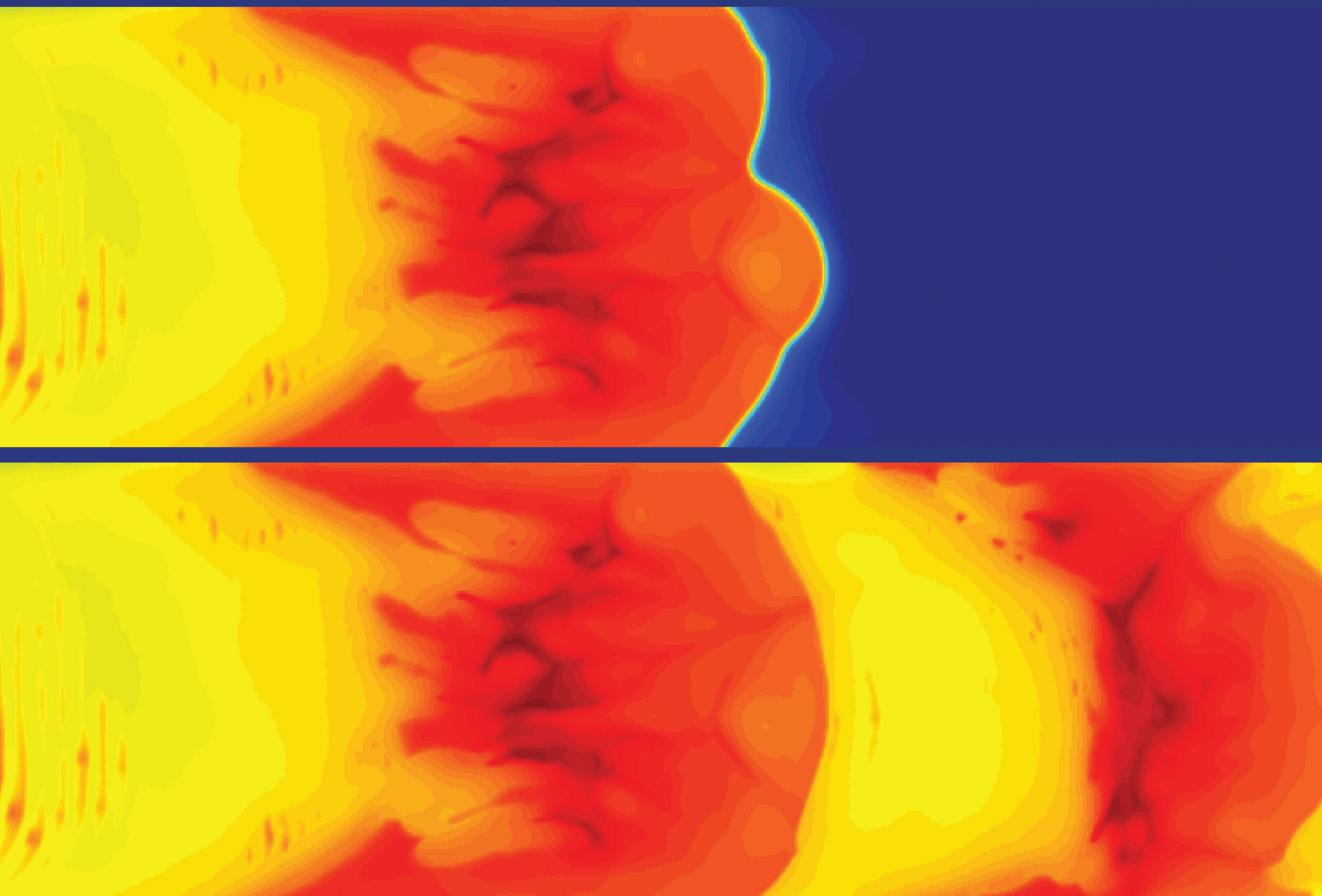
Aerospace Engineering/**2021**

# UPDATE

***Elevating ideas since 1944***




# Michael Paradise on getting an MEng

During my four years as an undergrad, I never quite knew what my specialty was as an engineer. I was good at a lot of things but not great at anything. But in senior design class I learned a lot of systems engineering principles, and I realized that this type of engineering matched my skill set.

I knew from the get-go that I wanted to go into industry, and with a Master of Engineering degree in aerospace systems engineering, I would get a lot of practical experience, from an industry standpoint, doing different types of projects. For example, I took an advanced risk analysis class as an elective because risk management is a big component in systems engineering. Understanding how risk enters a project, how to quantify and mitigate it, is very important.

Having competed in gymnastics since I was five, I was used to managing my time between school and practice. And due to the pandemic, most of my classes were synchronous Zoom sessions, which forced me stay on top of the lectures rather than putting them off.

My two core classes were taught by Professor Merret, who came to the university having worked as a preliminary design/systems engineer for Gulfstream, so he has a tremendous amount of practical and industry knowledge. He not only goes over the material, but he ties in a lot of his knowledge and gave me a lot of insight into the different aspects of systems engineering.

For my capstone project, I worked with a major aerospace company on developmental and exploration work for some ideas they were considering. The coolest—and scariest—part was that I got an initial proposal from the company, and that was it: no guidelines. It wound up being one of the most practical experiences I've ever had because, as an engineer, you want to solve every problem, but with a project of this scale and one this complex, you can't solve it all by yourself.

I accepted a position at Raytheon in Boston, and although I'm just starting out, I can see how I can grow into the eventual career that I want to make for myself.

*Above: Michael Paradise received his BS from University of Illinois Urbana Champaign in 2020. In 2021, he is the first graduate of the MEng program.*

*Below: Michael Paradise in competition at UIUC's Huff Hall when he was an undergraduate. Credit: Illinois Athletics.*


***For more information about advanced degrees, visit aerospace.illinois.edu or email aerospace@illinois.edu.***

# Greetings

Despite the challenges of the past year, with pride and pleasure I can tell you that aerospace engineering is thriving at Illinois. Innovative teaching has flourished in face of the pandemic. Our students have learned and prospered as we have adapted in myriad ways. We have strong foundations from the past and new tools to leverage going forward. Through it all, we have continued to innovate, bringing new research ideas to fruition and training future leaders.

This issue of ***UPDATE*** includes stories emblematic of our efforts and successes, the result of passion and hard work this year: faculty whose research efforts have landed us on Mars; students who excel intellectually, personally, and competitively; and alumni who are leaders in their fields of expertise, who harness the wind, and who even called the International Space Station "home" for a while this past year.

I hope you find our annual magazine informative and inspiring. It presents but a small sampling of stories selected to fit in its 16 pages.

Sincere wishes for a healthy and creative future!

Jonathan B Freund

Jonathan B. Freund
Willett Professor and Head

**Stay connected by joining our social networks.**

If you'd like to receive AE e-news throughout the year, please email a request to aerospace@illinois.edu.

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**On the cover:** Image from "Spontaneous Patterning during Frontal Polymerization," by Evan M. Lloyd, Elizabeth C. Feinberg, Yuan Gao, Suzanne R. Peterson, Bhaskar Soman, Nancy R. Sottos, and Jeffrey S. Moore. The image appears in the American Chemical Society *ACS Central Science* journal.

# **Robots need help** prioritizing tasks

As robots replace humans in dangerous situations such as search-and-rescue missions, they need to make quick decisions—to react and adapt like a human being would. AE's **Huy Tran** and his team used a model based on the game Capture the Flag to develop a new take on deep reinforcement learning that helps robots evaluate their next move.

"Given the overall task of capturing the flag, there are actually subtasks to accomplish along the way, which we model in a hierarchical structure. What we wanted to explore was whether or not this type of hierarchy would help with the ability to adapt," Tran said.

With hierarchical deep reinforcement learning, the tasks are split up so the model can handle more complex problems.

"By breaking the task into subtasks, we can improve adaptation. We trained a high-level decision maker who assigns a subtask for each agent to focus on," Tran said. The hierarchical structure helps by making updates to the model simpler: Only the hierarchical controller would need to be updated rather than each of the agents.

"This approach has the potential to solve interesting and challenging problems, but we need to address some issues before we can deploy these systems in real-world situations," Tran said. "For example, we learned that this framework can help with adaptation, but because we decided what the subtasks should be based on using our own intuition of how Capture the Flag works, it includes our own biases. Now we're looking at new techniques to allow agents to figure out on their own what those subtasks should be."

The study, "Evaluating Adaptation Performance of Hierarchical Deep Reinforcement Learning," written by Neale Van Stralen, Seung Hyun Kim, Huy T. Tran, and Girish Chowdhary, was funded by the Defense Advanced Research Projects Agency and presented at the 2020 IEEE International Conference on Robotics and Automation.

*Photo taken in 2019 of (left to right) grad student Neale Van Stralen, undergrad Ayberk Yaraneri, and Huy Tran testing a drone on the UIUC campus.*

*The heat shield (left) and back shell (right) comprise the aeroshell for NASA's Mars 2020 mission. Credit: NASA.*

# **Modeling radiation** to land safely on Mars

In 2015, AE's **Marco Panesi** received a NASA Early Career Faculty award to study radiation in the back shell of entry capsules. In 2021, we witnessed his research findings in action as Perseverance landed safely on Mars.

Understanding the heat generated by space objects during entry into a planetary atmosphere is critical for the design of the thermal protection system that prevents the vehicle from burning up. Under these extreme conditions, the gas radiation accounts for more than half of the total heat on the back shell.

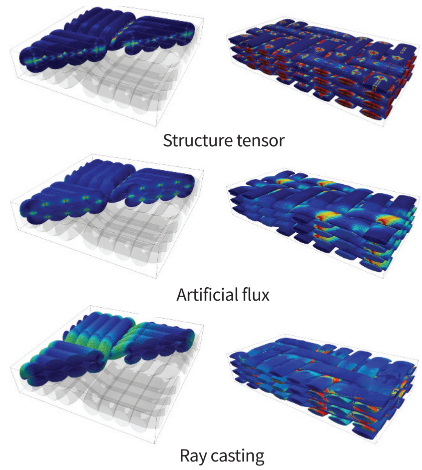
And, in the wakes of vehicles traveling at hypersonic speeds, the cooling of the gas results in a recombination of the carbon dioxide molecules and the formation of highly energetic but transient molecules that can release radiant energy.

Panesi and his former student Amal Sahai used novel methods to describe the microscopic kinetic state of molecules in the vicinity of the back shell and to drastically accelerate the calculation of the radiation heat-loads in the wake of the spacecraft, without sacrificing the physical fidelity of the model.

"Modeling the energy states of these nonequilibrium gas molecules represented a significant challenge, as hundreds of thousands of possible energy states are theoretically possible for a single molecule," Panesi said. "Modeling each possible state for all the molecules that could contribute to the thermal heating model of a Mars vehicle is computationally intensive."

The methods and models developed within the project were used by Christopher O. Johnston at the NASA Langley Research Center to compute the radiation heating in the back shell of the Mars vehicle during entry. In collaboration with Panesi, further development and refinement continue within the NASA Entry Systems Modeling Project.

# **New method sees fibers in 3D,** estimates conductivity




*The three methods used by Panerai et al. to visualize the fibers within composite materials had pros and cons. Ray casting, for example, showed promise to become a powerful approach to estimate the orientation of fibrous materials with little curvature.*

Designing a hypersonic vehicle that can tolerate dangerously high temperatures requires understanding the thermal properties of the materials it's made of. A two-part study developed a method to create 3D models of the fibers within composite materials, then used that information to predict the thermal conductivity of the materials.

"We used X-ray microtomography—similar to a CT scan but with high-energy X-rays that can detect fine details in microfibers—to create 3D images that show the orientation of the fibers," said AE's **Francesco Panerai**. "We use composite materials made with carbon fibers, but the method can be applied to any kind of fiber or composite."

Panerai used the data from the 3D grid to do simulations to compute material properties.

"Now that we can follow the direction of the fibers in space and determine the space between them, we can compute its directional thermal conductivity in three dimensions accurately. In essence, we can predict properties in the three directions far more rapidly and cost effectively," Panerai said.

He went on to say that this new method to visualize fibers and the proven ability to determine material properties can help with reengineering materials.

"We can use a very specific fiber architecture to achieve a certain property such as strength or conductivity," he said. "Thermal conductivity is something everyone who works on high temperature materials tries to estimate. It seems like a very simple property, but it is very hard to measure, especially for materials that are three dimensional. That's what is remarkable about the power of this method."

Supported by NASA and the Air Force Office of Scientific Research, the two studies, written by Federico Semeraro, Joseph C. Ferguson, Francesco Panerai, Marcos Acin, Robert J. King, and Nagi N. Mansour, appear in *Computational Materials Science.*


# **Research helps people, rovers,** arrive on time

*Left: Artist's concept of the Mars 2020 rover in action. Credit: NASA; right: An Orange route bus waits at a stop in downtown Urbana.*

Pranay Thangeda, one of **Melkior Ornik**'s graduate students, relies on the bus system in Champaign-Urbana to get to class. Despite following the bus schedule, he was frequently late. To understand why, he developed a tool that weighs transportation variables against how great a margin of error bus riders are willing to accept.

Thangeda and Ornik needed a lot of real-time data to develop their tool. C-U's local mass transit district was happy to oblige.

"We used the data to train the model to determine the underlying distribution of travel times on different road segments and their correlation," Thangeda said. "The enhanced model reduces the uncertainty, making it more feasible to predict what's going to happen next."

This first step in the research resulted in a proof-of-concept implementation.

"We showed that the model can calculate the tradeoff between reliability and expectation between any starting point and any destination," Thangeda said.

This work was partially funded by a 2018 NASA Early Stage Innovation Award.

"The original case study was on a lunar rover which uses the same principles," Ornik said. "The rover has an origin and a destination. We look at the reliability and expectation tradeoffs between the expected amount of energy or the time the rover needs to reach its destination based on the terrain and what we know of the agent's energy consumption. There's also the question of reliability. Can I ensure, not just expect, that the rover will reach its destination without running out of energy? I want hard guarantees here."

The study was presented by Pranay Thangeda and Melkior Ornik as part of the 23rd IEEE International Conference on Intelligent Transportation Systems.

# Scholarship gives **gift of experiences**

*Left: Emily Williams, BS '21; above: The late Professor Scott White, center, with students.*

Emily Williams, BS '21, served as the president of Women in Aerospace for two years running—a volunteer activity she says she probably wouldn't have had time for if she hadn't received merit-based scholarships during her undergraduate years.

"Having support from merit-based scholarships enabled me to take advantage of all that the University of Illinois has to offer," she said. "I'm involved in many different communities on campus, such as various student groups, research groups, and on-campus jobs, that have helped me build a network all around the college."

Williams received an Engineering Visionary Scholarship, presented in the spirit of the late Scott R. White's deep commitment to providing opportunities for undergraduate research.

"I chose aerospace engineering because I want to be challenged," Williams said, "and I also want to participate in making discoveries that are on the brink of scientific advancement. The work I'm doing in my research groups affects a wide range of different industries, and I believe aerospace engineering is a diverse field that impacts the lives of many."

In addition to playing a leadership role in WIA, Williams has been a head engineering learning assistant for The Grainger Engineering First-Year Experience. She helped instruct two engineering courses (ENG 100 and ENG 177), and she has been actively involved in different research groups that deal with computational aerodynamics, hypersonic flows, and numerical methods.

Williams said her favorite class at UIUC was AE 498: Hypersonic Aero-thermodynamics. "I was able to use some of my scholarship money to finish my general education requirements at a community college. Because of that, I've been able during my last couple of semesters at Illinois to take some really cool upper-level aerospace electives that related to my interests."

Like others graduating this year, Williams had an undergraduate experience that included multiple ramifications due to Covid-19.

"The pandemic impacted my grades and motivation in general," she said. "I had to increase the number of hours I put toward classes to get the grades I wanted. For WIA, I wanted to make sure I could still facilitate the

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*contact Tim Cochrane at tcochran@illinois.edu or 217-333-1149.*

development and network support of our community to be there for each other, especially throughout the past year."

Williams credits the help provided by scholarships during the out-of-the-ordinary challenges she experienced.

"My scholarships enabled me to buy a webcam and monitor, so I could adapt quickly to the new learning environment I found myself in. My scholarships also allowed me to move back home for a bit while still paying for my apartment on campus."

Despite the difficulties, Williams was inspired by how the students and faculty coped. "Their flexibility and adaptability surprised me the most. The empathy of professors really spoke to their dedication in supporting their students."

Williams said her dream job is to become a faculty member and focus on research and teaching at a university. She's already on her way—by beginning to work on a PhD this fall at MIT.

# Final Four in **ethics competition**

A hypothetical company is conducting a flight test on its new hypersonic vehicle for commercial use. Some aspects of an earlier ground test have raised concerns. Combine that with pressure from the client to complete the job early, and you have the gist of the scenario that was the basis for this year's Ethics in Engineering Case Competition at Lockheed Martin.

This year, the three-day competition began with 26 teams of three students each. It ended with Brigham Young University's team pitted against the University of California San Diego and Texas A&M arguing against a team from the University of Illinois Urbana-Champaign, which included aerospace engineering senior Lisa Rosov.

"In some of my aerospace classes, we've looked at small, ethical scenarios; most of the time the answers are clear-cut, but in this competition, it was much more complex," Rosov said. "A lot of intricate, minor ethical problems would pop up."

She gave examples, such as that of one engineer in the scenario who saw the results of a test but didn't communicate the results to her supervisor. Another engineer ran an unfunded test.

"Then there was a company leader who asked if anyone could prove that the vehicle is unsafe," Rosov said. "This is a hard question to answer because we want to prove that something is safe, not that something is unsafe. We had to focus on all of these smaller problems because they all played a role [in the scenario]."

Another dilemma came up, Rosov said, because the company wanted to bump up the deadline, so she consulted with AE's **Jason Merret**, who worked at Gulfstream for 14 years before joining the faculty in 2018.

*Lisa Rosov, BS '21.*

"Dr. Merret has experience in aircraft development, including flight testing," Rosov said. "He said that if a company wants an earlier deadline than the contract states, they'll likely offer additional resources, and the change will all be written into the amended contract. Our case study didn't say anything about renegotiating, just that they're adding pressure to complete it. That's when we realized that there's a whole other ethical issue that we had glossed over."

Because the scenario touches on issues like these that relate more to business and ethics than engineering, the team comprised students with expertise in all three areas. Rosov filled the aerospace engineering niche.

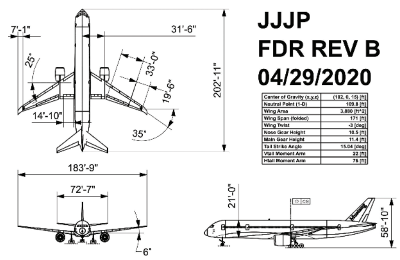
The competition this year took place online in three rounds. For round one, each team gave a 90-second "elevator pitch" to explain the problem and their proposed solution. In round two, the teams gave a 15-minute presentation. Round three was set up as a role play between teams in a tournament-style bracket.

"When it came to the semifinals, competition judges realized that all the teams were too well prepared, so they changed the rules," Rosov said. "Although our opening statement was supposed to be uninterrupted, they allowed judges to interrupt, act angry at something we said, and ask us questions. That threw everyone off a little bit because we weren't expecting it."

Rosov was glad she was able to participate in the unique opportunity. "It was an eye-opening experience."

# **Senior design team** takes 1st and 3rd places


*Team Mustang's 1st-place AIAA design, "Jay Jay the Jet Plane."*




*A drawing from Team Mustang's report.*


*Team Dauntless's AIAA design entry, "Argo."*

The challenge in the American Institute of Aeronautics and Astronautics Undergraduate Team Aircraft Design Competition was to design a high-capacity, short-range transport aircraft that could alleviate airport congestion, without the size and cost that comes with long-range capability. Two teams from Illinois finished with high marks in the competition, which included 33 student teams from eight countries.

Team Mustang took 1st place with their final design, presented as “Jay Jay the Jet Plane.” Each member of Team Mustang had a major and a minor assignment.

The team members were Sejal Sahu (major assignment, team leader/minor assignment, cost), Jack Wu (aerodynamics/avionics), Nicolas Alvarado (structures and landing gear/acoustics), Charlie Rovin (mass properties/configuration), Weizhuo Wang (performance/propulsion), Joshua Daniel (stability and control/loads and dynamics), and Ben Baker (systems/interior design and certification).

The judges for Team Mustang said their report was well written. “The topics addressed are all pertinent and there is very little fluff. The language is concise, the requirements (both the request for proposal and regulations) appear to be well understood.”

In Team Mustang’s section on aerodynamics and wing selection, the report describes multiple methods to analyze the airfoil and wing. The team used historical data, a vortex lattice method, and Vehicle Sketchpad. Because of this, the group was able to narrow the airfoil selection down to SC-0412 and RAE-5215. Consequently, they were then able to quickly move to the wing design, conducting multiple trade studies before settling on the final design.

One judge commented, “The numerous cross checks with alternate methods, historical trends, and similar aircraft are excellent and help guide the process and increase confidence in the design decisions.”

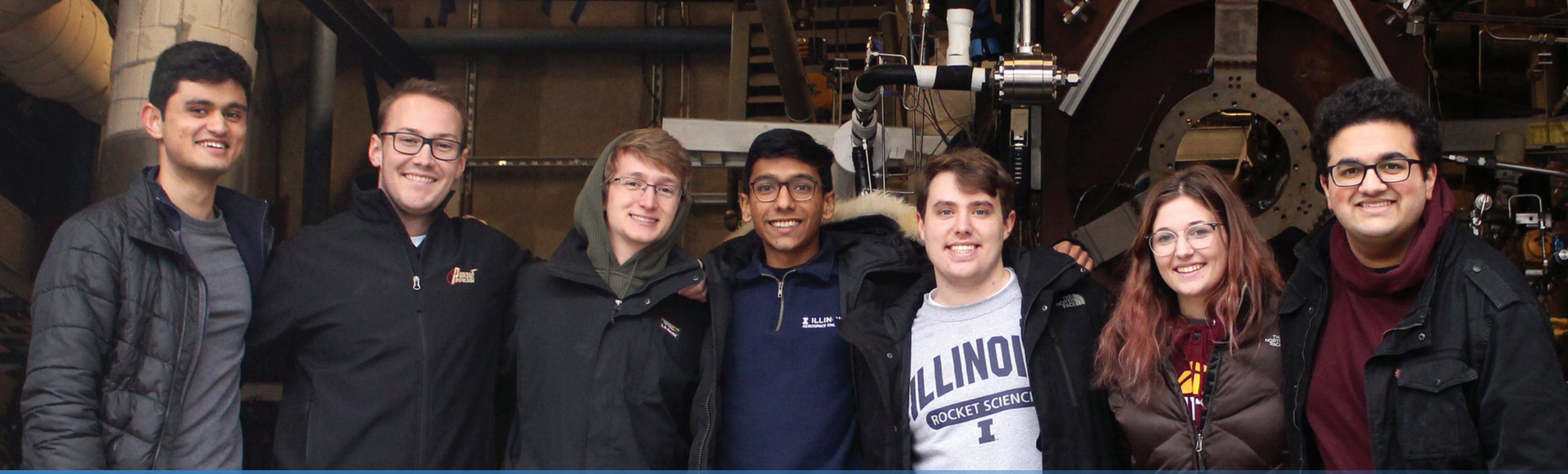
A second Illinois group, Team Dauntless, took 3rd place for their design, called “Argo.” Members of the team included Ted Lataif (major assignment, team leader/minor assignment, configuration), Andrew Cichon (concept of operations, propulsion, and performance/certification), Himmat Mann (mass properties/acoustics), Jason Moon (structures, loads, and dynamics/landing gear), Avantika Murali (aerodynamics, stability, and control/interior design), and Emily Tokarski (systems and cost/avionics).

The judges made a special mention of the team’s understanding of the broader impacts of Covid-19.

In the section on pneumatic, deicing, and environmental control systems, the team reported, “The air filters on the Argo are high efficiency and similar to filters used in hospital operating rooms, making them effective in removing not only bacteria, but also viruses and any other particles that might contaminate the cabin. Consumers have historically expressed concerns about possible health effects due to cabin air contamination, which is especially relevant in the COVID-19 era. Studies have shown, however, that people are no more likely to catch an infection on an aircraft than if they were travelling on other public transportation, attending a conference, or participating in any other similar activity that puts them in close contact with other individuals. Further, evidence from these studies did not establish a link between cabin air contamination and ill passenger health.”

The team’s senior design instructor was **Jason Merret**, who earned all three of his degrees from Illinois and could empathize with the teams. But one thing Merret didn’t experience as an undergrad in senior design was completing the design process and writing a lengthy report in the remote-learning pandemic environment.

“I tell my students that this class prepares them for a job in aircraft design because of all of the deadlines and hiccups that happen along the way. On top of all of that, these teams had to deal with a once-every-hundred-years pandemic, and yet they got it done and even outshone the competition. I couldn’t be prouder.”



# Rocket team develops **hybrid rocket engine**

*Above: A prepandemic photo of some of the ISS team members (from left): Abhiraj Majumder, BS '21; Chris Nielsen, Purdue University graduate student; Connor Latham, BS '20; Vignesh Sella, BS '21; Andrew Larkey, BS in ME '21; Avery Moore, BS '21; and Avinash Rao, BS '21.*

In a year defined by obstacles, an Illinois Space Society student rocket team persevered. Working together across five time zones, they successfully designed a hybrid rocket engine that uses paraffin and a novel nitrous oxide-oxygen mixture called Nytrox.

"Hybrid propulsion powers Virgin Galactic's suborbital tourist spacecraft, and the development of that engine has been challenging," said the team's faculty adviser **Michael Lembeck**. "Our students are now experiencing those challenges firsthand and learning how to overcome them."

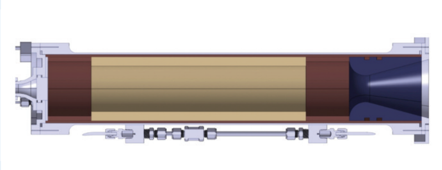
The team had already persevered through a number of failures with hybrid engines utilizing nitrous oxide. The propellant frequently overheated on tests in the New Mexico desert. Lembeck said this motivated the team to find an alternative fuel that could remain stable at temperature. Nytrox surfaced as the solution to the problem.

As the team began working on the engine last spring, excitement to conduct hydrostatic testing of the ground oxidizer tank vessel quickly turned to frustration, as the team lacked a safe test location.

Team leader Vignesh Sella said, "We planned to conduct the test at the U of I's Willard Airport retired jet engine testing facility. But all testing was halted until safety requirements could be met."

Sella said they were disheartened at first but rallied by creating a safety review meeting along with another student rocket group.

"We came up with a plan to move the project forward. The hybrid team rigorously evaluated our safety procedures and had our work reviewed by Dr. Dassou Nagassou, the Aerodynamics Research Lab manager. He became a great resource for us, and a very helpful mentor."



*Computer-aided design shows a cross-section of the combustion chamber.*

*Paraffin wax fuel grain, when used with Nytrox, powers the hybrid engine.*

Sella and team member Andrew Larkey also approached colleagues at Purdue University to draw from their experience in the realm of rocket propulsion. Sella and Larkey did preliminary over-the-phone design reviews and were eventually invited to conduct their hydrostatic and cold-flow testing at Purdue's Zucrow Laboratories, a facility dedicated to testing rocket propulsion with several experts in the field on-site.

"We sent a few of our team members to Zucrow to scout the location and take notes before bringing the whole team there for a test," Sella said. "These meetings, relationships, and advances, although they may sound smooth and easy to establish, were arduous and difficult to attain. It was a great relief to us to have the support from the department, a pressure vessel expert as our mentor, and Zucrow Laboratories available to our team."

The extended abstract, which the team had submitted much earlier to the American Institute of Aeronautics and Astronautics Propulsion and Energy conference, assumed the engine would have been assembled and tested before the documentation process began. Sella said the team wanted to document hard test data but had to switch tactics. The move to online-only classes curtailed all in-person activities, including those of registered student organizations like the Illinois Space Society.

"As the disruptions caused by Covid-19 required us to work remotely, we pivoted by focusing on documenting the design processes and decisions we made for the engine. This allowed us to work remotely and complete a paper that wasn't too far from the original abstract," Sella said. "Our members, some of whom are located in other countries, met on Zoom and Discord to work on the paper together virtually, over five time zones."

*Stanley A. Deal, BS '86*

*Michael S. Hopkins, BS '91*

## College recognizes Stanley Deal and Mike Hopkins

Each year, The Grainger College of Engineering selects exceptional alumni to receive the Alumni Award for Distinguished Service for professional distinction through outstanding leadership, contributions to the field of engineering, creativity, and entrepreneurship as well as service to society, to the professional community, and to the department, college, or university.

This year, two of the eight individuals honored are AE alumni.

**Stanley A. Deal**, BS '86**,** president and CEO of Boeing Commercial Airplanes, was selected for his successful and influential career in the aviation industry, along with his active alumni engagement at both the department and college levels.

NASA astronaut **Michael S. Hopkins**, BS '91, was commander on the Crew-1 SpaceX Crew Dragon Resilience, whose mission successfully ended in April 2021. He was selected as an engineer, a test pilot, and an astronaut for his decorated service in the U.S. Air Force and U.S. Space Force, his contributions to the NASA space program, and his continued dedication to the University of Illinois.

## Alumnus receives top award in plasmadynamics and lasers

**David L. Carroll**, BS '85, MS '86, PhD '92, received the 2021 Plasmadynamics and Lasers Award from the American Institute of Aeronautics and Astronautics, recognizing his contributions to the understanding of the physical properties and dynamical behavior of matter in the plasma state and lasers as related to need in aeronautics and astronautics.

The president and cofounder of CU Aerospace, Carroll works in high-energy lasers, space propulsion, nanosat fabrication, advanced materials, astrodynamics, and other advanced aerospace technologies. He also cofounded Autonomic Materials, Inc., which focuses on the commercialization of self-healing paints and coatings.

Carroll is active in numerous areas, including high-energy lasers, plasma-driven systems, dissociating and plasma flows, nonequilibrium flows, nozzles, optics, electrically driven in-space micropropulsion systems, plasma-assisted combustion, and plasma-actuated flow control technology. He is a coinventor of the hybrid electric oxygen-iodine laser system, the exciplex pumped alkali laser, the microcavity discharge thruster, the fiber-fed pulsed plasma thruster, and most recently the cyclotronic arc plasma actuator for aircraft flow control.

Carroll has published over 160 papers and holds 12 patents and patent applications in the multidisciplinary fields of high-energy discharge and gas lasers, space propulsion systems, plasma-driven devices, optics, fluid dynamics, laser physics, and genetic algorithms, which are computational search and optimization techniques based upon Darwinian survival-of-the-fittest concepts.

As an adjunct faculty, Carroll has taught undergraduate classes at UIUC, been an invited lecturer for graduate and undergraduate classes, and acted as an informal coadviser for 20 master's students and five doctoral students, as well as having mentored many young scientists in his industrial career. As a visiting professor teaching Illinois' capstone senior design course, he was the faculty adviser for Illinois teams that won four consecutive first place awards in AIAA space design competitions from 2012 to 2015.

## Life's detours led AE alum to head Orion navigation

**Chris D'Souza**, BS '83, MS '84, is one of an elite community of about 100 navigation specialists in the world. But having lived on both U.S. coasts, eventually landing in Houston, he has followed a career track that has not been a straight line.

D'Souza's first job was at NASA's Jet Propulsion Laboratory in Pasadena as a maneuver analyst for the Magellan Mission to Venus. In 1987, he went back to school and earned his PhD from the University of Texas Austin.

"The Air Force paid for my schooling, with me going to Eglin Air Force Base every summer," D'Souza said. "About the time I was getting ready to graduate, they made me an offer to come work full time. I did research for them for five years on trajectory optimization and navigation. That's when I first got involved with GPS."

D'Souza said that at that time GPS was just coming online; there were only a handful of satellites, and GPS receivers were about the size of a car battery.

"Eventually," he said, "the Air Force wanted me to go into management, and I really didn't want to do that." Fortunately, he heard about a job opening at Draper. "I was also getting pretty serious with a girl. I decided to accept the job, and we moved to New England on our honeymoon."

For about nine years, D'Souza worked for Draper as a guidance, navigation, and control systems engineer. He said that although working for Draper was good, he spent three hours a day commuting, and he needed a change.

"I was offered a job at Draper in Houston working on a project called the Space Launch Initiative," he said. "A month after I moved down to Houston, the project was cancelled, and I had to scramble to find other work, still at Draper. It was frightening."

That dramatic, stressful career move was what ultimately led D'Souza from guidance and trajectory optimization into navigation.

*The D'Souza family at daughter's college graduation this year. Left to right: Connie, Chris, and their daughters Olivia and Anna.*

"I got to know some people at Johnson Space Center and got in on the ground floor of Orion," he said. "The first year was a blast. We didn't have many meetings, and we had no management oversight. They let me do my work. Nobody bothered me."

Although everything worked out, D'Souza said leaving Draper to go to NASA/Orion was the most difficult career decision he had to make.

"In hindsight, it was the best decision I've made in my life," he said.

D'Souza said he learned navigation on his own. "People did orbit determination, but nobody taught me navigation, and I never studied under a navigator." Now he does the training.

"We bring in graduate students every summer to work with us. After they graduate with a PhD, they'll need another three years of training. Becoming a navigator requires dedication. But if someone wants it, they can get it. If I can do it, anybody can."

D'Souza describes navigation as very math heavy, requiring a knowledge of estimation theory, linear and nonlinear systems theory, and optimization theory. It involves a lot of numerical analysis. "It's very specialized, but if you want to have job security for the rest of your life, go into navigation."

D'Souza sees the work he is doing now as the groundwork for the future of spacecraft.

"We are designing systems to be ready for whatever comes in terms of human exploration in the next 30 years. It's going to be mature. It's going to be flexible. It's going to be as technically competent as we can make it not knowing the future. That's my goal."

*Qi "Joyee" Zhu with a wind turbine blade.*

## Adventures in the Wild West of the wind industry

AE alumna **Qi "Joyee" Zhu**, PhD '01, was **Philippe Geubelle**'s first doctoral student, studying the residual stress and warpage of thermoset composites. Zhu said she never actually applied for her first job.

"I was a summer intern at GE Global Research," Zhu said. "The last thing they said to me when I left was 'The offer is on the way.' The letter was under my door when I arrived back in Illinois."

While she was at GE Global Research, Zhu's team worked with GE Aviation to develop the first-of-its-kind carbon composite fan containment system for GEnx-1B and -2B engines.

"After working on that one project for about nine years, I wanted to do something new. I am passionate about technology and wanted to work on a core product."

Wind turbines were becoming an important new source for renewable energy at the time, and because the blades are made of 100 percent composite materials, working on wind turbines seemed like a good fit for Zhu.

Today, Zhu is a chief engineer at LM Wind Power, a GE Renewable Energy business and world-leading company in the design and manufacture of wind turbine blades. But making that major career change from research to business came with challenges.

"In aviation, you have a very long product development cycle of five to 10 years. But when I moved to wind, it was like the Wild West. The wind industry is very fast paced. In a year, you have a new product out, so you have to make lots of changes very quickly."

Zhu realized she had to adapt to this new work environment.

"The first half year was quite painful," she said. "Initially, I was very excited in this new world, but at the end of the first half year, I was frustrated. I drew a line on a graph. The horizontal axis was time, and the vertical axis was fun. My curve was going down. That's when I figured out what I should do and began kicking off to the next level."

Although she didn't originally set out to work in renewable energy, Zhu is glad she's in the field today.

"I have found a lot of purpose in my work with renewable energy and climate change. I think it is important that we look out for our planet. We need to do something for our children and grandchildren to keep our water clean, the environment clean. I believe the work I do is valuable and meaningful. And I'm very glad I stayed in the composite field."

Zhu's PhD thesis looked at deformation of the blade during the manufacturing process. In creating a turbine blade the size of a football field, Zhu has to understand and mitigate that deformation and shrinkage of the polymer.

"Creating a blade is not just design. It's manufacturing, materials—everything has to be considered. You need to balance between the aero team and the loads team and the design team, because there's always a conflict of interest. A good engineer knows how to balance that and maximize the value.

"That's why I still love being an engineer. There are endless problems to solve."

# Faculty highlights

**Phillip J. Ansell** (assistant professor/PhD, University of Illinois, 2013), an Allen Ormsbee Faculty Fellow, is PI for the NASA-funded Center for High-Efficiency Electrical Technologies for Aircraft. He established and was named inaugural chair of AIAA's Electrified Aircraft Technology Technical Committee, was organizer and panelist at the AIAA/IEEE Electric Aircraft Technology Symposium, and received the Penn State Engineering Alumni Society Young Alumni Achievement Award.

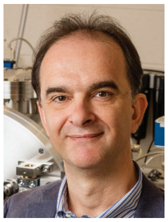
**Lawrence A. Bergman** (research professor, professor emeritus/PhD, Case Western Reserve University, 1980)

**Daniel J. Bodony** (Blue Waters Professor/PhD, Stanford University, 2005) is associate head and director of graduate studies. Bodony was promoted to full professor and awarded the Campus Distinguished Promotion Award. He received three new grants from federal government agencies to study hypersonic vehicles and reduce jet noise.

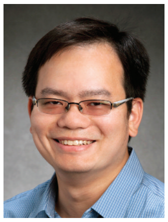
**Michael B. Bragg** (research professor, professor emeritus/PhD, The Ohio State University, 1981)

**Timothy Bretl** (associate professor/PhD, Stanford University, 2005) was named by The Grainger College of Engineering as a Severns Faculty Scholar for his contribution to engineering education.

**Rodney L. Burton** (professor emeritus/PhD, Princeton University, 1966)



**Ioannis Chasiotis** (professor and University Scholar/PhD, California Institute of Technology, 2002) was named Caterpillar Professor of Engineering in 2020-2021; received grants from NSF, NIH, AFOSR, and the International Space Station Laboratory; and delivered three plenary and keynote presentations at international conferences.



**Huck Beng Chew** (associate professor/PhD, National University of Singapore, 2007) received grants from NSF Civil, Mechanical and Manufacturing Innovation Mechanics of Materials and Structures and NASA Space Technology Research Institutes. He also led a research project that developed machine learning as a tool for bridging scales in mechanics of materials.

**Bruce A. Conway** (professor emeritus/PhD, Stanford University, 1981)

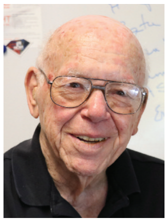
**Siegfried Eggl** (assistant professor/PhD, University of Vienna, 2013) was awarded the Vera C. Rubin Observatory Builder status for his contributions to solar system science and planetary defense with the Legacy Survey of Space and Time. He also led a research project that dispelled planetary safety concerns for the NASA Double Asteroid Redirection Test.

**Gregory S. Elliott** (professor/PhD, The Ohio State University, 1993) continues his research on advanced laser diagnostic techniques for combustion, plasmas, and high-speed flows. He is leading the experimental team on the recently awarded DOE Center for Exascale-enabled Scramjet Design. He is also on the team developing the Plasmatron X facility designed to create the high-enthalpy conditions needed to test materials for reentry and hypersonic flight.

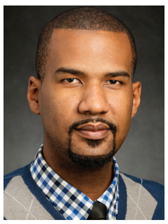
**Jonathan B. Freund** (Donald Biggar Willett Professor of Engineering and department head/PhD, Stanford University, 1998) kicked off the DOE/NNSA-funded $17M Center for Exascale-enabled Scramjet Design and chaired the 2020 APS Division of Fluid Dynamics conference, which was adapted to a virtual format on short notice.

**Philippe H. Geubelle** (Abel Bliss Professor of Engineering and executive associate dean/PhD, California Institute of Technology, 1993) is serving as the chair of the Executive Committee of the ASME Materials Division, which celebrates its 100th anniversary this year.

**Andres J. Goza** (assistant professor/PhD, California Institute of Technology, 2018) was selected as the department's AIAA Teacher of the Year and received two collaborative grants, one from NSF with MechSE professor Aimy Wissa and the second from AFOSR with MechSE professor Kathryn Matlack. Goza's group presented their work at the APS Division of Fluid Dynamics conference and published their findings in the *Journal of Fluid Mechanics*.



**Harry H. Hilton** (professor emeritus PhD, University of Illinois, 1951) is on the editorial board of the archival peer-reviewed *Aerospace Journal* and the *Transdisciplinary International Journal of Mathematics in Engineering, Science and Aerospace*. He received the 2020 Vebleo Scientist Award.



**Kai A. James** (assistant professor/PhD, University of Toronto, 2012) coauthored an article on the design of 3D-printed self-morphing mechanisms in the journal of *Structural and Multidisciplinary Optimization* and, with colleagues James Allison and Timothy Bretl, received a Strategic Research Initiative Phase I Award to fund the creation of a research center dedicated to 3D spatial packaging of interconnected systems.

**John Lambros** (professor and Donald Biggar Willett Professor of Engineering/PhD, California Institute of Technology, 1994) received grants from Sandia National Labs and the National Science Foundation to study additively manufactured metals. A paper written with graduate student R.B. Vieira on the use of machine learning for mechanical response predictions was selected for the cover art of *Experimental Mechanics*, Vol. 61, No. 4, April 2021.

**Cedric Langbort** (professor/PhD, Cornell University, 2005) is the PI on an ARO Multidisciplinary University Research Initiative on the propagation of (mis)information on networks and an NSF-funded project focusing on strategic information transmission as a mechanism to induce socially beneficial behaviors in shared infrastructures. Another component, centered on the fairness of such dynamic mechanism, is partially funded by IBM.

**Michael Lembeck** (associate professor of practice/Phd, University of Illinois, 1991) is collaborating with several Illinois aerospace companies to form the Illinois Small Satellite Consortium. The first product from the group is a dark matter detection satellite for FermiLab that recently completed its preliminary design review.

**Deborah Levin** (professor/PhD, California Institute of Technology, 1979) was selected by NSF for a research leadership allocation of supercomputing time on Frontera.

**Negar Mehr** (assistant professor/PhD, University of California Berkeley, 2019) joined the faculty in August 2020 and received the 2020 first prize for the best dissertation from the IEEE Intelligent Transportation Systems Society. She has served as a technical program committee member for the 2021 International Conference on Cyber-Physical Systems and the International Symposium on Multi-Robot and Multi-Agent Systems.

**Jason M. Merret** (associate professor/PhD, University of Illinois, 2004) received the Smart Transportation Infrastructure Initiative Grant and served as vice chair of the AIAA Aircraft Design Technical Committee and director of the Master of Engineering in Aerospace Systems Engineering, with the program's first graduate receiving a degree in May 2021.

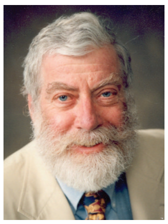
**N. Sri Namachchivaya** (research professor/PhD, University of Waterloo, 1984)

**Melkior Ornik** (assistant professor/PhD, University of Toronto, 2017) was selected to lead a $1-million grant from NASA for the development of resilient extraterrestrial robotic autonomy. He is the university lead for an industry-led, AFWERX-funded project on risk reduction and conflict avoidance for urban air mobility.

**Francesco Panerai** (assistant professor/PhD, von Kármán Institute for Fluid Dynamics, Università degli Studi di Perugia, 2012) won a NASA Early Stage Innovation award to study parachute fluid-structure interaction and became part of a newly awarded NASA Space Technology Research Institute. He published articles in *Computational Materials Science* and *Procedia Manufacturing.*

# Faculty highlights

**Marco Panesi** (associate professor/PhD, von Kármán Institute for Fluid Dynamics and Università degli Studi di Pisa, 2009) received the prestigious Vannevar Bush Faculty Fellowship as well as a number of grants, including a Multidisciplinary University Research Initiative on chemistry-turbulence interaction. He leads the flow physics research in the $16M NASA Space Technology Research Institute and has served on DoD committees to shape the future of research in hypersonics in the U.S.



**John E. Prussing** (professor emeritus/ScD, Massachusetts Institute of Technology, 1967)

**Zachary R. Putnam** (assistant professor/PhD, Georgia Institute of Technology, 2015) gave virtual seminars at the University of Texas Austin and the University of Minnesota.

**Joshua L. Rovey** (associate professor/PhD, University of Michigan, 2006) leads a team as part of the Joint Advanced Propulsion Institute, a 5-year, $15M NASA Electric Space Propulsion Institute. He published an invited review paper on multimode space propulsion in *Progress in Aerospace Sciences* and leads a team to develop education and outreach materials on space engineering as part of a 3-year, $3M DoD National Defense Education Program grant.

**Theresa A. Saxton-Fox** (assistant professor/PhD, California Institute of Technology, 2018) received two grants: the Office of Naval Research Young Investigator Program award and an unsolicited grant from the National Science Foundation. Her research group made four presentations at the APS Division of Fluid Dynamics conference.

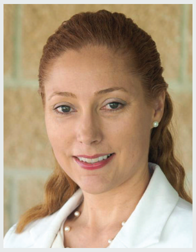
**Michael S. Selig** (research professor, professor emeritus/PhD, The Pennsylvania State University, 1992) is conducting research focused on aerodynamics and airfoil design for a downwind segmented coning concept rotor for a 25 MW offshore wind turbine. Collaborators include five other institutions led by the University of Virginia.

**Huy T. Tran** (research assistant professor/PhD, Georgia Institute of Technology, 2015) received one continuation grant on multiagent autonomy, led a project exploring explainable AI, gave a talk at the GE probabilistics seminar series, and published on topics including machine learning for transportation and network robustness.

**Laura Villafañe Roca** (assistant professor/PhD, von Kármán Institute for Fluid Dynamics, Universitat Politècnica de València, 2014) received an Early Stage Innovations award from NASA's Space Technology Research Grants Program; published articles in the *International Journal of Multiphase Flow* and the *International Journal of Heat and Fluid Flow;* and gave a Chair's Distinguished Lecture at the University of Michigan, an invited seminar at the Center for Environmental and Applied Fluid Mechanics at Johns Hopkins University, and a space talk for the IllinoisX Space Technology Academy MOOC (massive open online course). She continues serving as associate editor for *Measurement* and editor for *Results in Engineering.*

**Brian S. Woodard** (director of undergraduate programs/PhD, University of Illinois, 2012) was selected to serve as an assistant dean in The Grainger College of Engineering Undergraduate Programs Office beginning in the summer of 2021. He will work with transfer students and outreach programs for the college.

# New faculty



### Robyn Woollands

Robyn Woollands began her new position as an assistant professor in 2021 while finishing a project 33 million miles away.

For four years prior to coming to UIUC Woollands was a mission design engineer at NASA's Jet Propulsion Laboratory, where she was part of the navigation team for the Mars Reconnaissance Orbiter. As one of the longest-serving science and communication satellites orbiting Mars, MRO has provided reconnaissance support for numerous missions, including the landings of InSight and Mars 2020, which delivered the Perseverance Rover and Ingenuity Helicopter to the surface of Mars.

While at JPL, Woollands was also a member of the navigation team for the return phase of JAXA's Hayabusa2 mission—an asteroid sample return mission which collected a sample of the asteroid Ryugu and returned to Earth in 2020.

As a member of the AE faculty, Woollands conducts research in the field of astrodynamics and optimal trajectory design. She earned her PhD in aerospace at Texas A&M University in 2016.

### Jeff Baur

Jeff Baur will join the department in January 2022 as a Founder Professor of Engineering. He will work on the design, additive manufacturing, and characterization of composite materials for multifunctional and adaptive structures in the new composites lab in Talbot Laboratory and with the Autonomous Materials Group at the Beckman Institute. Founder professorships commemorate Stillman Williams Robinson, the first faculty member to teach engineering at Illinois and the first dean when the College of Engineering was organized in 1878.

With over 25 years working in the Air Force, teaching, and leading teams in aerospace-related research, Baur brings a depth and breadth of knowledge and experience to the University of Illinois.

Baur, who received his PhD from MIT in 1997, is coming to UIUC from the Air Force Research Laboratory, where he led teams of government, contract, and student researchers in understanding the process-structure-property relationships of polymeric and ceramic composite using the latest computational, testing, and characterization techniques. Baur taught classes on polymers, physics, and chemistry at the Massachusetts Institute of Technology, the University of Dayton, and the University of Cincinnati.

# **Faculty** research areas

**Aeroacoustics**
Daniel Bodony
Jonathan Freund

**Aeroelasticity**
Lawrence Bergman
Daniel Bodony
Philippe Geubelle
Andres Goza
Harry Hilton
Kai James

**Aerospace Materials**
Jeff Baur
Ioannis Chasiotis
Huck Beng Chew
Philippe Geubelle
Harry Hilton
Kai James
John Lambros
Francesco Panerai

**Aerospace Structures**
Jeff Baur
Lawrence Bergman
Harry Hilton
Kai James
John Lambros

**Aerospace Systems Design and Simulation**
Phillip Ansell
Harry Hilton
Kai James
Michael Lembeck
Jason Merret
Zachary Putnam
Michael Selig
Huy Tran

**Applied Aerodynamics**
Phillip Ansell
Daniel Bodony
Gregory Elliott
Andres Goza
Jason Merret
Francesco Panerai
Theresa Saxton-Fox
Michael Selig
Laura Villafañe Roca
Brian Woodard

**Astrodynamics**
Bruce Conway
Siegfried Eggl
Michael Lembeck
John Prussing
Zachary Putnam
Robyn Woollands

**Combustion and Propulsion**
Phillip Ansell
Daniel Bodony
Gregory Elliott
Jonathan Freund
Deborah Levin
Francesco Panerai
Marco Panesi
Joshua Rovey

**Computational Fluid Dynamics**
Daniel Bodony
Jonathan Freund
Andres Goza
Deborah Levin
Marco Panesi

**Controls, Dynamical Systems, and Estimation**
Timothy Bretl
Bruce Conway
Cedric Langbort
Negar Mehr
Melkior Ornik
Zachary Putnam
Huy Tran
Robyn Woollands

**Experimental Fluid Mechanics**
Phillip Ansell
J. Craig Dutton
Gregory Elliott
Francesco Panerai
Theresa Saxton-Fox
Laura Villafañe Roca

**Flow Control**
Phillip Ansell
Daniel Bodony
J. Craig Dutton
Gregory Elliott
Jonathan Freund
Andres Goza
Theresa Saxton-Fox
Laura Villafañe Roca

**Hypersonics**
Daniel Bodony
Huck Beng Chew
Gregory Elliott
Jonathan Freund
Deborah Levin
Francesco Panerai
Marco Panesi
Zachary Putnam

**Robotics**
Timothy Bretl
Negar Mehr
Melkior Ornik
Huy Tran

**Satellite Design and Manufacturing**
Rodney Burton
Siegfried Eggl
Michael Lembeck
Deborah Levin
Zachary Putnam
Joshua Rovey

**Space Systems**
Timothy Bretl
Rodney Burton
Bruce Conway
Michael Lembeck
Deborah Levin
Negar Mehr
Melkior Ornik
Zachary Putnam
Joshua Rovey
Huy Tran
Robyn Woollands

**Unmanned Aerial Vehicles**
Phillip Ansell
Timothy Bretl
Gregory Elliott
Negar Mehr
Melkior Ornik
Michael Selig
Huy Tran

**Grainger College of Engineering**
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

**Aerospace Engineering**
306 Talbot Laboratory
104 South Wright Street, MC 236
Urbana, IL 61801-2957

# Aerospace Engineering at Illinois adds up in 2021

**FACULTY**

- 26 faculty members (+1 January ’22)
- 12 affiliate faculty members
- 8 adjunct faculty
- 10 emeritus faculty
- 75+ current research grants

**GRADUATES**

- $70,000 starting salary with a BS
- 4,912 current alumni worldwide

**STUDENTS**

- 547 undergraduate students
- 199 graduate students
- 22 PhDs granted
- 9 registered student organizations

**RANKINGS**

- 9th-ranked undergraduate program in the U.S.
- 6th-ranked graduate program in the U.S.

**FUNDING & FACILITIES**

- $9-million research expenditures
- 25+ laboratories and research centers
- 10 interdisciplinary research centers
- 3,800 sq ft of composite manufacturing and CubeSat labs