF) program brings highly accomplished and recognized scholars and practitioners to the College of Engineering to catalyze collaborations with faculty and students. Fellows are individuals who have been recognized for their standing and achievements in engineering or related disciplines and who collaborate with Purdue Engineering faculty members on research projects and initiatives, including new research directions, industry engagement and on-campus and online educational efforts. Their selections were based on nominations made by faculty and on the potential impact their engagement may have on Purdue Engineering.



Paul Bevilaqua (MSAAE '68, PhD AAE '73) was part of Purdue's inaugural Neil Armstrong Distinguished Visiting Fellows program.

PHOTO: AAE

"My hopes are to make Purdue better known, to advertise its strengths. There seems to be too much Midwestern modesty along the lines of, 'Shucks, ma'am, just doing my job,'" Bevilaqua says of his involvement in NAVDF. "I also want to help the younger professors get started and help some of the more experienced professors to try something different — something that will really make an impact and make people say, 'Wow, Purdue did that.'"

BELCHER selected AIAA Fellow

Alumnus Brad Belcher was one of 29 individuals selected as Fellow by the American Institute of Aeronautics and Astronautics (AIAA) in its 2019 class.

AIAA confers the distinction of Fellow upon individuals in recognition of their notable and valuable contributions to the arts, sciences or technology of aeronautics and astronautics. Belcher has been with Rolls-Royce



BRAD BELCHER

Corporation since 1982, the year he graduated with a bachelor's degree from Purdue's School of Aeronautics and Astronautics. He currently serves as program director for the U.S. Civil R&T Funded Programs where he manages NASA and FAA research activities for Rolls-Royce.

"It is a tremendous honor and very humbling," Belcher says. "I am deeply grateful for the education I got at Purdue's School of Aeronautics

and Astronautics and for my involvement with AIAA that helped me so much in my career."

Belcher's induction as Fellow comes in his 40th anniversary with AIAA. He initially joined as an AAE student in 1979, even serving as a VP for the student branch while at Purdue. He's currently a member of AAE's Industrial Advisory Council.

Belcher served as general chair for the annual Joint Propulsion Conference — now called the Propulsion & Energy Conference — when it was held in Indianapolis for the first time 25 years ago. The conference again will be hosted and sponsored in Indianapolis in 2019.



PURDUE SPACE DAY

EVENT PHOTOS: PURDUE SPACE DAY.
BACKGROUND PHOTO: NASA.

One girl, having just completed assembly of a straw rocket, clapped loudly and pumped a fist before a loud “yes!” escaped her lips.

Later, a boy literally jumped, contorting his body in the air, and, upon landing, shook both arms in excitement. He’d just seen the execution of a dry-ice launch of a paper rocket, complete with a loud pop as it shot off the pavement.

Later, a group of children had mouths open wide and heads cocked back, looking up toward the second-floor bridge in Neil Armstrong Hall of Engineering. A Purdue student volunteer was getting ready to drop another experiment, a kid-assembled Mars Lander, to see how sturdy it’d be

on landing and how well it’d protect its marshmallow cargo. The kids offered up a dramatic countdown, heard from well beyond the building’s atrium, and celebrated a successful landing.

Purdue Space Day (PSD) accomplished its mission, again, in 2018.

The program, offered to children in third through eighth grades, seeks to inspire the next generation of space explorers by participating in age-appropriate STEM activities with a space theme. The 2018 theme was “Blast from the Past” — and it reached an unprecedented number of children.

PSD set a program record with about 850 participants.

“I think it went really well,” says Rachel Collicott, PSD director of group leaders and a junior in biology. “I watched kids working together, and I think they ended up taking a lot away from the activities, which is what we really hoped for.”

Collicott says she heard a fifth-grader perfectly define aerodynamics, in technical terms, and she was in awe.

That’s probably how most of the kids felt when they were in the presence of the day’s VIP guest, astronaut Charlie Walker (BSAAE ’71). Walker, who flew three NASA shuttle missions, participated in his third PSD.

“I’m passionate about this because these kids are the future,” Walker says.

In Memoriam

1940s

Eugene Bigelow
(BSAE '48)

John Crawford
(BSAE '45)

Richard DeTamble
(BSAE '49)

James Harry Jr.
(BSAE '48)

Robert McIntyre
(BSAE '49)

George Palmer
(BSAE '45)

Arthur Strathman Jr.
(BSAE '48)

1950s

Joel Benson
(BSAE '50)

John Ciabrone
(BSAE '50)

Albert Cleaver
(BSAE '57)

Claybourne Crouch
(BSAE '54)

Roger Davidson Jr.
(BSESc '59)

John Donelson
(BSAE '59)

LaVerne Eklund
(BSAE '53)

Joseph Fagerstrom
(BSAE '56)

William Gearan
(MSAE '58)

Darrell Gibson
(BSAE '57, MSEC '59)

Ralph Gilbert
(BSAE '50)

Nick Kusak
(BSAE '50)

Kenneth Naab
(BSAE '55)

William Riggs
(BSAE '58)

William Schatz II
(BSAE '56)

Joseph Shackford
(BSAE '58)

Allen Soughers
(BSAE '54)

Richard Stammerjohn
(BSAE '51)

Herbert Stugart
(BSAE '54)

Philip Truax
(BSAE '54, MSAE '55)

Peter VanGorp
(BSAE '51)

Wallace VanderVelde
(BSAE '51)

John Wasson
(BSAE '57)

Walter Whitacre
(BSAE '59)

1960s

Joseph Barr
(BSAAE '64)

Michael Bernard
(BSESc '57, MSAE '59, PHDAAE '65)

Ross Bradshaw
(BSAAE '67)

Christopher Hendrickson
(MSAAE '64)

Lee Hesler
(BSAAE '64, MSAAE '66)

Fred Isaacs
(BSAAE '66)

Charles Miller Jr.
(BSAE '59, MSAAE '61)

William Schmitendorf
(BSESc '63, MSAAE '65, PHDAAE '68)

Craig Simcox
(PHDAAE '69)

Richard Stall Jr.
(BSAAE '63)

Paul Traylor
(BSAAE '62)

Jacob Wasserman
(BSAAE '64)

S. Anthony Wuichet
(BSAAE '64)

Steven Yaros
(MSAAE '65)

1970s

Robert Bever
(BSESc '69)

James Valrance
(BSAAE '71)

1980s

Andre Bucove
(BSAAE '82)

Jane Cass
(BSAAE '76)

Norman Virgil Scurria Jr.
(MSAAE '80)

2000s

Justin Patrick McCurdy
(BSAAE '05)



George Palmer 1921-2018

A longtime Purdue professor known as a committed teacher, a devoted researcher, an innovative mind, an inspiration to countless aerospace leaders, and a trusted and loyal friend, passed away on Nov. 13, 2018. George Palmer, emeritus professor and Purdue alumnus, was 97.

Palmer is best known for his work and tireless efforts in developing Purdue's wind tunnel program, including designing and constructing The Boeing Wind Tunnel.

"I want to convey our sincerest sympathies to Mrs. Palmer and her family and to express our deepest respect and gratitude for Professor Palmer's life of impact," says Tom Shih, the J. William Uhrig and Anastasia Vournas Head and Professor of Aeronautics and Astronautics. "To many, Professor Palmer was the driving force behind

our department's exceptional curriculum, a resource of knowledge and inspiration, and a friend. He impacted the lives of thousands of students during his tenure."

After receiving his bachelor's in aeronautical engineering from Purdue in 1945 and working in industry until the end of WWII and getting a graduate degree from Caltech, Palmer joined Purdue as an instructor in the Mechanical Engineering School in 1947. In 1948, Palmer transferred to the School of Aeronautics as it was then called and later was promoted to assistant professor and associate professor.

During his tenure at Purdue, Palmer taught Stability and Control, Airplane Aerodynamics, Jet Propulsion and Rocketry, Space Propulsion, and 490, 590 and 690 Special Individual Projects, all of which invariably used the wind tunnel he designed and built. He retired after 41 years of dedicated service in 1987.

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