Aerospace Engineering/**2023**

UPDATE

Elevate society. Create wonder.

Left: PhD student Ivan Wu, AE Dept. Head Jonathan Freund, Executive Associate Dean and AE Professor Philippe Geubelle, CEO of Continuous Composites Inc. Dean Tyler Alvarado, Founder Professor of Engineering Jeff Baur, and AE undergraduate student Morgan Scott at the ribbon cutting. Right: CF3D printer

Paradigm-changing composite technology

AE's composite processing and manufacturing lab has a new continuous fiber 3D printer by Continuous Composites. It is the first to be installed outside the company and in academia.

According to Founder Professor of Engineering **Jeff Baur**, "This is a paradigm-changing composite technology because it allows you to create structures with complex shapes that have mechanical properties approaching those of traditional aerospace composites. Currently, high-performance composites are made by laying resin-filled fabric or fibers by hand and cooking them for a long time in a pressure cooker called an autoclave. Now, we lay the fibers by robot, snap-cure them into shape and then cure them in an oven in a fraction of the time."

Baur said the CF3D printer will be used in research on multiple levels.

"Imagine you have a new fiber, a new reinforcement, maybe a bio-derived fiber and you want to use it to make a structural composite. This machine should be able to handle that. At a completely different level, we can use this machine to make big structures like wind tunnel prototypes or structures that can be deployed in space. When you print with structural composites, your prototype can be at the performance level you need for the final structure."

The printer comes with a unique industry/academic partnership. Continuous Composites, Inc. provides some supplies, tech support, and hardware updates to the lab. In return, Baur's lab will provide feedback about the equipment so they can make improvements for future customers.

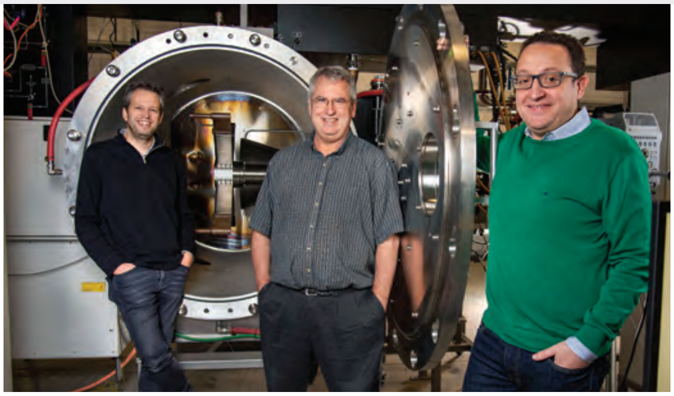
New plasma wind tunnel goes to the extreme

The new Plasmatron X tests materials to determine their ability to withstand the extreme conditions of hypersonic flight. It is the largest inductively coupled plasma wind tunnel in the United States.

Plasmatron X is part of The Grainger College of Engineering's multidiscipline Center for Hypersonics and Entry Systems Studies. AE's **Marco Panesi** and director of CHESS said, "Our mission is to address all the challenges of hypersonic flight. Plasmatron X is critical because thermal protection is one of the weakest links in hypersonic systems."

In Plasmatron X energy is added to gas to the point that it ionizes and becomes plasma, mimicking hypersonic flight and atmospheric reentry conditions. In an inductively coupled plasma wind tunnel, there is no contact between the high-temperature plasma and electrodes.

AE's **Francesco Panerai** said Plasmatron X is a superior research tool. "The absence of contact prevents contamination, creating a pristine environment that is the same one that vehicles find when they travel high up in the atmosphere. The result is a much better understanding of materials' behavior, enabling materials-science-grade type of testing."



AE faculty members Marco Panesi, Greg Elliott, and Francesco Panerai at Plasmatron X facility.

AE's **Greg Elliott** noted that the Plasmatron X size and long runtimes are another unique feature. "The Plasmatron X produces a high enthalpy jet over a larger area and for longer run times than comparable facilities. We can operate the facility continuously for several minutes and even hours allowing us to test multiple models or material samples in a single run. This also allows us to change flow properties during a run to better mimic the varying conditions encountered during a hypersonic vehicle flight or reentry profile." Elliott said.

Additional members of the CHESS executive team are AE's **Daniel Bodony** and AE affiliates and Mechanical Science and Engineering's faculty **Tonghun Lee** and **Kelly Stephani**.

Greetings

I'd like to share with you the goals we set for our aerospace community.

*We educate the future leaders of aerospace engineering, so they can advance human knowledge, **elevate society**, and continue a tradition of **creating wonder.***

To do this we:

Build an inclusive environment that draws excellence from the widest possible talent pool and has the broadest positive impact on society.

Provide an immersive hands-on residential learning experience with our courses and student groups.

Offer flexible local and remote options for professionals to advance their expertise in new and traditional areas.

Develop the teamwork skills needed for work on integrated projects.

Teach the rigorous fundamentals of flow, mechanics, materials, dynamics, and all the subdisciplines that impact modern aerospace engineering.

Cultivate an expert faculty, internationally renowned for their research impact and engaged in our educational mission.

Tackle current and emerging challenges of aerospace engineering, such as sustainability, hypersonics, autonomy, space systems, aerospace manufacturing, and next-generation computation.

Grow aerospace talent to meet industry needs.

Leverage our alumni family to drive our continuous improvement and commitment to excellence.

As you enjoy this year's ***UPDate***, I hope you'll see how we **elevate society and create wonder.**

Jonathan B. Freund
Donald Biggar Willett Professor and Head

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

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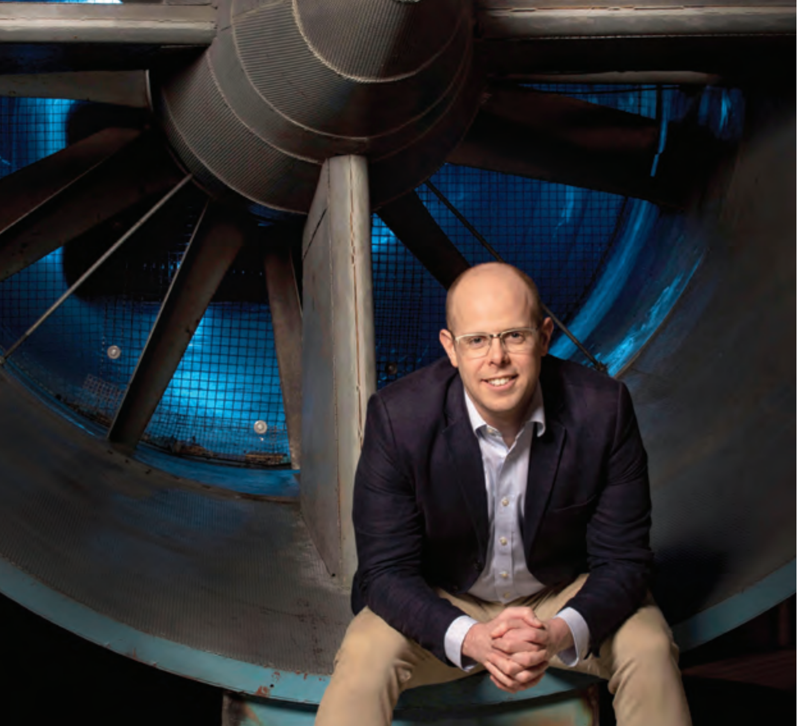
On the cover: PhD student **Henry Varona**, advised by **Francesco Panerai** and **Greg Elliott**, uses a McKenna burner to test carbon fiber based thermal protective materials.



New Center for **Sustainable Aviation**

Conversations about making aviation more sustainable typically land on reducing greenhouse gas emissions and the reliance on fossil fuel resources as top priorities. AE's **Phillip Ansell** says, although these factors are the foundational underpinning of the sustainable aviation field, the discussion also needs to be much broader than that.

As the director of the new Center for Sustainable Aviation, Ansell is taking a holistic approach to the problem by leveraging expertise from a broad range of disciplines in academia, industry, and government.

"The more you look at the sustainable aviation challenge, the more you realize it touches a much broader energy ecosystem than just an airplane," Ansell said.

"Alternative fuels and fully electric power systems are still a long way from being a viable replacement for the nearly 100-billion gallons of jet fuel currently used by global aviation every year. We can't leave this problem on the table for our children to solve," Ansell said.

Ansell described the three-prong philosophy for the center as meeting the needs of the economy, the environment, and society through future developments.

"To be truly sustainable, aviation solutions must be economically viable and competitive," he said. "Technically, we need to look at what role aviation serves in future transportation markets, how these demands can be coupled to be economically viable under fully renewable energy pathways, and how aircraft should be designed as a result," he said.

DART deflected an asteroid, but by how much?

In September 2022, NASA successfully conducted the double asteroid redirection test. A team of scientists including AE's **Siegfried Eggl** and his PhD students **Rahil Makadia** and **Bhaskar Mondal** analyzed DART mission data and calculated the momentum transferred to the target asteroid on impact. They found it to be greater than expected—changing the period of Dimorphos' orbit by 33 minutes. The larger momentum transfer was due to the recoil created from streams of particles produced by the impact.

"The smaller asteroid of the binary Didymos, Dimorphos, that was hit by the DART spacecraft is basically a rubble pile, so I wasn't surprised at the larger quantity of ejecta the impact created," Eggl said.

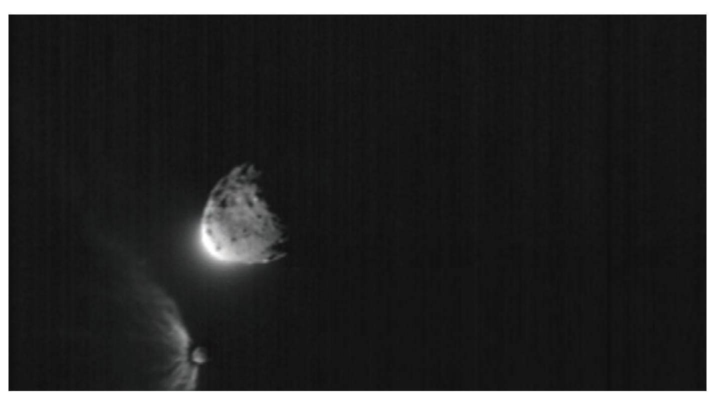
Before the impact, NASA didn't know how asteroids would react to a kinetic impact making it difficult to estimate the momentum transfer required to deflect their orbits.

"Prior to DART we tried to derive all the deflection predictions based on first principles, but we didn't have a single, actual data point. Now we have that and can compare which results match and which ones give us a better understanding, to make better predictions in the future."

Eggl has worked on DART since 2013. "A lot of the work I do is predictive in nature and yet to be validated. In that respect, DART was unusual. The mission had a quick turnaround, thanks to the well-prepared, international team.

"I think what we also learned is that if people work together, we can achieve amazing things, like to actually deflect an asteroid."

The studies, "Momentum Transfer from the DART Mission Kinetic Impact on Asteroid Dimorphos," by Andrew F. Cheng, et al., and "Ejecta from the DART-produced active asteroid Dimorphos" by Jian-Yang Li and other coauthors, included Rahil Makadia are published in the journal *Nature.*



CREDIT: ASI/NASA

Image taken just after the DART spacecraft's closest approach to the Dimorphos asteroid.

Juniors lead senior design teams

Top: Illustration of Valkyrie in flight.
Bottom: Firehawk

Two senior design teams were awarded second and third place in AIAA's 2022 Undergraduate Team Aircraft Design Competition. Although it is a course typically taken during a student's senior year, both winning teams were led by juniors.

This year's challenge was to design a responsive aerial firefighting aircraft to quench the growing number and intensity of annual wildfires.

Team Njord took second place for their design called Valkyrie. Team lead **Macy Nanda** said "A purpose-built firefighter with all the specifications that AIAA outlined is very hard to justify practically and financially because it's so niche."

To address the issue, Nanda said the team added extra functionality to make Valkyrie more marketable, such as the ability to serve as a cargo aircraft when not needed for firefighting.

Team Albatross was awarded third place for their design called Firehawk. Team lead **Andy Strubhar** said one of the main technical challenges of this year's project was how to carry enough water/fuel retardant in the aircraft to meet the goal set by AIAA.

"The team had to consider the shifting or sloshing of the liquid during flight, the changing characteristics during a payload drop, such as over a fire, the changing weight distribution of the aircraft as the payload was loaded into the tanks, and many other issues."

Strubhar said the project brought together all the undergraduate aerospace curricula.

"Working on a full-stack project like this required us to connect each of those separate classes back together. I learned how the disciplines interact with and depend on one another to a deeper level."

AE's **Jason Merret**, who teaches the senior design class, said "In the fall class Macy and Andy were two of the quietest students, but in the second semester I saw them spring out of their shells to become effective leaders."

Members of Illinois Space Society at launch of Intrepid III

Third time's the charm for **student rocket**

A rocket named Intrepid III might imply that it's the third in a series of successful rockets. But the truth is, Intrepid III was born out of the failed launches of Intrepid I and II. The "III" reflects the determination and resiliency of the students who overcame two devastating failures with one outstanding success.

"Intrepid I was unfortunate," said **Harry Zhao**, AE senior and technical director for the Illinois Space Society rocket. "After it exploded, we noticed uneven burning. Purdue's rocket failed for the same reason, so the company gave us a free replacement motor.

"Intrepid II suffered from fin failure," Zhao said. "It reached Mach 1.3, broke the sound barrier, then the fins sheared off. It was our first time trying this type of fin attachment and with the extreme forces the rocket experienced, it was clear we needed to go back to the drawing board."

From that failure, the team modified the rocket to include four fins and more reinforcement.

In June, 31 team members traveled to New Mexico as Intrepid III competed among over 150 rockets at the Intercollegiate Rocket Engineering Competition.

"Intrepid III reached a staggering height of 29,049 feet, giving us 2nd place in the 30K Commercial Off the Shelf Components category," said AE senior **Sebastian Macias** and the team's project manager. "And every student-developed component on board the rocket was successful, from the reefing recovery system deploying, to the controls flaps bringing the altitude down, and the nosecone and fins withstanding Mach 1.7."

Sparked by fantasy, **student seizes real-life opportunities**

Sophie Pieta has seen the film "Top Gun Maverick" seven times, so far. The film opens with Tom Cruise's character test flying an experimental hypersonic vehicle. This summer, Pieta interned at Hermeus in Atlanta, Georgia—a company developing a real-life version of Hollywood's fictitious Darkstar vehicle.

Pieta already has an impressive list of fellowships and internships during her first three years as an AE undergrad. "I've hopped from one thing to the next. Every four months I'm in a different place and I'm having a blast."

She attributed the string of opportunities to two classes she took in her first year on campus.

"In Engineering 100 fall semester I was new to aerospace, so I let the others in my group pick hypersonics as the topic for our final presentation. I thought, man, this is really cool."

That spring in Computer Science 101, Pieta learned from her professor that the Center for Exascale-enabled Scramjet Design was hiring for the summer. She applied, got the job, and spent the summer working on a research project while becoming proficient with Python and Github.

Pieta then applied for a very competitive fellowship and didn't get it. Disappointed, but undeterred, she applied for a similar program and was accepted. The Zed Factor Fellowship, included a summit in Washington, D.C. for professional development and an internship at Astra in Alameda, California in propulsion development.

"I learned a lot about propulsion at Astra, but I also had a couple of data analysis projects—taking in hot fire engine data and turning it into color-coded graphs." She said it was that aspect of the work that continued the theme of programming in her education. "I think that's what gave me the qualifications to work at SpaceX this past semester as a Falcon engineering intern and do a lot more of the data routing."

Although Pieta said she found the work at SpaceX interesting, the experience solidified for her that she prefers to have her hands on hardware.

"To put it childishly, I want to be where the things go boom," she said. "There's a lot you can do with engines like analysis and design. It's just all in a pretty little package that you can also set on fire. I love it."

Pieta has also received a number of scholarships, including an Engineering Visionary Scholarship in the spirit of the late Professor **Scott R. White's** deep commitment to providing students undergraduate research opportunities. Pieta said she is extremely grateful for the financial assistance scholarships have provided.

"It gave me the financial freedom to pursue non-academic interests," she said. Pieta was on the university rowing team for two years, getting up at 4:30 every morning to row, then back to campus four hours later. "It was intense, but it gave me an awesome community on campus, and I think that's important—to have a community outside of the academics."

Pieta with the UIUC rowing team, (wearing an orange visor, third from the left), at the head of the Charles Regatta in Boston, Massachusetts in October 2021.

***For information about scholarships and other ways you can support the department,** contact Tim Cochrane at tcochran@illinois.edu or 217-333-1149.*

Sophie Pieta while on an internship with SpaceX

When life alters **your academic path**

Young demonstrates a rocket motor on a rocket thrust stand to a group of Illinois Aerospace Institute summer camp students.

Top: Young at UT Austin commencement in 1992
Bottom: Christopher Young outside Talbot Lab during commencement weekend in May 2022

In 2022, **Christopher Young** completed something he started 35 years earlier. At the age of 53, Young earned a BS in aerospace engineering. He is candid about the ways his life unfolded and his original career plans derailed, while also proud of what he has accomplished.

At 18, he began working on a BS in aerospace at the University of Texas Austin, joining the Navy ROTC to pay for his education.

“My plan was to be an engineer in the Navy for an initial tour, get out, and get an engineering job,” Young said. “Unfortunately, I didn’t hit UT running hard enough. I wasn’t the best engineering student.”

To get a commission in the Navy, Young had to get out of engineering.

“As a junior, I pivoted to economics. When you transfer from engineering to liberal arts, you pick up a lot of extraneous credits, so I wound up with minors in math and aerospace engineering.”

The pivot meant his degree took more than four years, but he did it, then served in the Navy for three and a half years as a surface warfare officer. That’s when a new reality changed his plans again.

“My significant other at the time became pregnant with twins, so I had to find a different job fast,” Young said. With roots in Illinois, Young joined the Champaign Police Department. He served as a patrolman and bomb technician for 23 years.

“I liked police work, but I didn’t love it. My biggest problem was the lack of mental stimulation,” he said. “Working on the bomb squad fed that technical brain thing I craved.”

Prior to retirement, Young began planning how he could finish what he started at UT. He took one course per semester at Parkland Community College while still working full time as a police officer. At the age of 50, Young was accepted into UIUC’s AE undergrad program.

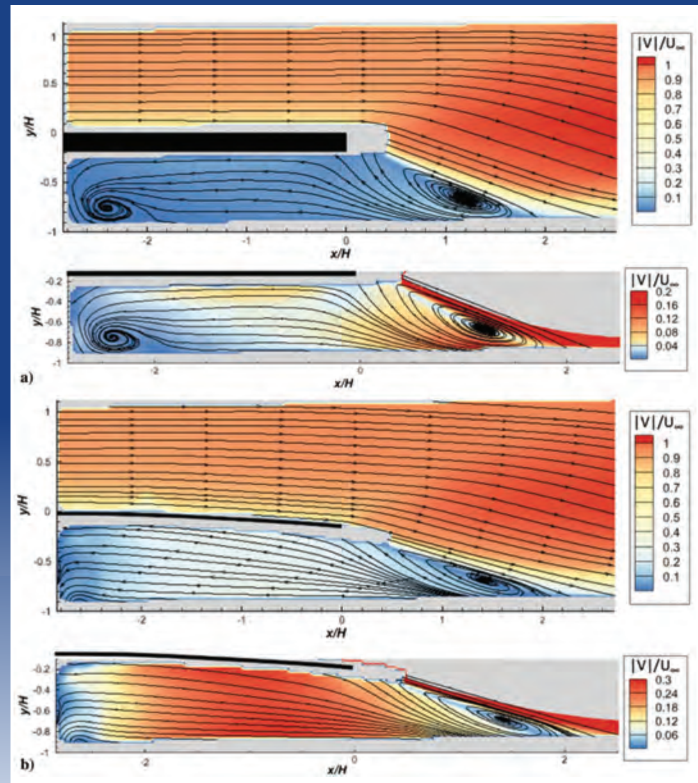
“One of my goals in life was to touch something that went into space,” Young said. “I accomplished that while working in the Laboratory for Advanced Space Systems at Illinois when CAPSat was launched to the International Space Station in August 2021 and deployed two months later, so that’s pretty awesome.”

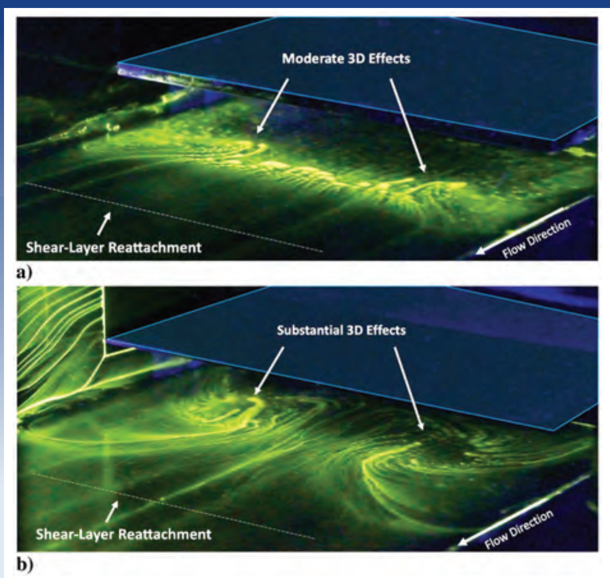
After graduating last May, he began working on a master’s degree with Professor **Michael Lembeck**.

“My thesis is the preliminary design review for a CubeSat that will conduct radio astronomy in orbit around the moon,” Young said. “It’s challenging because the science can only be done when the moon is eclipsing the sun and the Earth at the same time and the satellite is pointing toward a specific spot in the galaxy. I’ll use astrodynamics software to analyze orbital mechanics and mission design for power, thermal, and communications configurations.”

Young said he will pursue a PhD that will likely expand on this work, but if it goes in a different direction, that’s fine, too. “My goal remains the same—to learn as much as possible and apply that to real world problems.”

New data set **improves modeling of supersonic flows**





Above: Velocity contours of the fully started flow field around the a) rigid plate and b) flexible plate.
Left: Oil flow visualization for the a) rigid plate and b) flexible plate at fully started conditions.

Extreme pressures come with high-speed flight. The resulting aerodynamic forces can bring significant risk to deforming the components of the vehicle in motion—even to the point of aeroelastic deformation and failure—when solids behave more like liquids. This can jeopardize stability or controllability of the entire vehicle.

AE researchers conducted experiments to help understand fluid/structure interaction in the flow around a vehicle traveling at high speeds.

According to AE's **Greg Elliott**, the relationship between nonlinear structural and aerodynamic responses makes this problem an extremely difficult one to model computationally. And although high-speed fluid-structure interaction has been the subject of many research efforts, only a few focus on the deformation of control surfaces.

"People have been designing and evaluating cantilever beams for a long time," he said. "We took this classic configuration to study the fluid/structure interaction starting with such a simple geometry, then added the complexity of an unsteady supersonic flow on top of the plate and highly separated flow under the plate," he said.

Elliott said the re-circulation region underneath the plate has two very complex flows that are interacting.

"Quite frankly, we didn't know what that interaction would look like," Elliott said. "Now that we do, we hope this will help the computational community. The experimental data set will help validate their models."

The data were simultaneously collected by multiple diagnostic tools, evaluating both a stiff cantilever plate and a flexible plate at Mach 2 conditions.

"We took flow data using high-speed Schlieren photography and plate deformation data using stereo digital Image correlation," Elliott said. "Many others have done one or the other, but this is one of first times these temporally resolved measurements—structural measurements with flow measurements—have been taken simultaneously in this configuration."

Elliott said another unique outcome from this research is the complete data set describing the flow underneath the cantilever plate, including its velocity field.

"This is a very unsteady flow problem, with the shock and expansion waves moving across the plate as it deforms, coupling the unsteady flow with the surface deformation.

"Probably one of the most surprising results was how three-dimensional the flow was in the re-circulation region under the plate," he said. "Everything setting up the problem looked two-dimensional, but to correctly characterize the flow there are significant changes across the span of the plate also."

This research was funded in part by the U.S. Air Force Research Laboratory High Speed Experimentation Branch. The paper, "Fluid/Structure Interaction of Cantilevered Plate in Supersonic Separated Flow," by **Griffin K. Bojan**, **J. Craig Dutton**, and **Gregory S. Elliott**, is published in the *AIAA Journal.*

AEROSPACE COMPUTATION
AT ILLINOIS

Specialized algorithms in the 1930s first enabled human "computers" to calculate wing lift and induced drag. This led to the co-development of silicone-based computer processors, control algorithms, and flight hardware for the Apollo missions, and the rise of computational power started in earnest. Computational fluid dynamics and finite-element methods became central to most aerospace design.

Today, computation pervades all disciplines and the Department of Aerospace Engineering is leading a holistic and intentional reimagining of how computation should permeate teaching and research.

This is a fundamental change in perspective, but it is emphatically not a fundamental change in what we consider to be aerospace engineering. It is the systematic and intentional incorporation of new tools to make us all more effective, the faculty in their research and instruction, and the students in their education and eventually in their careers.

Giving students a computation foundation

An evolving curriculum

Mathematicians solve problems. But when aerospace engineers use math, AE's **Tim Bretl** says they use it to solve problems different from those you would encounter in the field of mathematics. This is also true for computation.

"This same philosophy carries over into our curriculum," Bretl said. "Our undergrads need to take courses in math and computation to prepare them to be the best aerospace engineers they can be — not the best mathematicians or computer scientists."

It follows that the types of computation and curriculum needed to prepare AE undergrads for work in the field should be different and provide a strong foundation in the first two years of study. For example, students are required to take Computer Science 101 along with core math courses that have been redesigned for engineers and place a strong emphasis on computational methods.

The department is also exposing students to computation earlier in AE courses. Bretl used numerical methods as a good example of this shift in strategy.

"The course is about using computers to find approximate solutions to ordinary and partial differential equations. It places equal focus on theory, algorithms, and implementation with code. We originally offered numerical methods to seniors, then to juniors, and now we are encouraging our students to take it as sophomores so they can use what they learn in all their other courses.

"We have also changed the way we teach other core subjects like controls. Our course on aerospace control systems used to be entirely pencil and paper, with a little MATLAB. Now students in that course do several mini-projects in which they design, implement, and test a controller for a real aerospace system in simulation — and the implementation is done in Python. Students must write code if they want to see their controller work."

Bretl stressed that physical experiments and computational work do not need to be seen as in opposition.

"I think of computation as enabling more hands-on work. To fly an autonomous fixed-wing aircraft, you need to write code. To get results from experiments with a modern wind tunnel, you need to write code. It doesn't have to be either/or."

Bodony assists AE senior Theo Angkasa in the computer lab

Training students to confidently compute

When he began hearing of the same need from multiple sources, AE's **Daniel Bodony** paid attention.

"Students on senior design teams and registered student organizations regularly ask for computational fluid dynamics help. Recent alums were sending me emails saying, 'one thing I wish I'd learned was how to use a CFD code' and in conversations with aerospace alumni and their employers I heard that CFD is something their companies are looking for job and internship candidates," Bodony said.

The department offers a computational aerodynamics course geared toward research needs, but few undergraduates take it. "Those who did say they were glad they took it because it helped them be a better user of a commercial or in-house code. That's why I decided to offer a class for undergrad and graduate credit to teach computational fluid dynamics as it specifically relates to applied aerospace problems."

Bodony uses computation in his own research and has collaborated with commercial companies and federal labs on CFD-related research. He learned what companies want from their employees running CFD calculations.

"I thought about what outcome companies want and how they want their employee to state problems and characterize the answer," he said. "I took both of those goals and created a curriculum around that."

Bodony said a lot of students know how to code, but they don't know how to think algorithmically.

"For example, what steps would you use to sort a table? Would you sort them alphabetically? How do I do that? It's easy for us to conceptualize, but it's harder to think about that as an algorithm. And that's often one of the key differentiators between a good CFD user and a mediocre one. We're training our Illinois graduates to be the good ones."

Why three AE students minored in computer science

Majoring in aerospace engineering is academically rigorous. Adding to the mix a minor in computer science brings the likelihood of a heavy STEM course load every semester and probably fewer slots to take a lightweight elective, but for students who are passionate about computation, it's the perfect combination.

Bella Watters took some computer science classes in high school and liked them, so she wanted to take more in college.

"I came into the AE program at Illinois expecting to be drawn to avionics applications," Watters said. "I immediately got involved with the avionics sub team of the Illinois Space Society's rocketry team. I also did a software engineering co-op at Collins Aerospace my sophomore year."

But, between the first few computer science classes and the co-op, Watters changed her mind and began pursuing structural design. "Even though I'm no longer working on flight software, there are heavy CS applications in structural design. For example, complex finite element analysis would not be possible without computational software and tools. Coding skills are becoming increasingly crucial in the core AE classes to enable computation and data processing, and an elevated understanding of CS topics is very beneficial."

Although computer science may not directly relate, she believes the minor has given her a more comprehensive understanding of large-scale aerospace systems.

David Robbins planned to major in aerospace and minor in math, but after his first math class, it became clear that math was not fun for him.

"I happened to be in CS 101 at the same time and fell in love with it," Robbins said. "The combo makes a lot of sense because pretty much every higher-level AE class uses code, and my CS minor has made those classes a lot easier for me. Plus, AE is a very well-rounded major. By coupling aerospace with computer science you can become a completely full-stack engineer from hardware to software."

He said it can be difficult to finish both a CS minor and AE major in four years.

"I didn't come into college with as many credits as a lot of my peers and have had to take a few semesters with 18 technical credit hours to finish in eight semesters," Robbins said. "There have been a lot of late nights in the aero computer lab where I have been stuck on CS assignments, but I have a compressible flow exam the next day."

Audrey Godsell knew a few aerospace juniors and seniors who were minoring in computer science. They told her it gave them job opportunities they might not have had otherwise.

"I had some background in coding and knew I enjoyed it, so I decided to pursue the minor," Godsell said. Although she doesn't have a concrete career goal yet, she said there is a strong chance it will include coding. "I had a co-op writing software for helicopters and I really enjoyed that experience. I wouldn't mind writing software fulltime, especially in an aerospace-related field."

Godsell said many of her aerospace courses incorporate coding in some form. In introductory theoretical and applied mathematics courses, she used MATLAB on nearly every homework assignment. Learning Python has also been extremely beneficial.

She admitted C++ was the most challenging computer science course she took but said "The experience of knowing how to get started with learning new coding languages is something I can repeat over and over with new languages."

Model simulates variable flap stiffness for the best lift

Andres Goza

Much like a bird can tense, or stiffen, the musculature and tendons connected to covert feathers, AE researchers wondered if they could model a flap on an airfoil, or wing, with varying stiffnesses over time.

AE's **Andres Goza** and his student **Nirmal Nair** modeled a variable stiffness actuator on a flap hinged to an airfoil via a torsional spring to create a hybrid controller that changes the stiffness over time. The flap itself cannot flop or bend in any way. The stiffness refers to how tightly the torsional spring is holding onto the flap.

"In the simulation, we trained a controller that determined a specific value on the spectrum from very stiff to very loose. The controller was built using reinforcement learning and trained to select a stiffness to improve lift on the airfoil," Goza said.

The results showed a big benefit.

"Our flap with a variable stiffness was better than having no flap by 136 percent and 85 percent better than the best possible single stiffness flap from an earlier study we conducted."

Goza said they used variable stiffness actuators to obtain the changes in stiffness values of the spring. The spring is a simplified model. In practice, this functionality can be implemented using variable stiffness actuators, though this is a non-trivial step that would require a new research effort, beyond the scope of what they looked at.

The results of their tunable stiffness paradigm were compared to the best possible single stiffness case, obtained by building a performance map for several different simulations corresponding to a single stiffness value each.

Goza said the lift improvements are achieved due to large-amplitude flap oscillations as the stiffness varies over four orders of magnitude.

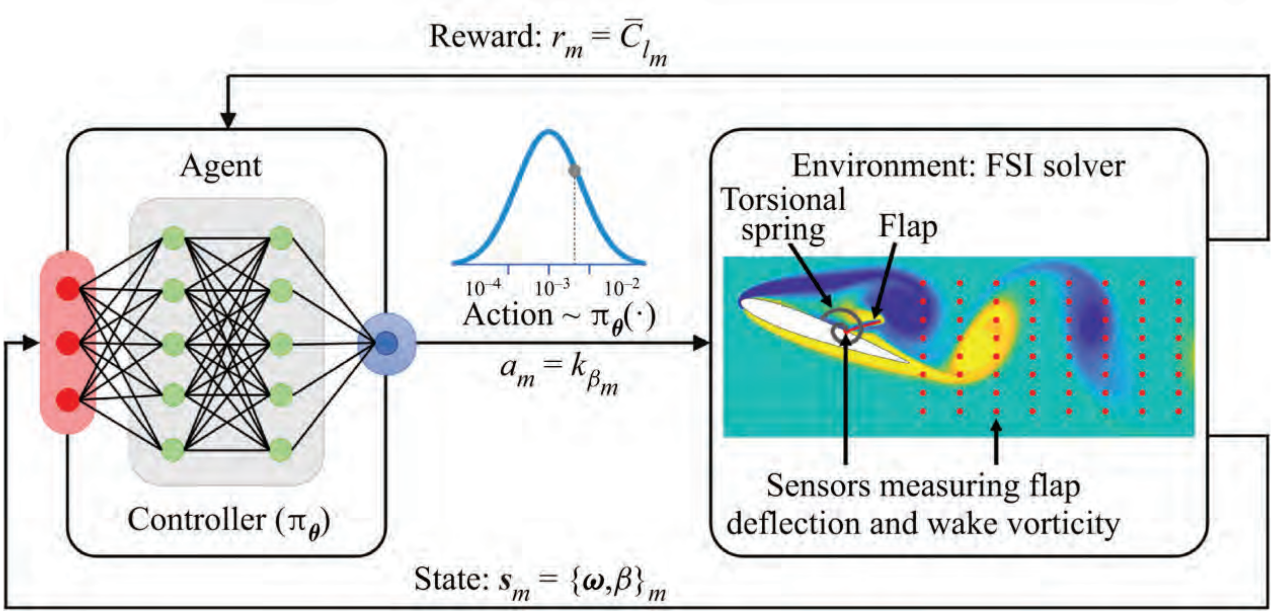
"For the first nine time units, the controller tried different stiffnesses and learned what happened," Goza said. "Then we turned it loose for the remainder of the simulation: at a given instance in time, it decides to change the stiffness and actively adapt over time based on what the flow is doing to get a boost in lift."

Goza said it is complicated to develop a control strategy like this one.

"As the stiffness changes, the flap moves. Then the flap motion changes the airflow around it, so there is a complex coupling going on," Goza said. "Simulating this two-way coupling is a source of complexity. A strength of our work is that we model all of that. We fully account for the two-way coupling between the structural motion and the response. And that's key to developing an accurate controller.

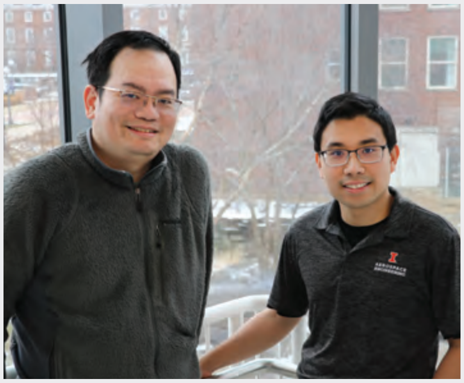
"And, because we're not constrained by physical limitations, we can explore parameter spaces that we wouldn't otherwise know about and use that as a springboard to motivate clever experimentalists to realize these parameter ranges.

The study, "Bio-inspired variable-stiffness flaps for hybrid flow control, tuned via reinforcement learning," by Nirmal J. Nair and Andres Goza is published in the *Journal of Fluid Mechanics.*



Schematic of the problem set-up and reinforcement learning framework

Predicting lifespan of electric space propulsion systems



Huck Beng Chew and Huy Tran

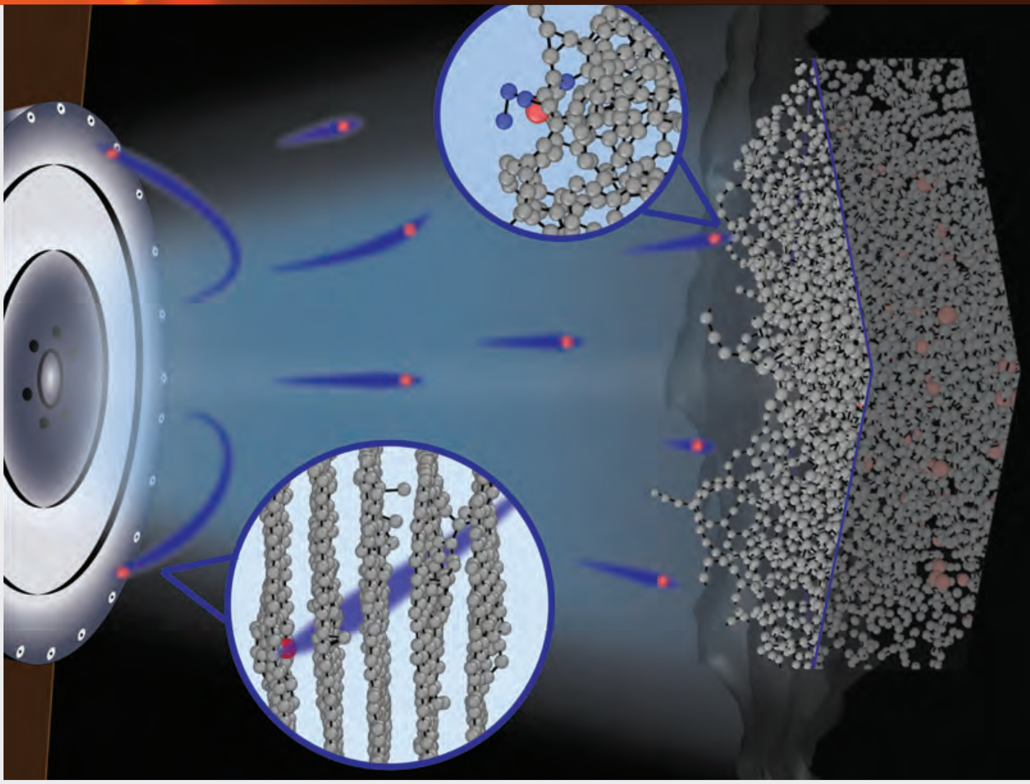


Illustration of the Hall Thruster plumes impacting the carbon surfaces at the atomistic level.

Electric space propulsion systems use energized atoms to generate thrust. The high-speed beams of ions bump against the graphite surfaces of the thruster, eroding them a little more with each hit, and are the systems' primary lifetime-limiting factor. When ion thrusters are ground tested in an enclosed chamber, the ricocheting particles of carbon from the graphite chamber walls can also redeposit back onto the thruster surfaces. This changes the measured performance characteristics of the thruster.

"We need an accurate assessment of the ion erosion rate on graphite to predict thruster life, but testing facilities have reported varying sputtering rates, leading to large uncertainties in predictions," said AE PhD student **Huy Tran**.

Using data from low-pressure chamber experiments and large-scale computations, Tran and his adviser **Huck Beng Chew** developed a computational model to better understand the effects of ion erosion on carbon surfaces —the first step in predicting its failure.

Tran said it is difficult to replicate the environment of space in a laboratory chamber because it is difficult to construct a sufficiently large chamber to avoid ion-surface interactions at the chamber walls. And although graphite is typically used for the accelerator grid and pole covers in the thruster, there isn't agreement on which type of graphite is most resistant to erosion, known as sputtering.

"The fundamental problem with testing an ion thruster in a chamber is that the thruster is continuously spitting out xenon ions that also impact with the chamber walls made out of graphite panels, but there are no chamber walls in space," Tran said. "When these xenon ions hit the graphite panels, they also sputter out carbon atoms that redeposit on the accelerator grids. So instead of the grid becoming thinner and thinner because of thruster erosion, some people have seen in experiments that the grids get thicker with time because the carbon is coming back from the chamber walls."

The simulation resolved the limitations and uncertainties in the experimental data and the researchers gained insight into a critical phenomenon.

"When the ions come and damage the surface, they transform the surface into an amorphous-like structure regardless of the initial carbon structure," Chew said. "You end up with a sputtered surface with the same unique structural characteristics. This is one of the main findings that we have observed from our simulations."

Chew said they even tried it with diamond. Regardless of the much lower initial porosity and the more rigid bond configuration, they got the same sputtered structure.

"The model we developed bridges the molecular dynamics simulation results to the experimental data," Chew said

The research is part of a NASA center known as the Joint Advanced Propulsion Institute which includes researchers at nine universities, including AE's Chew, **Debbie Levin**, and Illinois' team lead **Joshua Rovey**.

The simulations were performed using NCSA's Delta, a supercomputing facility at Illinois.

The paper, "Surface morphology and carbon structure effects on sputtering: Bridging scales between molecular dynamics simulations and experiments," by Huy Tran and Huck Beng Chew is published in the journal *Carbon.*

When accidents happen, drones can compute their options

Flying cars, drones, and other urban aerial mobility vehicles have real potential to provide efficient transportation and delivery solutions, but what happens if a drone delivering cheeseburgers breaks down over a city park or in the middle of a crowded street? AE researchers developed a method to measure vehicles' ability to recover and complete its mission safely.

"Engineers build a lot of redundancy into every system, because failure is not an option when it comes to ensuring safety," said AE's **Melkior Ornik**. "When accidents do happen, the vehicle's system requires a sort of rapid, real-time replanning to continue its mission or, less ideal, figure out a safe alternative mission. For example, the malfunctioning drone may not be able to reach its destination, but it has enough power to avoid a highly populated area and crash in an empty field instead."

Ornik developed a notion he calls quantitative resilience of a control system which tries to establish the capabilities of a system after it experiences an adverse event. One scenario examined the ability to recover from the loss of an actuator—when an engine, rudder or other part gets damaged and you no longer have control over a portion of your system.

"The other cases looked at situations in which all of the actuators still work, but not at full power," Ornik said. "Say, you're driving your car and suddenly you can only turn your steering wheel a quarter of the way around, not all the way. We're trying to establish how to still control the system as safely as possible after such a thing happens."

Ornik said computing quantitative resilience is a complex task as it requires solving four nested, possibly nonlinear, optimization problems.

"The main technical contribution of this work is that we provided an efficient method to compute quantitative resilience," he said. "Relying on control theory and on two novel geometric results we reduce the computation of quantitative resilience to a single linear optimization problem."

Part of the project was an industrial collaboration with Bihrle Applied Research, Inc.

"This was my first experience with this type of collaborative effort. Bihrle is an aerospace company interested in tools to ensure safety of aircraft and urban aerial vehicle and be prepared for when something bad happens. This ability to work through when equipment malfunctions has real life implications."

This story represents research from two studies.

"Quantitative Resilience of Linear Driftless Systems" is written by **Jean-Baptiste Bouvier**, **Kathleen Xu**, and **Melkior Ornik**.

"Online Inner Approximation of Reachable Sets of Nonlinear Systems with Diminished Control Authority" is written by **Hamza El-Kebir** and **Melkior Ornik**.

Both studies are published in the Society of Industrial and Applied Mathematics' *2021 Proceedings of the Conference on Control and its Applications.*

Computational evaluation of data transport concept using train of satellites

Although the Pony Express lasted only a short time in the mid-1800s before being outperformed by the transcontinental telegraph, it inspired a concept for a string of small satellites to transport data from Mars to Earth and help alleviate the data logjam currently occurring in the Deep Space Network.

Robyn Woollands

"The Solar System Pony Express is a mission concept that aims to augment the data transmission capabilities of the Deep Space Network using the idea of data mules," said AE's **Robyn Woollands**.

She described the data mules as small spacecraft that can travel to a remote location, such as Mars, where they acquire data in close range to the probe's transmitter, then carry the data back to Earth where it is downlinked in close range to the receiver. This enables high-latency and high-bandwidth communication.

"A network of interplanetary data mules could be established using cycler orbits," Woollands said. "After launch, the data mules use their own low-thrust propulsion system to inject into a cycler orbit and target subsequent flybys of Earth and Mars."

Woollands explained that the trajectories encounter two or more celestial bodies along their path and require a modest amount of propellant for correction maneuvers. After launch, the data mules use their own low-thrust propulsion system to inject into a cycler orbit and target subsequent flybys of Earth and Mars.

"During the Mars flybys, data is uplinked from spacecraft already operating at Mars—on orbit or on the surface—and during Earth flybys data is downlinked back to Earth," Woollands said.

Alex Pascarella

Woollands' PhD student **Alex Pascarella** developed the computational tools to enable the trajectory design and optimization of Earth/Mars cycler orbits for the Solar System Pony Express mission.

"Our study revealed that the total data volume returned during the simulated mission exceeded our goal of 1 Petabit per year," Pascarella said.

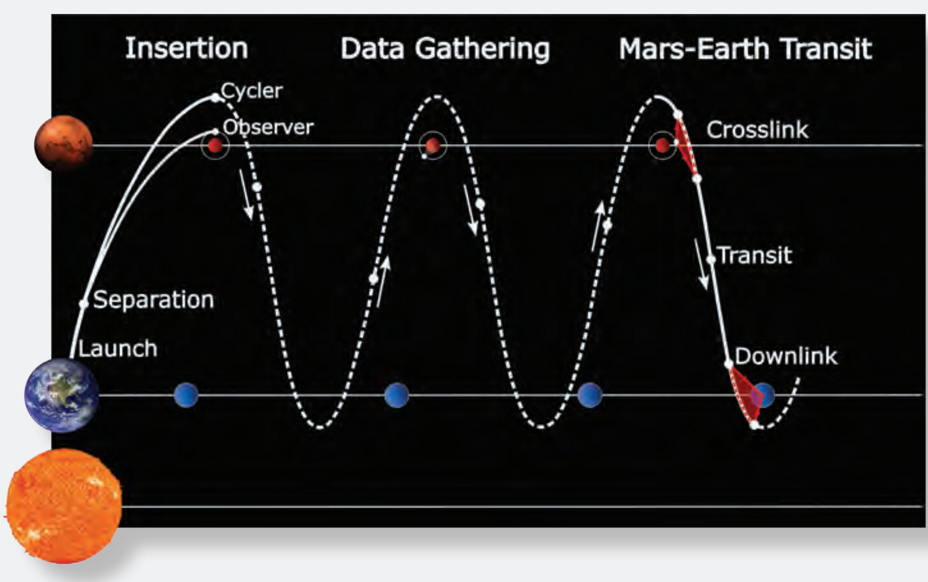
"Because we care about the high-fidelity accuracy of the simulations, we needed to take into account the gravitational influence of other planets on the spacecraft," Pascarella said. "In our simulation, we included the gravity from the sun—which is the main attractor when you're flying in interplanetary space—but we also added the gravity perturbation caused by the Earth, and the gravity perturbation caused by Mars."

Pascarella said the difficulty isn't in the mathematical modeling because that is already well understood. It's a computational problem.

"When you add more accuracy to your setup, the computation gets slower. You need a better formulation of the problem, so the computation is as efficient as possible," Pascarella said. "Professor Woollands and I exploit advanced methods for fast, efficient computations."

Solar System Pony Express is a NASA Innovative Advanced Concept project led by Joshua Vander Hook at NASA's Jet Propulsion Laboratory.

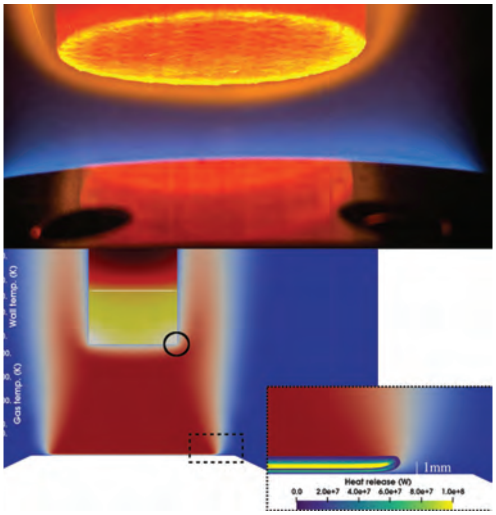
The paper, "Low-thrust trajectory optimization for the solar system pony express," was written by Alex Pascarella, Robyn Woollands, Etienne Pellegrini, Marc Sanchez Net, Hua Xie, and Joshua Vander Hook. It is published in the journal *Acta Astronautica*.

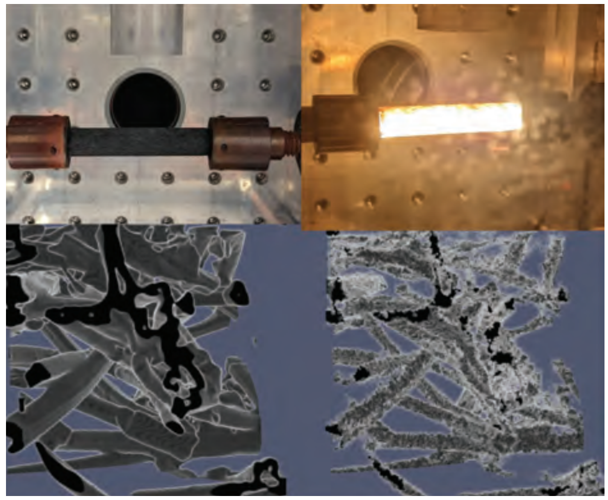


Artist's depiction of the Solar System Pony Express system.

Credit: Joshua Vander Hook

Center for Exascale-enhanced Scramjet Design





Two examples of research pairings in CEESD.

Left: Top image shows the experiment, provided by Henry Varona. Bottom image shows the simulation, provided by Tulio Ricciardi.

Right: Upper images show FiberForm samples heated to higher temperatures and exposed to oxygen. Below are visualizations of oxidation process of material from simulations.

Images provided by Kaan Kirmanoglu and Nicholas Anderson

A group of scientists, some who conduct experiments in a lab and others who use computers to create simulations, are working together to do what they call "predictive science." Computationalists write complex equations that require a supercomputer to solve. The computer simulations they do can guide design and help predict conditions that are unachievable in a lab. However, they require some of the largest computers in the world.

"We seek to do simulations that are truly predictive to impact the design of scramjets—the technology for airbreathing hypersonics propulsion. We have a good idea of the physics required, including the high-speed flow, combustion kinetics, transport, and the degradation of the new composite materials we are considering," said AE's **Jonathan Freund**. "We have a suite of physics-targeted experiments and physics-integrated experiments to inform our integration of models. And we have our ACT II acoustic combustion tunnel against which to test our integrated physics predictions."

Jonathan Freund

Freund is the director of the Center for Exascale-enabled Scramjet Design. He leads a team of 13 faculty researchers, 7 postdocs and research staff, and 19 graduate students who are studying various aspects of this predictive science challenge.

One of the questions being tackled by experiments and simulation is about how carbon oxidizes at different pressures, temperatures, and gas environments. PhD candidates Kaan Kirmanoglu and Nicholas Anderson are an example of the many synergetic relationships between experimentation and simulation within the center.

"I use Nick's experimental data to build and validate my models/simulations," said Kirmanoglu. "But sometimes simulation results lead to reevaluating experiments. Together, we learn which experimental configuration and data are most suitable for model validation and how simulations can best represent experimental conditions. We also do a lot of brainstorming and calculations together to tackle the problems we encounter. Although the end goal is experimental results informing simulations, we work two-way to build the tools needed."

Freund said their close pairing is part of the bigger model the center is tasked with. ACT II can simulate the interior flow of a scramjet if it were flying at supersonic speeds of Mach 6 to Mach 8. Ultimately, the simulations will represent turbulent combustion, oxidation, and pyrolization of new composite materials.

"We're creating multiphysics simulations to affirm that we can indeed do simulations that are truly predictive," Freund said.

"We're developing models for things people have not represented before," Freund said. "But the predictive science methods, the approach we are developing to handle uncertainties, is a new way of looking for physics that is missing. That part of the effort is general and can be used in many applications outside of scramjet design."

The Center for Exascale-enabled Scramjet Design includes faculty experts in The Grainger College of Engineering and the National Center for Supercomputing Applications. CEESD is in the third year of a 5-year project funded by the Department of Energy.

Young team presents **Mars water-to-propellant concept**

University teams from across the United States presented their space mission designs at NASA's annual Revolutionary Aerospace Systems Concepts—Academic Linkage competition at the Kennedy Space Center in Cocoa Beach, Florida. This year's RASC-AL team from Illinois took second place.

"The Illinois team shared the podium with an all-varsity MIT team taking first place and in third place, the team from the University of Puerto Rico, Mayagüez Campus, who are the reigning champions for the past two years," said the team's faculty adviser **Michael Lembeck**.

Their Mars Ice Thermal Harvesting Rig and In-Situ Resource Utilization Laboratory included all stages of a functioning system on Mars: accessing the subsurface ice reserve, mining the ice, using it to produce fuel and oxidizer, and liquefying and storing those propellants long-term on the surface.

"Our storage tank design represented a huge challenge from the get-go," said team lead and AE junior **Alec Auster**. "One of our most pivotal trades was whether to use rigid body tanks or inflatable tanks to store our propellant. Rigid tanks are reliable and have a high technology readiness level, but they take up unwieldy amounts of space, and are very heavy. Inflatable tanks are lightweight and small, but not as mature as rigid tank designs. We ended up choosing inflatables, knowing it would be a challenge to design them from the ground-up, but we did it. The storage team spent countless hours, iterations, and effort leading up to the final design. We believe the end result is truly revolutionary."

The judges said they were particularly intrigued by the innovative inflatable tanks. AE alumni **Stephen Hoffman**, BS '78, MS, '80, PhD '84, helped the team review their designs.

Left to right: Shikhar Kesarwani, Alec Auster, Komol Patel, Riya Shah, Ana Bojinov, Madeline Odeen, and Galen Sieck, back row.

Student follows passion for flight and space

After attending numerous aerospace conferences throughout high school and earning her pilot's license, AE first-year student **Chy-Amari Finley** chose to continue her passion for both flight and space at Illinois.

Finley's interest in flight started when she was just a child.

"It started with planes, just looking up and wondering 'How does a plane just not fall out of the sky?'" Finley said. "The interest grew as I got deeper into math and science. I started to understand how it was all possible.

"Now, I want to work with human space flight, but I think flying is always going to be a part of my life," she said.

Finley has been working with Tuskegee Airmen—a flight academy—since high school, where she first started building rockets. Now, she is enrolled in another flight program with them to complete ground school.

Finley began a research project with AE Department Head **Jonathan Freund**.

"We're researching bone loss when people go to space," Finley said. "That deals with human anatomy and physiology, which are my other interests," she said. "I wanted to combine my interests in flight and people.

"Next year, I'm looking forward to taking flight mechanics because it covers both aircraft and spacecraft," she said.

Richard L. Mange:
AE Distinguished Alumni award

Amy and Rick Mange at AE's annual awards celebration.

Rick Mange earned three AE degrees from Illinois, BS '86, MS '90, and PhD '96. His 37-year career in the aerospace industry includes 11 years at McDonnell Douglas Aerospace in St. Louis, and 25 years at Lockheed Martin Aeronautics in Ft. Worth. During this career, Mange held positions of increasing responsibility culminating in his current position as the F-35 Chief Engineer, responsible for ensuring the safety, airworthiness, and technical integrity of all F-35 Engineering products. He is the 2023 Aerospace Engineering Distinguished Alumni award recipient.

Vice President and Chief Engineer at Lockheed Martin Linda O'Brien said Rick Mange is recognized as a consummate technical leader at Lockheed Martin and in the industry.

"Rick makes some of the most difficult decisions in the Lockheed Martin business on a daily basis—decisions that have serious implications on human life, national defense, and shareholder value," O'Brien said. "His elite educational background and comprehensive aerospace experience, his technical judgment, steady, logical decision-making, and his impeccable integrity make him one of the most respected technical leaders in the company."

During his career as an aerodynamicist, Mange helped pioneer the use of advanced experimental methods such as pressure-sensitive paint and particle image velocimetry in practical applications on high-performance fighter aircraft.

"Throughout his 25 years as a leader on the F-35 Program, Mange has been a driving force throughout the lifecycle of the program from prototype testing through air system design and ramp to full-rate production and fleet sustainment," O'Brien said. "As the F-35 Short Take-Off Vertical Landing Aerodynamics Lead, he led the effort to characterize the X-35B STOVL characteristics leading up to a successful first flight, which was a vertical takeoff. Subsequent flights of the X-35B included a historic first-ever Short Takeoff, level supersonic accel and vertical landing, which was dubbed Mission X."

Mange led an award-winning F-35 STOVL Jet Effects wind tunnel effort which significantly pushed the state of the art for SJE wind tunnel model design and testing and was the subject of multiple technical papers. The database produced through this effort has been used without correction throughout F-35 flight test and production.

Heather Arneson:
Outstanding Recent Alumni award

Heather Arneson, MS '07, PhD '12, is the 2023 recipient of AE's Outstanding Recent Alumni award. Since 2011, she has been a research aerospace engineer at NASA Ames Research Center in Moffett Field, California.

Throughout her career at Ames, Arneson's research has focused on a variety of topics including air traffic flow management using machine learning methods to develop decision support tools, integrated demand management for traditional aviation, and air traffic management for urban air mobility.

After completing her BS in mechanical and aerospace engineering at Cornell University, Arneson took a three-year break from academia. During those years, she joined the science imaging team for NASA's Mars Exploration Rover Mission.

Observing colleagues in other jobs and whether or not they had an advanced degree, convinced her to get a master's degree.

"I chose Illinois because it is a top school in aerospace engineering, but at that point, I still wasn't sure if I wanted to go on for a PhD, too," Arneson said. "I really enjoyed the research and working with my adviser, **Cedric Langbort**, so I decided to stick around for a PhD."

Her graduate research focus was on the development of control design techniques with applications to air traffic flow management.

Michael W. Miller: Hilton award for service

Michael Miller with his wife Donna Perillo

Mike Miller graduated from Illinois in 1976 with two BS degrees—electrical and aerospace engineering. He also earned an MBA at the University of Chicago and was one of five forward-thinkers who launched the risky start-up that became Orbital Sciences Corporation.

In 1990, Miller received the department's Outstanding Recent Alumni Award and in 2003, the Distinguished Alumni Award, both of which he was on campus to accept. Over the years, he has served on the alumni board which also afforded him regular campus visits.

"I began having more opportunities to engage with students," Miller said. "Some have sent me business plans and I've been able to give them some feedback, mentor, and guide them. During the pandemic, I participated in online panels with other alumni about entrepreneurship. Talking with students, hearing about their aspirations, and seeing how I can help—that's been meaningful for me."

His experience with Orbital fueled his passion for entrepreneurship and led him to create the Michael W. Miller Aerospace Engineering Innovation Award. It is given each year to an AE student who has a big idea and a plan for how to accomplish it.

Miller said because of his interest in space and in particular small satellites, he has collaborated with NASA's Illinois Space Grant Consortium at Illinois and more recently contributed his time and resources in support of the department by sponsoring the Systems Engineering Test Center for Small Satellites.

This year, Miller received the **Harry H. Hilton** Dedicated Service Award. Miller said the award is special to him because he knew Hilton well and had great admiration for his accomplishments.

"Harry was acting department head when I was an undergrad. I remember coming back to campus one time Harry sought me out and took me on a tour. He showed me where his first classroom was and how they had renovated Engineering Hall and found beautiful mosaics and took me inside the new Grainger Engineering Library. I always enjoyed talking with him."

Award created to honor **Larry Bergman**

Don Leo with his wife Jeannine Alexander
Don Leo with Larry Bergman in 2014 when Leo received the Distinguished Alumni Award.

Donald J. Leo, BS '90, said his undergraduate experience working on a research project with AE Professor Emeritus **Larry Bergman** was "incredibly impactful" in his life. This year, Leo and his wife Jeannine Alexander decided to recognize that impact by creating the Lawrence Bergman Undergraduate Research Award.

"Stuart Pang and I worked on a project about innovative space propulsion funded by NASA Glenn with nuclear engineering's Clifford Singer and Dr. Bergman," Leo recalled. "When it came time to give a presentation, he said, 'You guys did the work. You should do the presentation.' That's not something every professor would do."

Leo completed his master's degree in '92 and his doctorate in '95, then worked in industry for a couple of years. He said he always knew he wanted a career in academia. Leo has served as the dean of the College of Engineering at the University of Georgia since 2013.

"I've used that undergraduate research project as an example to my students," Leo said. "My hope is that undergrad research is as impactful for them as it was for me."

Bergman's expertise is in the areas of linear and nonlinear dynamics and vibration and applied stochastic processes. He retired in 2016 but remains an active professor emeritus.

Leo said Bergman has been a great mentor.

"He wanted to give me a different experience—one I hope the future recipients of this award will also be impacted by. Jeannine and I wanted to do something, and this endowment—even if it's small—will go on in perpetuity. We hope it will help recognize Dr. Bergman and his influence on me and my career path and help others find their career."

Faculty highlights

Phillip J. Ansell (Allen Ormsbee Faculty Fellow, associate professor/ PhD, University of Illinois, 2013) received the 2023 AIAA Lawrence Sperry Award and is co-investigator on a team awarded a DoD Multidisciplinary University Research Initiative Program. He recently established the Center for Sustainable Aviation and continues to direct the Center for High-Efficiency Electrical Technologies for Aircraft.

Jeffrey Baur (Founder Professor/PhD, Massachusetts Institute of Technology, 1997) developed a unique industry/academic partnership between UIUC and Continuous Composites, Inc. that included having a continuous fiber 3D printer installed on campus.

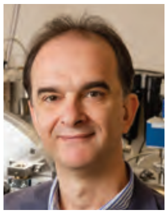
Lawrence A. Bergman (research professor, professor emeritus/PhD, Case Western Reserve University, 1980) gave a talk at the 2022 European Nonlinear Oscillations Conference in Lyon, France, July 2022. Co-authors were Michael Duffy (Raytheon Missiles and Defense) and Soon-Jo Chung (Caltech).

Daniel J. Bodony (Blue Waters Professor/PhD, Stanford University, 2005) is the associate dean for graduate, professional, and online programs. Bodony was elected to the Big Ten Academic Alliance leadership program and started new, federally funded projects to reduce jet noise and control the flow within scramjet isolators.

Michael B. Bragg (professor emeritus/ PhD, The Ohio State University, 1981) was named executive director for The Grainger College of Engineering Chicago Initiatives.

Timothy Bretl (William H. Severns Faculty Scholar, professor/PhD, Stanford University, 2005) was promoted to professor.

Rodney L. Burton (professor emeritus/PhD, Princeton University, 1966) received the 2023 AIAA Wyld Propulsion Award for outstanding achievements in the development of electric rocket propulsion systems. Worked with Deborah Levin on satellite aerodynamics through a CU Aerospace R&D program.



Ioannis Chasiotis (Caterpillar professor and University Scholar/ PhD, California Institute of Technology, 2002) is the director of graduate studies and an associate head of AE. He is the co-chair of the 2024 Gordon Research Conference on Multifunctional Materials and Structures

Huck Beng Chew (associate professor/ PhD, National University of Singapore, 2007) published papers in *Carbon*, *Acta Materialia*, and the *Journal of the Mechanics and Physics of Solids*, and served on the executive committee of The American Society of Mechanical Engineers materials division.

Bruce A. Conway (professor emeritus/ PhD, Stanford University, 1981) had three MS students present papers at the UN-sponsored 2023 Planetary Defense Conference in Vienna, Austria in April and received a 3-year contract from the Air Force Research Laboratory to support research on a new paradigm for optimal feedback control for hypersonic flight vehicles.

Siegfried Eggl (assistant professor/PhD, University of Vienna, 2013) received the 2023 AIAA Award for Aerospace Excellence with the NASA Double Asteroid Redirection Team, joined the leadership of the new International Astronomical Union Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference, and published papers in *Nature* and *The Astrophysical Journal*.

Gregory S. Elliott (professor/PhD, The Ohio State University, 1993) continues to lead the experimental team on the DOE Center for Exascale-enabled Scramjet Design and co-lead the Plasmatron X facility which replicates the high-enthalpy conditions during reentry and hypersonic flight. He received the College Award for Excellence in Faculty Mentoring.

Jonathan B. Freund (Donald Biggar Willett Professor of Engineering and department head/ PhD, Stanford University, 1998) continues to direct the Illinois DOE/NNSA-funded $17M Center for Exascale-enabled Scramjet Design and served on the editorial board of *Annual Reviews of Fluid Mechanics*. This year he was elected vice chair of the Division of Fluid Dynamics of the American Physical Society.

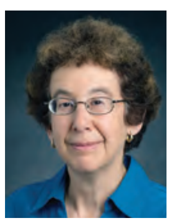
Philippe H. Geubelle (Abel Bliss Professor of Engineering and executive associate dean/PhD, California Institute of Technology, 1993) is part of the large UIUC-led Dept. of Energy grant (with MIT, U. Utah, Stanford, Harvard, and Sandia National Lab) to discover the next generation of high-performance recyclable thermoset polymers and polymer composites using a combination of high-throughput experiments and machine learning.

Andres J. Goza (assistant professor/PhD, California Institute of Technology, 2018) was part of a Multidisciplinary University Research Initiative led by UIUC and received a single-PI grant through the National Science Foundation. His research group published two peer-reviewed journal articles and presented work at AIAA and APS conferences.

John Lambros (professor and Donald Biggar Willett Professor of Engineering/PhD, California Institute of Technology, 1994) gave a keynote presentation at the spring Materials Research Society conference on the topic of Machine Learning Predictions for Microscale Strain Accumulation in Polycrystalline Metals. He is co-PI on a new FAA-funded project on failure assessment of airport pavements which aims to develop new standards for asphalt concrete materials used in airport taxiways and runways.

Cedric Langbort (professor/PhD, Cornell University, 2005) was an invited speaker at the 2023 Midwest Workshop on Control and Game Theory held at the University of Minnesota. He presented his ongoing works on the dynamics, regulation, and mitigation of strategic misinformation online, supported by DoD and conducted in collaboration with several of his graduate students and social scientists.

Michael F. Lembeck (associate professor of practice/PhD, University of Illinois, 1991) is the co-chair of the AIAA Unidentified Anomalous Phenomena Integration and Outreach Committee. His lab has ongoing satellite and space flight hardware programs with JPL, Fermilab, Cornell, and Rogue Space Systems.



Deborah Levin (professor/PhD, California Institute of Technology, 1979)

Negar Mehr (assistant professor/PhD, University of California Berkeley, 2019) led two National Science Foundation projects focused on safe and intelligent interactions between robots and humans. She served as an associate editor for the Conference on Decision and Control and the American Control Conference.

Jason M. Merret (associate professor of practice/PhD, University of Illinois, 2004) received the 2023 Stanley H. Pierce Faculty and AIAA Teacher of the Year awards.

Melkior Ornik (assistant professor/PhD, University of Toronto, 2017) received a Young Investigator Program award from the Air Force Office of Scientific Research for work on autonomous system resilience, was funded by several Department of Defense programs, and was included on the List of Teachers Ranked as Excellent by Their Students.

Francesco Panerai (assistant professor/PhD, von Kármán Institute for Fluid Dynamics, Università degli Studi di Perugia, 2012) published four journal articles, received eight research grants, and was elected to AIAA's Class of 2023 Associate Fellows.

Marco Panesi (Caterpillar Faculty Scholar, professor/PhD, von Kármán Institute for Fluid Dynamics and Università degli Studi di Pisa, 2009) was promoted to professor and elected to AIAA's Class of 2023 Associate Fellows.

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

Faculty highlights

Joshua L. Rovey (professor/PhD, University of Michigan, 2006) was promoted to professor and received the 2023 Provost Award for Excellence in Undergraduate Teaching.

Theresa A. Saxton-Fox (assistant professor/PhD, California Institute of Technology, 2018) was part of a team awarded a Multidisciplinary University Research Initiative grant on metamaterials for turbulent flow control. She was awarded the College Award for Leadership and Institutional Impact in Diversity, Equity, and Inclusion.

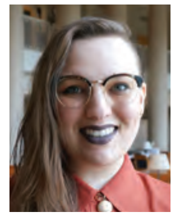
Michael S. Selig (research professor, professor emeritus/ PhD, The Pennsylvania State University, 1992) published papers on the aerodynamics of multi-megawatt scale offshore wind turbines. His collaborators extend across multiple institutions, spearheaded by the University of Virginia.

Huy T. Tran (assistant professor/PhD, Georgia Institute of Technology, 2015) published a paper in the Institute of Electrical and Electronics Engineers *Robotics and Automation Letters* and gave an invited talk at the International Conference on Intelligent Robotics and Systems 2022 Decision Making in Multi-agent Systems Workshop.

Laura Villafañe Roca (assistant professor/ PhD, von Kármán Institute for Fluid Dynamics, Universitat Politècnica de València, 2014) organized a Multiphase-Flow Mini-Symposium and hosted USMA cadets and faculty for MRI flow experiments. She was invited to the Linné FLOW Centre at KTH for an EU project meeting and as a seminar speaker. Her research is published in *Experiments in Fluids* and the Institute of Electrical and Electronics Engineers *Transactions on Microwave Theory and Techniques* journals and was presented at AIAA and American Physical Society conferences. She serves on AIAA and APS committees and is an editor for *Measurement.*

Robyn Woollands (assistant professor/ PhD Texas A&M University, 2016) received grants from NASA's Small Business Technology Transfer and The Aerospace Corporation. Her students presented work at the American Astronautical Society Space Flight Mechanics Conference and AAS Guidance Navigation and Control Conference.

Brian S. Woodard (director of undergraduate programs/PhD, University of Illinois, 2012) began serving as an Assistant Dean for Undergraduate Programs for The Grainger College of Engineering. He works primarily supporting new college students with the teams in outreach and community engagement, admissions and recruiting, and first-year programs.



Elle Wroblewski (assistant professor/ PhD, University of Illinois, 2022) is a specialized teaching faculty. Their research interests are sustainable aviation, engineering safety, and aerospace engineering professional development. This year they taught AE 100, AE 202, AE 416, and AE 419.

Matthew Clarke

Matthew Clarke is a new AE assistant professor. He earned his MS and PhD in aeronautics and astronautics from Stanford University and a BS in mechanical engineering from Howard University. He is a V/STOL Aircraft Systems Technical Committee member of the American Institute of Aeronautics and Astronautics.

Before joining the department, Clarke was a Boeing Distinguished Postdoctoral Fellow in the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology. He has also worked on the advanced concepts team at A3 by Airbus and briefly as a battery modeling data scientist at Toyota Research Institute in the Accelerated Materials Design & Discovery Division.

Clarke is the principal investigator of the Laboratory for Electric Aircraft Design and Sustainability at Illinois. The core research interests of LEADS are electric propulsion architecture design and aircraft noise modeling. These efforts position LEADS to address some of the technical challenges at the intersection between the key domains of energy and noise that impede progress toward sustainable aviation.

Xin Ning

Xin Ning is a new AE assistant professor, but he is not new to The Grainger College of Engineering. He was a postdoctoral research associate from 2015 to 2018, where he worked on soft electronics with John A. Rogers in the Department of Materials Science and Engineering.

Most recently, Ning has been an assistant professor at Pennsylvania State University for the past five years.

He earned his MS and PhD in aeronautics from Caltech and a BEng in aircraft design and engineering from Beihang University.

Ning's PhD dealt with buckling-resistant thin shells. His primary research today focuses on aerospace structures with interdisciplinary work across mechanics, soft electronics, bioelectronics, etc. His group has been supported by AFOSR, NASA, ONR, NSF, and various other external and internal grants.

He has received the William F. Ballhaus Prize for outstanding doctoral dissertation in aeronautics at Caltech, the Office of Naval Research Young Investigator Award, and the American Society of Mechanical Engineers Haythornthwaite Foundation Research Initiation Award.

Faculty research areas

Aeroacoustics
Daniel Bodony
Jonathan Freund

Aeroelasticity
Lawrence Bergman
Daniel Bodony
Philippe Geubelle
Andres Goza

Aerospace Materials
Jeff Baur
Ioannis Chasiotis
Huck Beng Chew
Philippe Geubelle
John Lambros
Francesco Panerai

Aerospace Structures
Jeff Baur
Lawrence Bergman
Xin Ning

Aerospace Systems Design and Simulation
Phillip Ansell
Matthew Clarke
Jason Merret
Michael Selig
Huy Tran

Applied Aerodynamics
Phillip Ansell
Daniel Bodony
Matthew Clarke
Gregory Elliott
Andres Goza
Theresa Saxton-Fox
Michael Selig
Laura Villafañe Roca
Brian Woodard

Astrodynamics
Bruce Conway
Siegfried Eggl
Michael Lembeck
John Prussing
Robyn Woollands

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

Computational Fluid Dynamics
Daniel Bodony
Jonathan Freund
Andres Goza
Deborah Levin
Francesco Panerai

Controls, Dynamical Systems, and Estimation
Timothy Bretl
Cedric Langbort
Negar Mehr
Melkior Ornik

Experimental Fluid Mechanics
Phillip Ansell
Gregory Elliott
Francesco Panerai

Flow Control
Phillip Ansell
Daniel Bodony
Gregory Elliott
Jonathan Freund
Andres Goza
Theresa Saxton-Fox
Laura Villafañe Roca

Hypersonics
Jonathan Freund
Deborah Levin
Francesco Panerai
Marco Panesi

Nanosatellites
Rodney Burton
Siegfried Eggl
Michael Lembeck
Deborah Levin
Joshua Rovey

Space Systems
Timothy Bretl
Rodney Burton
Michael Lembeck
Deborah Levin
Negar Mehr
Melkior Ornik
Joshua Rovey
Robyn Woollands

Unihabited Aerial Vehicles
Phillip Ansell
Timothy Bretl
Gregory Elliott
Negar Mehr
Melkior Ornik
Michael Selig

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GRADUATES

$82,373 average starting salary with a BS
5,805 current alumni worldwide

STUDENTS

645 undergraduate students
302 graduate students
12 PhDs granted
8 registered student organizations

FUNDING & FACILITIES

$15 million research expenditures
25+ laboratories and research centers
11 interdisciplinary research centers

FACULTY

28 faculty members
16 affiliate faculty members
8 adjunct faculty
11 emeritus faculty
65+ current research grants