Aerospace Engineering/**2018**

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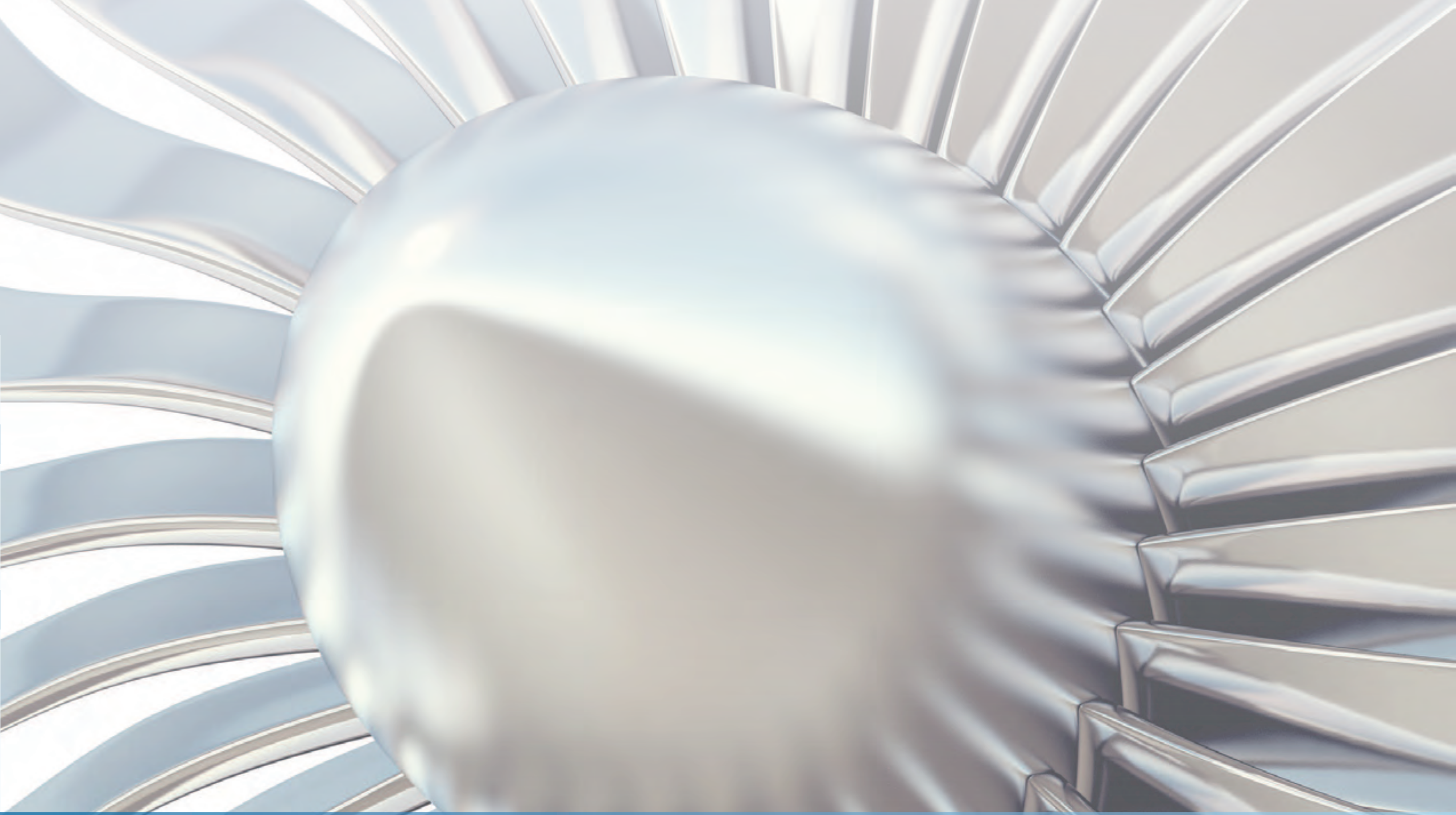

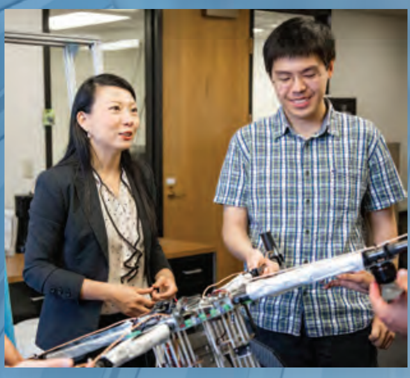

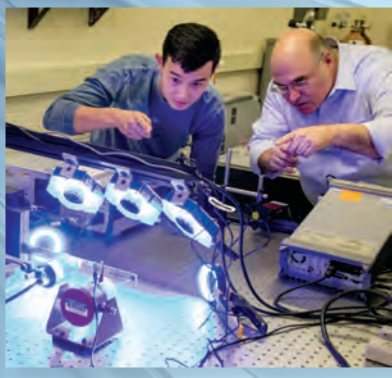

ILLINOIS

PHOTO: RYOH ISHIHARA

Taming Tiny Tornadoes:

Research examines wing shapes to reduce vortex and wake

It's common to see contrails in the sky behind the engines of a jet airplane. What's not always visible is a vortex coming off of the tip of each wing—like two tiny horizontal tornadoes—leaving a turbulent wake behind the vehicle. The wake poses a destabilizing flight hazard, particularly for smaller aircraft that share the same flight path.

Recent AE research demonstrated that, although most wing shapes used today create turbulent wake vortices, wing geometrics can be designed to reduce or eliminate wingtip vortices almost entirely. In the study, the vortex and wake characteristics were computed for three classic wing designs: the elliptic wing, and wing designs developed in classic studies by R.T. Jones and Ludwig Prandt.

"The elliptic wing configuration has been used as the gold standard of aerodynamic efficiency for the better part of a century. We teach our students that it has the optimal loading characteristics and that it's often used when looking at wing efficiency for say, minimizing drag," said AE Assistant Professor **Phillip Ansell**.

In a previous experimental study on optimizing wing configurations, Ansell learned you can gain efficiency of the wing system with a non-elliptic wing profile. "Previous academic studies have shown that, theoretically, there are other designs that actually provide lower drag of a planar wing for a fixed amount of lift generation and wing weight. But what has been missing is an actual apples-to-apples experiment to prove it."

In this new research, Ansell, and his graduate student, **Prateek Ranjan**, used experimental data from the previous study to analyze the three wing configurations. Although the elliptic wing is the most conventional, they found that the Jones or Prandtl wings showed a significant delay in the roll-up process of the wake and a decrease in the swirling strength of the wing tip vortices.

Ansell said the findings, published in the *Journal of Aircraft*, can be used to re-tailor how formation flight is viewed between aircraft, or to develop an ideal configuration for the lift loading for takeoffs and landings, and subsequently reduce the length of separation between aircraft in the same flight path.

Welcome

to the 2018 edition of the AE Newsletter.

I am delighted for you to receive this **UP**DATE on AE. This is only a small sampling of the research and extra-curricular activities in the department, but I believe it will give you a taste of the diversity and quality of the contributions made by AE's faculty and students. For example, on pages 10 and 11, you can read about the caliber and potential of our young faculty members. This year, two received National Science Foundation CAREER Awards, which is remarkable for a department of our size.

Also during this academic year, AE welcomes **seven new faculty members**. For a department of just 21 faculty members, this growth is truly unprecedented. It reflects the confidence that the U of I College of Engineering places in our program, which has experienced a substantial growth in both undergraduate and graduate enrollments over the past decade.

Two of the seven new faculty joined the department this past summer. Check out **Michael Lembeck** and **Jason Merret** among the Faculty Highlights on pages 12 to 14. They are professors of practice who bring to our students the expertise they have built during their successful industry careers in the analysis and design of aircraft and spacecraft systems.

If you would like to receive AE news throughout the year via email, featuring stories about our students, alumni, and faculty, please contact AE's communications coordinator, Debra Levey Larson at dlarson@illinois.edu.

As always, I welcome your comments and suggestions.

Best,

Philippe Geubelle
Abel Bliss Professor and Department Head

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Packing Light for Space Travel

Koki Ho with students

Sending a human into space and doing it efficiently presents a galaxy of challenges. AE Assistant Professor **Koki Ho**, and his graduate students, **Hao Chen** and **Bindu Jagannatha**, explored ways to integrate the logistics of space travel by looking at a campaign of lunar missions, spacecraft design, and creating a framework to optimize fuel and other resources.

Ho said it's about finding a balance between time and the amount of fuel. If time isn't an issue, slow but efficient low-thrust propulsion might be a better choice. Taking advantage of this classical tradeoff, Ho noted that there are opportunities to minimize the launch mass and cost when looking at the problems from a campaign perspective—multiple launches/flights.

"Our goal is to make space travel efficient," Ho said. "One way to do that is to consider multiple missions together—not just launching everything from the ground for every mission like Apollo. In a multi-mission campaign, previous missions are leveraged for subsequent missions."

Ho used data from previously flown or planned missions to create simulated models of a combined campaign. The model can be modified to include heavier or lighter spacecraft, specified destinations, the precise number of humans on board, etc., to validate his predictions about the efficiency.

Ho's research incorporates the concept of propellant depots in space, like strategically located truck stops on a turnpike. He said it is an idea that has been tossed around for a while among scientists. "There are questions about how efficient the depots actually are," Ho said. "For example, if it takes the same or more amount of propellant just to deliver the depot, then what's the point of sending it ahead?"

Ho's studies, published in the *Journal of Spacecraft and Rockets*, provide one solution to this question by leveraging a combination of high-thrust and low-thrust propulsion systems.

"A preparatory mission might be conducted beforehand to deliver into orbit mini-space stations that store fuel, cargo, or other supplies," Ho said. "These craft can be pre-deployed so they are orbiting and available to a manned spacecraft that is deployed later. The cargo/fuel spacecraft can make use of low-thrust technologies because the time it takes to get to its destination isn't critical. Then for the manned spacecraft, we'd use high-thrust rockets because time is of the essence when putting humans in space. This also means that because the fuel is already at these space stations, the actual manned ship doesn't have to carry as much fuel."

Cooler Reentry for Space Crew

Huck Beng Chew and Abhilash Harpale

When a spacecraft reenters Earth's atmosphere, atmospheric friction heats its surface to very high temperatures. At its peak the surface is almost as hot as the surface of the sun. To protect the crew a heat shield is attached to the leading edge of the spacecraft. AE researchers created a model to determine the optimal thickness and composition of the shield material needed.

"The material we used for the model was chosen by NASA for the Orion space capsule and was first used in the 1960s in the Apollo missions. It's a syntactic, silica-phenolic foam called AVCOAT. On the microstructural level, it's comprised of phenolic micro-balloons, like small hollow plastic balls, that are mixed with glass fibers. They are fused together with epoxy glue into a solid form," said lead investigator **Abhilash Harpale**, who conducted the research as a part of his PhD in the Department of Aerospace Engineering.

Harpale said the material is designed to burn away and dissipate the heat. "Because of this, we need to know the exact rate at which it burns to determine the optimum thickness of the heat shield required."

Although Harpale was primarily interested in understanding the atomistic response of the material at temperatures ranging from 440 to almost 4,000 degrees Fahrenheit in the spacecraft's trajectory, when attempting to recreate a data set from the 1960s, he realized that the material response is highly sensitive to the actual microstructure of AVCOAT.

"We needed to consider the size and geometry of the micro-balloons, as well as the proportion of glass fibers, to determine the best recipe to achieve a specific rate of burn on reentry," Harpale said.

According to Harpale's advisor and co-author Associate Professor **Huck Beng Chew**, this is the first model that accounts for the complex microstructure of the heat shield material. The proportion of micro-balloons, glass fibers, and epoxy, can all be varied to determine the best heat shield response. This was not possible before."

AE Professor Deborah Levin, AE PhD student Saurabh Sawant, and Rakesh Kumar, who is from the Indian Institute of Technology in Kanpur, co-authored the study. The work was funded by NASA and published in *Carbon*.

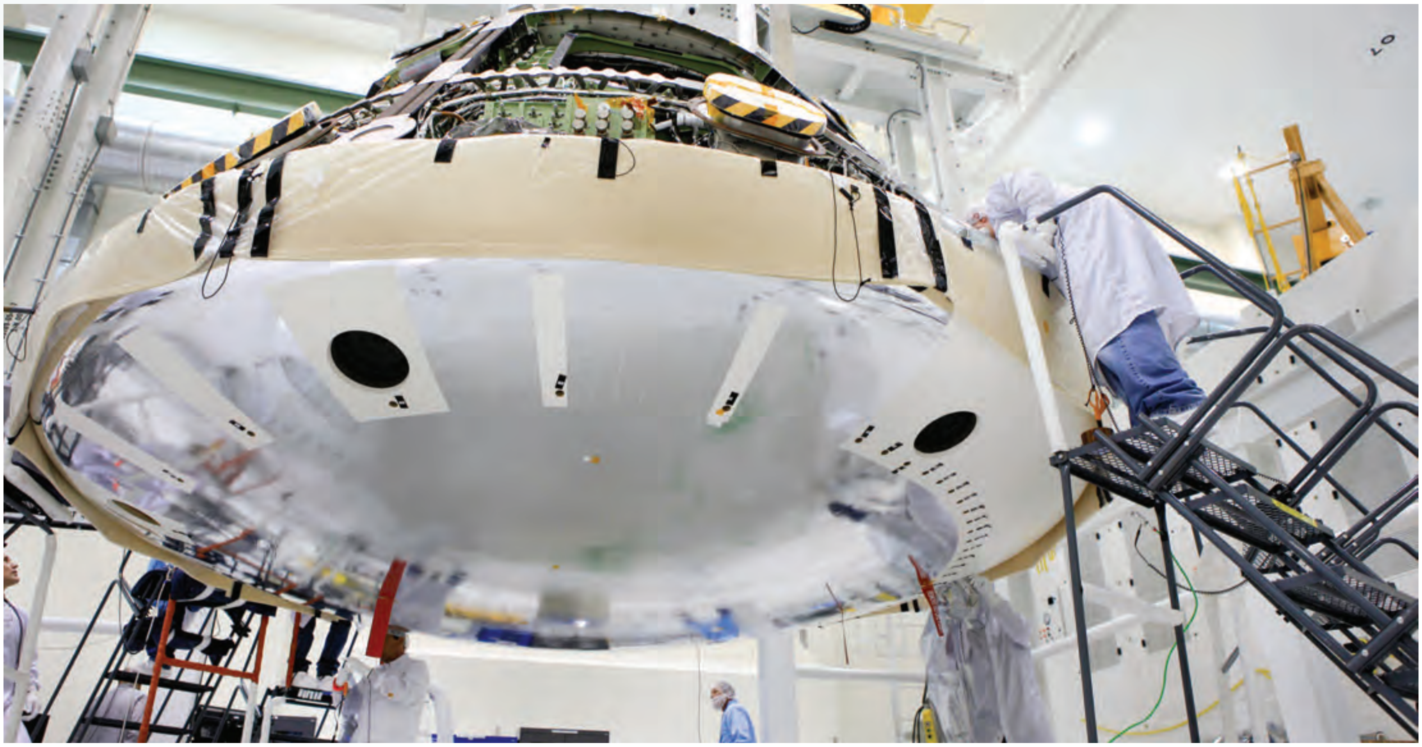


Photo Courtesy of NASA

Once Upon a **Launch**

It had rained the night before the final competition in Huntsville, Alabama, leaving the open field muddy—a factor that ultimately benefited this year's Illinois Space Society NASA Student Launch team.

Andrew Koehler (BS '18) was the team's project manager. "This year, as far as the rocket goes, it was nearly a perfect flight. As far as the payload, unfortunately there was a small problem with the battery, but other than that, the system worked great."

Koehler said this year's team of about 30 students overcame a lot of adversity and some technical challenges. "All three of our competition flights were successful," Koehler said. "For our first flight, we just flew too high. It went to about 6,100 feet, which was too high for the altitude limitation of 5,600 feet. We adapted it by using a smaller motor. Our second test flight flew just a couple of hundred feet under one mile."

This year's competition allowed teams to choose between three payload challenges. "We chose a deployable rover payload. There's a rover inside the rocket, like the Mars Curiosity. After it lands, the rover drives out of the rocket."

Ultimately, battery failure was the team's only real downfall.

"The rover is held inside the rocket with latches. There are batteries that hold the latches in place with servos. If the battery dies, the servo disconnects the latch, which is what happened during the descent in Huntsville at about 1,000 feet altitude."

Unfortunately, waiting too long to launch drained the batteries.

"At the competition, we're not allowed to go the rocket once it's on the launch pad. There were about 10 rockets in the queue ahead of ours, so the rocket was out on the launch pad for about two hours. Next year, we'd like to get higher-quality batteries that will hold their charge longer. It's a problem for real-world missions, too. Batteries and power often drive mission requirements—especially when you're in outer space."

Ever optimistic, Koehler described the silver lining in the failure: The muddy field provided a messy, but cushioned landing for the rover.

"We were worried that when it fell out, it would be shattered into a million pieces, but because it had rained the night before, the ground was fairly soft so it wasn't broken. We recharged the batteries and it was still able to drive."

Koehler's positive attitude reflects a life with a glass that is definitely half-full.

"One of the biggest lessons I learned this year is that things aren't always perfect, but they're often still good. We overcame challenges. We didn't give up when things got difficult. We believed in our skills and knowledge and got the job done."

The 2018 Illinois Space Society NASA Student Launch Team at this year's competition in Huntsville, Alabama.

AE Registered Student Organizations

- Design, Build, Fly
- Student Aircraft Builders
- Illinois Space Society
- Women in Aerospace
- The Satellite Development Organization
- American Institute of Aeronautics and Astronautics
- Illini Aerospace Outreach
- Student Space Systems
- Illinois Robotics in Space

Gift of a Lifetime

A fishing trip to Bull Shoals Lake in Arkansas in his Uncle David's Cessna sparked in 16-year-old **Robert C. Beatty** an enthusiasm for aviation that would last a lifetime. Beatty's cousin Terry Ladage, who was also on the trip, said their uncle let him fly the plane most of the three hours from Springfield, Illinois to Arkansas. Robert flew most of the way home. Ladage said after that one-day adventure, he and Robert talked about nothing but aviation.

After high school, Beatty went on to take classes at the University of Illinois Institute of Aviation, and earn two degrees in aeronautical and astronautical engineering—a BS in '69 and an MS in '71. He spent the majority of his career working in design at McDonnell Douglas and Boeing in Irvine, California.

Beatty died in May 2016 at the age of 68, leaving an estate gift to the Department of Aerospace Engineering for $1.48 million—the largest single donation the department has ever received.

The Department of Aerospace Engineering's Associate Director of Advancement Tim Cochrane said the gift was made to support AE graduate students. "The gift established an endowment fund whose annual income will assist generations of AE graduate students with the creation of multiple fellowships."

Robert C. Beatty with his wife, Mary Jean Hylak, in June 1969 when he received his bachelor's degree from U of I. Photo courtesy of Wilma Beatty and Kevin Beatty, Robert's aunt and cousin.

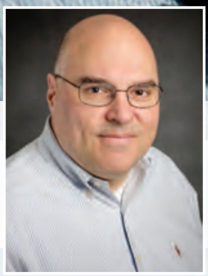
Thank You, Class of '77

The year 1977 was a big one for aeronautics and aerospace—both real and fictional. The Concord made its first commercial flight, the NASA space shuttle had its first test flight, and the first Star Wars film opened in cinemas. In hindsight, it was also a year that a generous class of aerospace engineers graduated from the University of Illinois.

A little over 40 years later, the AE Class of '77 is establishing a scholarship to be named, The Aerospace Engineering Class of '77 Engineering Visionary Scholarship. The EVS scholarship drive is a $100 million College of Engineering initiative to help make attending college more affordable for future generations of students.

Photo courtesy of NASA, July 26, 1977

For more information about ways you can support the department, contact Tim Cochrane at tcochrane@illiinois.edu or 217-333-1149.


John Lambros

Building a **Better Lithium Battery**

AE researchers applied a technique using 3D X-ray tomography of an electrode to better understand what is happening on the inside of a lithium ion battery to ultimately build batteries with more storage capacity and longer life.

When a lithium battery is being charged, lithium ions embed themselves into host particles, typically graphite, that reside in the battery anode and are stored there until needed to produce energy during the battery discharge.

“Every time a battery is charged, the lithium ions enter the graphite, causing it to expand by about 10 percent in size, which puts a lot of stress on the graphite particles,” said AE Professor **John Lambros**. “With each successive charge/discharge cycle of the battery, the host particles begin to fragment and lose their capacity to store the lithium. They may also separate from the surrounding matrix leading to loss of conductivity.

“We wanted to see inside a working anode how the graphite particles expand when the lithium enters them. You can certainly let the process happen and then measure how much the electrode grows to see the global strain—but with X-rays we can look inside the electrode and get internal local measurements of expansion as lithiation progresses.”

Lambros and his team first custom built a rechargeable lithium battery cell that was transparent to X-rays. However, when they made the functioning electrode, in addition to graphite particles, they added another ingredient to the recipe—zirconia particles.

“The zirconia particles don’t absorb or store any lithium ions, but for our experiment, the zirconia particles are indispensable: they serve as markers that show up as little dots in the X-rays which we can then track in subsequent X-ray scans to measure how much the electrode deformed at each point in its interior.”

Lambros said internal changes in the volume are measured using a Digital Volume Correlation routine—an algorithm in a computer code that is used to compare the X-ray images before and after lithiation. “We’ve been using this technique for a decade, but the novelty of this study is that we applied this technique that allows internal 3D measurement of strain to functioning battery electrodes to quantify their internal degradation.”

Joseph F. Gonzalez, Dimitrios A. Antartis, Manue Martinez, Shen J. Dillon, and AE Professor Ioannis Chasiotis co-authored the article. It is published in *Experimental Mechanics* and funded by U of I’s Interdisciplinary Innovation Initiative, a National Science Foundation Graduate Research Fellowship, and the Air Force Office for Scientific Research.

New **Polymer-Curing** Process

Makers of cars, planes, buses—anything that needs strong, lightweight, and heat resistant parts—are poised to benefit from a new manufacturing process that requires only a quick touch from a small heat source to send a cascading hardening wave through a polymer. A research team including AE Professors **Scott White** and **Philippe Geubelle** developed a new polymer-curing process that could reduce the cost, time, and energy needed, compared with the current manufacturing process.

The findings, reported in *Nature*, state that the new polymerization process uses 10 orders of magnitude less energy and can cut two orders of magnitude of time over the current manufacturing process.

"This development marks what could be the first major advancement to the high-performance polymer and composite manufacturing industry in almost half a century," White said. "The materials used to create aircraft and automobiles have excellent thermal and mechanical performance, but the fabrication process is costly in terms of time, energy, and environmental impact. One of our goals is to decrease expense and increase production."

Take, for example, aircraft assembly. For one major U.S. producer, the process of curing just one section of a large commercial airliner can consume over 96,000 kilowatt-hours of energy and produce more than 80 tons of CO_2, depending on the energy source, White said. That is roughly the amount of electricity it takes to supply nine average homes for one year, according to the U.S. Energy Information Administration.

"The airliner manufacturers use a curing oven that is about 60 feet in diameter and about 40 feet long—it is an incredibly massive structure filled with heating elements, fans, cooling pipes, and all sorts of other complex machinery," White said. "The temperature is raised to about 350 degrees Fahrenheit in a series of very precise steps over a roughly 24-hour cycle. It is an incredibly energy-intensive process."

The team is part of the Beckman Institute for Advanced Science and Technology at U of I and includes chemistry professor and Beckman Institute Director Jeffrey Moore and materials science and engineering professor Nancy Sottos. They proposed that they could control chemical reactivity to economize the polymer-curing process.

"By touching what is essentially a soldering iron to one corner of the polymer surface, we can start a cascading chemical-reaction wave that propagates throughout the material," White said. "Once triggered, the reaction uses enthalpy, or the internal energy of the polymerization reaction, to push the reaction forward and cure the material, rather than an external energy source."

Left to right: Philippe Geubelle, Scott White, Nancy Sottos, and Jeffrey Moore.

The team has demonstrated that this reaction can produce safe, high-quality polymers in a well-controlled laboratory environment. They envision the process accommodating large-scale production due to its compatibility with commonly used fabrication techniques like molding, imprinting, 3-D printing, and resin infusion.

The work was supported by the U.S. Air Force Office of Scientific Research.

Grace Gao receives NSF CAREER award for UAV research

Self-driving cars and unmanned aerial vehicles are growing in popularity. To safely navigate in these autonomous vehicles, reliable and accurate information from the Global Positioning System is critical. AE Assistant Professor **Grace Gao** received funding for her research on the subject through the National Science Foundation Faculty Early Career Development (CAREER) Program.

Gao's project will study, not just the accuracy of GPS information, but also its integrity. "Integrity, in this case, means that you have a certain confidence level of the accuracy," Gao said. It's like someone qualifiying their answer to a question by saying that they are 99 percent confident that they are correct. Gao wants to see the same sort of measurement for GPS coordinates for UAVs.

Although positioning integrity has been well addressed in the Federal Aviation Administration to guide and land commercial aircraft, Gao said it has not been well studied for many emerging autonomous navigation positioning integrity. And unfortunately, the FAA systems won't work in many UAV circumstances.

"UAVs, such as drones and small aircraft, autonomous cars, and even regular cars using GPS navigation, often have to navigate in urban environments where GPS signals can be blocked or reflected by buildings," Gao said.

There has been a lot of work done on trying to make the navigation positioning more accurate, but Gao's research seeks to find a better way to assess and monitor the confidence level and to quantify the accuracy of that confidence level. "To achieve that, we use multiple sensors. We pair up GPS with camera vision and other sensors. Traditionally, people try to eliminate the signal reflection off of buildings, treating it as an error source. But instead of trying to mitigate or get rid of what we call multipath we want to utilize that signal as an additional navigation signal."

NSF CAREER proposals are written by individual early-career investigators and include research and education activities that are integrated, innovative, and ambitious. Gao has already demonstrated innovation in the novel method she developed to test a drone's accuracy in an urban environment without the danger of injuring pedestrians, buildings, cars, or other structures.

"We didn't want to simulate the reflection off of buildings," Gao said. "We wanted real-world data." To do that, she flew the drone through the streets of U of I's campus town, while safely tethered inside a cage made of netting attached to a frame, all on the back of a tow truck. Gao said she strives to do research that it is at the connection between academic value and real-world application.

Grace Gao, second from left, with her students.

Kai James gains NSF CAREER Award to study advanced computational design

When designing mechanisms that move and work together, the variables may seem unlimited. But in fact, there is likely a design that optimizes the efficiency of the mechanism. It's like finding the sweet spot for the fulcrum on a pair of pliers to get maximum force. AE Assistant Professor **Kai James** is working to design a computer algorithm to find that point of greatest efficiency. And, he is using the science to attract more underserved students to STEM—science, technology, engineering and math.

James' project is funded through the National Science Foundation Faculty Early Career Development (CAREER) Program.

"I want to create a framework where algorithms could, starting with a black box, generate an entire design concept for compound machines that contain multiple components," James said. "In addition to optimizing the structure of each component—its shape, geometry, and material layout—the algorithm can also optimize the connectivity between the components. So the algorithm, for example, will tell us where a hinge should be placed to maximize mechanical advantage."

James explained that the algorithm will generate a series of numbers, resulting in a mathematical description of the design. After it is interpreted, a corresponding computer-aided design file, or CAD, is created that contains a 3D representation of the design.

"What's new about this project is that the types of algorithms we're using have previously only been applied to the designs of structures—meaning that the system you're creating contains a single part," James said.

James said, this level of physics is what a first-year graduate student would likely understand, but the science will be modified to be accessible to undergraduate students.

The NSF funding will make possible a series of workshops every other week through 2023. The workshops will be less formal than an actual course.

Undergraduate students who participate in the workshops don't need to be math, science, or engineering majors. James will work with the university Office of Minority Student Affairs to market the program to attract students who wouldn't normally gravitate toward STEM disciplines. The outcome of the workshops will be activities for K-12 visitors to the Engineering Open House at the University of Illinois the following spring.

Rather than being theoretical, the information students receive will be focused on applications, taking a high-level look at optimal design. "It will look at some new breakthroughs in the research community to whet the students' appetite for STEM," James said. "There will be some technical instruction as well. They'll learn to understand some of the mathematics that govern these algorithms and design strategies."

Faculty Highlights

Phillip J. Ansell (Assistant Professor / PhD, University of Illinois, 2013) received the Research Office Young Investigator Award, established a new AFOSR-sponsored international research partnership with École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, and served as the technical chair and organizer for the first AIAA/IEEE Electric Aircraft Technologies Symposium in July.

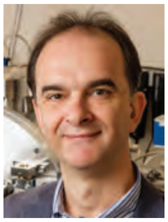
Maciej Balajewicz (Assistant Professor / PhD, Duke University, 2012) received an Air Force Office of Scientific Research grant in computational mathematics. He presented at the Conference on Model Reduction of Parametrized Systems IV in Nantes, France.

Lawrence A. Bergman (Research Professor, Professor Emeritus / PhD, Case Western Reserve University, 1980) was an invited speaker at the Symposium on Noise, Vibration and Harshness sponsored by the Institution of Mechanical Engineers, in Birmingham, UK. His talk was titled "Targeted Energy Transfer: Intentional Use of Strong Nonlinearity in Design." He also gave an invited seminar in the College of Engineering at the Northwestern Polytechnical University in Xi'an, China, titled "Some Examples of Complexity-induced Coexistence of Traveling and Standing Waves in One-dimensional Linear Continua."

Daniel J. Bodony (Blue Waters Associate Professor/ PhD, Stanford University, 2005) received the College of Engineering Everitt Award for Teaching Excellence. He received two new grants: Aeroelastic Resonances in Extreme-Speed Turbochargers in Unmanned Air Vehicles and Experimental and Computational Investigation of the Response of Flexible Panels to Shock-wave/boundary Layer Interactions in Hypersonic Flow. Bodony gave invited talks at: ONR-NAVAIR-Caltech Workshop on Jet Noise Reduction, Caltech, Pasadena, Cal.; AFOSR Workshop on Fluid-Structure Interaction, UNSW Canberra, Australia; and Swedish Engineering Research Council TRANSEP Research program in Stability, Transition and Control, KTH, Stockholm, Sweden.

Timothy W. Bretl (Associate Professor / PhD, Stanford University, 2005) received the Campus Award for Excellence in Undergraduate Teaching and the College of Engineering Teaching Excellence Award. He was also named the College of Engineering Rose Education Innovation Fellow. His three most recent PhD graduates have taken positions at Cornell University (Andy Borum), Microsoft Research (Joseph DeGol), and the Wadsworth Center (James Norton).

Rodney L. Burton (Professor Emeritus / PhD, Princeton University, 1966) received his 11th patent in space propulsion. He also invented the AE/CU Aerospace CubeSail satellite scheduled for launch in 2018.



Ioannis Chasiotis (Professor / PhD, California Institute of Technology, 2002) authored/co-authored nine published papers in 2018. He continues as Editor in Chief of *Experimental Mechanics.*

Huck Beng Chew (Associate Professor / PhD, National University of Singapore, 2007) was an author on papers published this 2018 in *Carbon, Materials Science and Engineering,* and *Philosophical* magazine and was promoted from assistant to associate professor.

Bruce A. Conway (Professor Emeritus / PhD, Stanford University, 1981) is in the final year of a three-year contract with the Air Force Research Laboratory, Eglin AFB titled "Real-Time Optimal Control for HSSW Guidance." Co-author Christian Chilan presented their paper, "Optimal Nonlinear Feedback with Feedforward Control of High Speed Aerospace Vehicles Using a Spatial Statistical Approach" at the 2018 AAS/AIAA Astrodynamics Specialist Conference. Conway is associate editor for the *Journal of Guidance, Control & Dynamics* and the *Journal of Optimization Theory and Applications.*

J. Craig Dutton (Professor / PhD, University of Illinois, 1979) co-authored a paper published this year in the *AIAA Journal* and has a NASA research grant to study turbulent compressible mixing layers for computational fluid dynamics and an Army grant to study the structure of high-speed compressible flows.

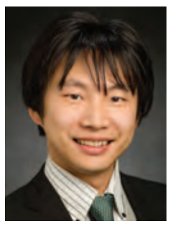
Gregory S. Elliott (Professor / PhD, The Ohio State University, 1993) gave an invited presentation, along with Jonathan Freund, at the AIAA Applied Aero Special Session in Atlanta, Georgia on Collaborative Ground Test and Computations. He is co-PI on grants from DOE, NASA, and ARO on topics including advanced laser diagnostics, high-speed flows, and plasma- assisted combustion.

Jonathan B. Freund (Donald Biggar Willett Professor of Engineering / PhD, Standford University, 1998) received the U of I Excellence in Faculty Mentoring Award. He also directed the Center for Exascale Simulation of Plasma-coupled Combustion to complete state-of-the-art multiphysics prediction.

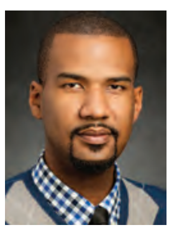
Grace Xingxin Gao (Assistant Professor / PhD, Stanford University, 2008) received five grants and Best Presentation of the Session Award at the ION GNSS+ Conference (together with her PhD student, Sriramya Bhamidipati). She also received the U of I Engineering Council Award for Excellence in Advising and was on the list of Teachers Ranked as Excellent by Their Students. In addition, she received a National Science Foundation CAREER Award. See page 10.

Philippe H. Geubelle (Department Head and Abel Bliss Professor of Engineering / PhD, California Institute of Technology, 1993) gave seminars at four Texas universities as the invited speaker for the Southwest Mechanics Lecture Series. He also co-authored a paper on a new polymer-curing process that appeared in *Nature.* See page 9.

Harry H. Hilton (Professor Emeritus /PhD, University of Illinois, 1951) was an invited speaker at a symposium entitled "From Waterloo to the World and Back" at the University of Waterloo in Ontario, Canada.



Koki Ho (Assistant Professor / PhD, Massachusetts Institute of Technology, 2015) served as the Chair of the AIAA Space Logistics Technical Committee and led a research project on modeling and optimization for large-scale satellite constellation design in collaboration with Mitsubishi Electric Corporation. He also received two grants/contracts from NASA on space commercialization and lunar resource utilization.

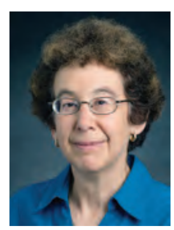


Kai James (Assistant Professor / PhD, University of Toronto, 2012) gave an invited lecture in the University of Michigan, Department of Aerospace Engineering Graduate Seminar Series. He also received three grants totaling over $800,000 and a National Science Foundation CAREER Award. See page 11.

John Lambros (Professor and Donald Biggar Willett Professor of Engineering / PhD, California Institute of Technology, 1994) received the Society of Engineering Mechanics Hetényi Award and the Society of Engineering Mechanics P.S. Theocaris Award. He was also named Director of the Advanced Materials Testing and Evaluation Laboratory (AMTEL) and President-elect of the Society for Experimental Mechanics.

Cedric Langbort (Associate Professor / PhD, Cornell University, 2005) gave semi-plenary talks at the 2nd Symposium on Control of Network Systems at Boston University and the 7th Midwest Workshop on Control and Games at Michigan State University. He lectured at two international winter and summer schools on smart cities and transportation in Singapore and Sweden. Together with his students and postdocs, he conducted work on the use of strategic information transmission in the context of traffic control/congestion alleviation, cyber-security, and algorithmic transparency/auditing.

Michael Lembeck (Associate Professor of Practice / PhD, University of Illinois, 1991) joined the AE department in August 2018 to lead the senior design teams and serve as the Director of the Laboratory for Advanced Space Systems at Illinois (LASSI).

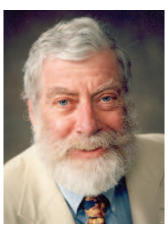


Deborah Levin (Professor / PhD, California Institute of Technology, 1979) co-authored seven articles in 2018 that appeared in *Physics of Fluids, Journal of Computational Physics, Computers and Fluids*, *Journal of Physical Chemistry C., Physical Review E., Aerospace*, and *Carbon.*

Faculty Highlights

Jason Merret (Associate Professor of Practice / PhD, University of Illinois, 2004) joined the AE department in July 2018 to lead the Aerospace Systems Engineering program. He is a recently named AIAA Associate Fellow and serves on the AIAA Aircraft Design Technical Committee. This past year, he participated in Design Build Fly as an Organizing Committee Member and was a flight line judge at the fly-off this past spring.

Marco Panesi (Associate Professor / PhD, von Kármán Institute for Fluid Dynamics and Universita degli Studi di Pisa, 2009) was promoted from assistant to associate professor. He was also awarded several research grants that total just over $2 million.



John E. Prussing (Professor Emeritus / Sc.D., Massachusetts Institute of Technology, 1967) authored the book *Optimal Spacecraft Trajectories,* published by Oxford University Press.

Zachary R. Putnam (Assistant Professor / PhD, Georgia Institute of Technology, 2015) co-authored five technical conference papers with his students in 2018. He served as the Entry, Descent and Landing Systems session chair at the AAS Guidance and Control Conference in Breckenridge, Colorado and spoke at the SmallSat short course at the 15th International Planetary Probe Workshop in Boulder, Colorado.

Joshua L. Rovey (Associate Professor / PhD, University of Michigan, 2006) led a research project that identified species never before seen in the plume of electrospray thrusters. He also gave invited talks at the Micropropulsion and CubeSat Workshops in Washington, D.C. and Bari, Italy.

Michael S. Selig (Research Professor and Professor Emeritus / PhD, The Pennsylvania State University, 1992) performed low Reynolds number airfoil research and wind tunnel testing for Facebook's Aquila solar-powered airplane. His Segmented Ultralight Morphing Rotor research with collaborators from five other institutions (led by University of Virginia) was featured in *Scientific American* online and on the front cover of the *Wind Energy* journal. The SUMR team presented at the ARPA-E Congressional Showcase in Washington, D.C.

Huy T. Tran (Research Assistant Professor / PhD, Georgia Institute of Technology, 2015) was named Fellow in the Air Force Research Lab Summer Faculty Fellowship Program at AFIT. He gave an invited talk at AFIT on "Towards Understanding Patterns in Critical Infrastructures with Social Media and Public Operational Data." He also gave talks at the IEEE SysCon and AIAA Aviation conferences on statistical and machine learning methods for air traffic management.

Petros G. Voulgaris (Professor / PhD, Massachusetts Institute of Technology, 1991) received three NSF grants, one NASA, and one ZJUI for the period 2017-2020 totaling approximately $3 million. His paper, "Multilayer Compute Resource Management with Robust Control Theory," with PhD students Raghavendra Pradyumna Pothukuchi and Sweta Yamini Pothukuchi, and Professor Josep Torellas, won the ACM Student Research Competition in the International conference on Parallel Architectures and Compilation Techniques. Voulgaris was also an invited plenary speaker at the International Conference in Nonlinear Problems in Aviation and Aerospace, World Congress, held in Yerevan, Armenia.

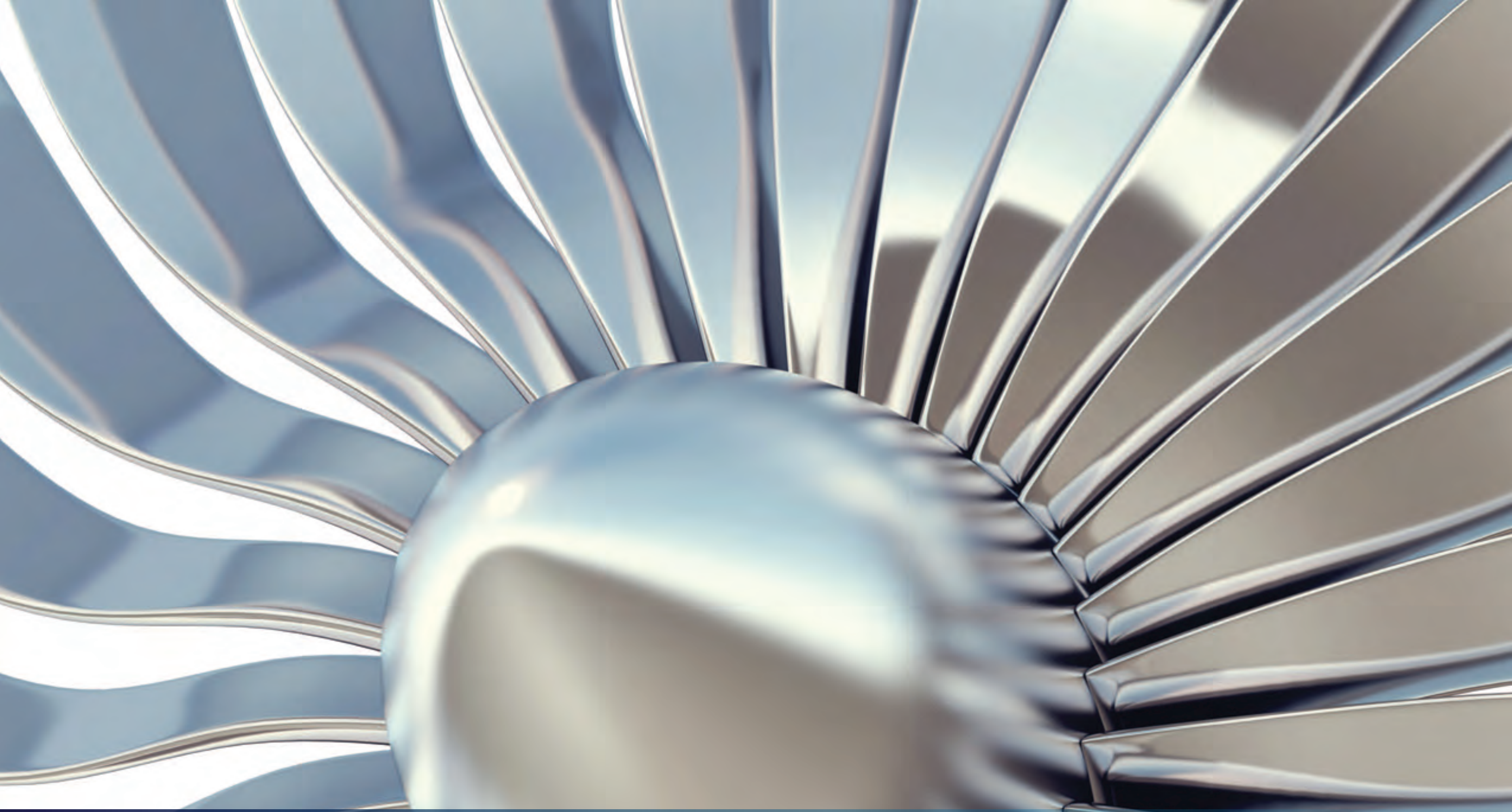
Brian S. Woodard (Director of Undergraduate Programs / PhD, University of Illinois, 2012) received the American Institute of Aeronautics and Astronautics Teacher of the Year Award and led a major series of international wind tunnel test campaigns to better understand the aerodynamic performance of a swept wing with an ice accretion.

In memoriam

Steven J. D'Urso

Scott R. White

The scholarly and personal contributions from Steven J. D'Urso and Scott R. White, members of our faculty who passed away this year, will be greatly missed.



Faculty Research Areas

Aeroacoustics
Daniel Bodony
Jonathan Freund

Aeroelasticity
Maciej Balajewicz
Lawrence Bergman
Daniel Bodony
Philippe Geubelle
Harry Hilton
Kai James

Aerospace Materials
Ioannis Chasiotis
Huck Beng Chew
Philippe Geubelle
Harry Hilton
John Lambros

Aerospace Structures
Maciej Balajewicz
Lawrence Bergman
Harry Hilton
Kai James

Aerospace Systems Design and Simulation
Phillip Ansell
Grace Gao
Harry Hilton
Koki Ho
Kai James
Jason Merret
Zachary Putnam
Michael Selig
Huy Tran

Applied Aerodynamics
Phillip Ansell
Maciej Balajewicz
Daniel Bodony
Gregory Elliott
Jason Merret
Michael Selig
Brian Woodard

Astrodynamics
Bruce Conway
Koki Ho
John Prussing
Zachary Putnam

Combustion and Propulsion
Daniel Bodony
Rodney Burton
Gregory Elliott
Jonathan Freund
Deborah Levin
Marco Panesi
Joshua Rovey

Computational Fluid Dynamics
Maciej Balajewicz
Daniel Bodony
Jonathan Freund

Controls, Dynamical Systems and Estimation
Maciej Balajewicz
Timothy Bretl
Cedric Langbort
Petros Voulgaris

Experimental Fluid Mechanics
Phillip Ansell
J. Craig Dutton
Gregory Elliot

Flow Control
Phillip Ansell
Daniel Bodony
J. Craig Dutton
Gregory Elliott
Jonathan Freund

Global Positioning Systems
Timothy Bretl
Grace Gao

Hypersonics
Deborah Levin
Marco Panesi
Zachary Putnam

Nanosatellites
Rodney Burton
Koki Ho
Michael Lembeck
Zachary Putnam
Joshua Rovey

Space Systems
Timothy Bretl
Rodney Burton
Grace Gao
Koki Ho
Michael Lembeck
Deborah Levin
Zachary Putnam
Joshua Rovey

Unmanned Aerial Vehicles
Phillip Ansell
Timothy Bretl
Gregory Elliott
Grace Gao
Michael Selig

ILLINOIS
Aerospace Engineering
COLLEGE OF ENGINEERING

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104 South Wright Street, MC 236
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AE By the Numbers

RANKINGS

6 ranked undergraduate program in the nation
8 ranked graduate program in the nation

FUNDING AND FACILITIES

$9.4 million research expenditures
25+ laboratories and research centers
7 interdisciplinary research centers
3,800 sq. ft. new educational labs (coming 2019)

FACULTY

21 faculty members/7 new starting in 2018-19
17 faculty ranked excellent by their students
50+ current research grants
2 NSF Career awards in 2018

STUDENTS

32.3 average ACT score of incoming freshmen
518 undergraduate students
198 graduate students
9 registered student organizations

GRADUATES

$69,933 average starting salary with a BS
4,450 alumni worldwide, including 4 astronauts