HIGHFLIGHT

WILLIAM E. BOEING DEPARTMENT OF AERONAUTICS & ASTRONAUTICS

Onboard Decision-Making Record

A&A researchers achieve a NASA breakthrough, boosting space landing capabilities on unknown terrain.

2025 ALSO IN THIS ISSUE

- **Trailblazing Women of Aerospace**
- **Tackling Plasma's Mysteries**
- **Sounding the Alarm on Asymmetric Flows**

Dear A&A Alumni and Friends,

Welcome to the 2025 edition of *Highflight* magazine! The cover story features the groundbreaking work of A&A researchers who broke a long-standing NASA record for onboard spacecraft decision-making, enabling precision landing on hazardous terrain. This research is just one example of the innovative and impactful work being conducted within our department.

This issue highlights the remarkable achievements of three pioneering women who graduated from A&A in the mid-20th century: Rose Lunn ('37), Eleanor Dickson ('49), and Luella Armstrong ('51). These trailblazers, each the sole woman in their graduating class, made significant contributions to the aerospace industry.

You'll read about the innovative research of Jimmy O'Neil, a doctoral student using origami principles to design crash-resilient structures, potentially leading to safer vehicles and smoother rocket landings. You'll meet doctoral student Daniel Alex, who is using simulations to understand the unpredictable behavior of plasma, paving the way for advancements in clean fusion energy.

This issue also explores the work of undergraduate Evelyn Madewell and the system she is developing to facilitate wilderness search and rescue efforts by utilizing a network of drones.

Our alumni continue to make their mark on the aerospace industry, including leadership roles in critical areas like space security, as exemplified by Lt. Gen. John Shaw, our 2024 Distinguished Alum.

And finally, you'll learn about how A&A researchers are combining machine learning with optimal transport theory to enhance the safety and reliability of autonomous systems, as well as how they are drawing inspiration from sunflower seed patterns to develop innovative noise reduction techniques. Our faculty and students are at the forefront of ensuring a safe and sustainable environment, both on and off our planet.

These stories demonstrate A&A's commitment to addressing real-world challenges and highlight the innovative spirit of our students and faculty. We hope you enjoy this edition of *Highflight*!

Kristi Morgansen
Professor and Boeing Egtvedt Endowed Chair

HIGH**FLIGHT**

WILLIAM E. BOEING DEPARTMENT OF AERONAUTICS & ASTRONAUTICS | 2025

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John Shaw

is the **2024 A&A Distinguished Alum**

Excerpts from our Q&A with General Shaw about his time at the UW, his career, national security and his advice for our students.

Lt. Gen. John Shaw, U.S. Space Force, Retired (M.S. '91), is the 2024 A&A Distinguished Alum. His impressive career spans over three decades in the U.S. Air Force and U.S. Space Force, where he emerged as a thought leader in national security and space policy.

Shaw rose through the ranks, ultimately serving as the Commander of 14th Air Force and the Combined Force Space Component Command at Vandenberg Space Force Base. In this pivotal role, he was responsible for providing space capabilities to combatant commands worldwide, ensuring the nation's space superiority.

His leadership and expertise were instrumental in shaping the newly established U.S. Space Force, where he played a key role in its formation and strategic direction. We spoke to Lt. Gen. Shaw about his time at the UW, his career, the state of national security in space and his advice for our A&A students.

Q: With the changing environment in space and national security, what key implications does this have for the next generation of aerospace students?

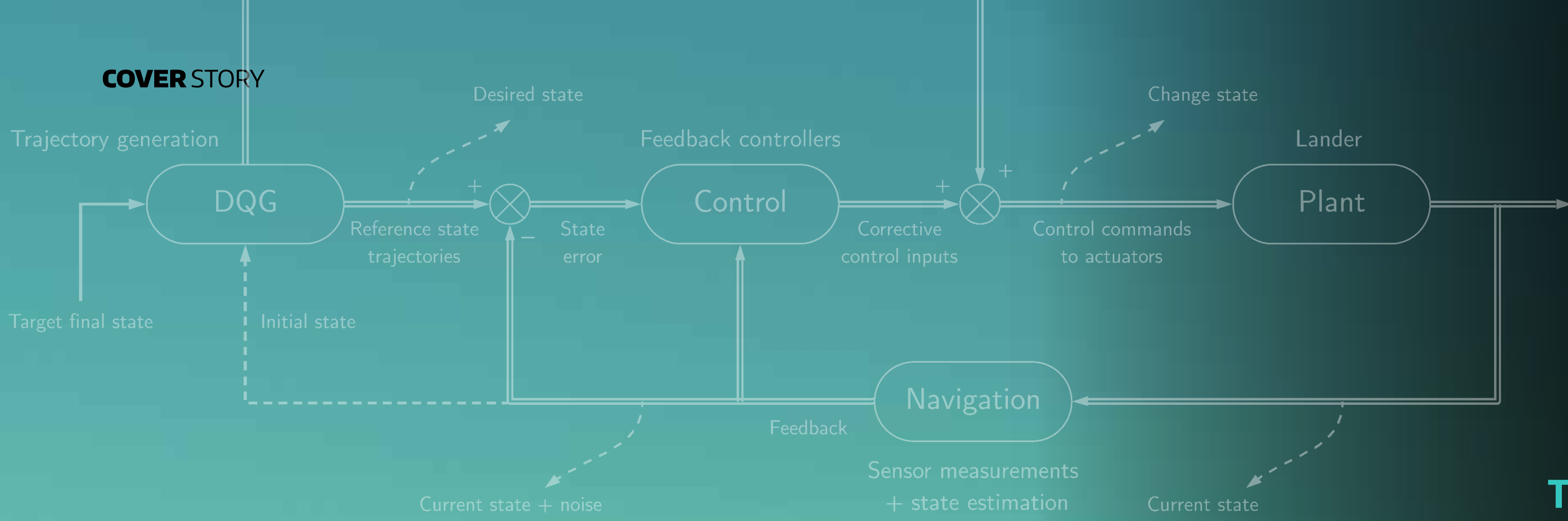
A: Future engineers need to consider how we can leverage the physics of the domain and our technologies for maximum societal benefit while ensuring we maintain an advantage over potential adversaries. It's about striking a balance between exploration, commerce and security.

Q: As someone who has been at the forefront of space operations and policy, what perspective can you offer on the U.S. Space Force's role in safeguarding access to space?

A: I want to emphasize the importance of the Space Force's role in sustaining the space domain for human society. I like to say the three basic components of the universe are space, time, and mischief - that last part will always be present. The Space Force's true purpose is to preserve security and enable prosperity for all by deterring bad actors and nefarious mischief, while maintaining a stable and accessible space environment.

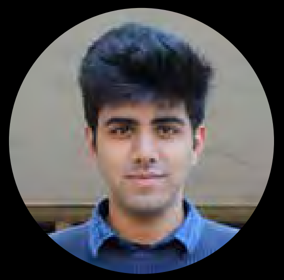
We often take for granted how much we rely on space-based systems in our daily lives. Without them, our modern world could essentially grind to a halt or descend into chaos. Ensuring the continued availability and integrity of these vital capabilities is a critical mission that our new engineers will play a pivotal role in advancing.

Go to the source: Access our full interview with Lt. Gen. John Shaw.



ONBOARD DECISION-MAKING RECORD

This winning solver earns A&A researchers an AIAA Best Paper Award and the achievement of the first to break a NASA requirement for sub-second onboard decision-making.



Abhinav Kamath

Purnanand Elango

Behçet Açıkmeşe

A&A researchers are the first to break a NASA requirement of sub-second onboard landing decisions for rockets, opening up capabilities for precision landing on hazardous terrain. This accomplishment was recognized with the 2023 AIAA Guidance, Navigation, and Control Best Paper Award. The research team, led by doctoral students Abhinav Kamath and Purnanand Elango, builds upon years of work at the A&A department, with contributions from Professor Behçet Açıkmeşe, Professor Mehran Mesbahi, A&A alum Yue Yu, labmates Taewan Kim and Skye Mceowen, and John M. Carson III and others from the NASA Johnson Space Center.

The need for real-time onboard decisions in rocket landing

Powered-descent guidance (PDG) algorithms are crucial for guiding rockets to safe landings. These algorithms need to be both reliable and extremely fast, ideally running in real-time (typically sub-second) on the rocket's flight computer.

Kamath explains why real-time performance is so important: “It is nearly impossible to predict the exact location, speed, and orientation of a rocket at the instant powered-descent needs to be initiated. In the event that a hazard is detected at the original landing site, real-time performance is extremely important to divert to a safer landing site. Onboard computations also ensure that potential lapses in wireless communication links between the rocket and the ground station do not lead to mission failure. For Mars landing missions, the only feasible solution is to perform the computations autonomously onboard the rocket system, since two-way communication between Earth and Mars takes several minutes.”

Evolution of powered-descent guidance: From 3-DoF to 6-DoF

In 2007, Professor Açıkmeşe, then working for the Jet Propulsion Lab, and his colleagues developed a real-time-capable PDG solution using a three-degrees-of-freedom (3-DoF) approach based on lossless convexification and convex optimization. This approach accounted for movement along the three axes (translation) but not rotations around them (attitude).

Meanwhile, Professor Mesbahi and his students were working on real-time optimization techniques for constrained trajectories that considered the orientation of the space vehicle. This work, building upon his earlier research on constrained attitude control for the Cassini spacecraft at JPL, culminated in the development of dual-quaternion trajectory optimization in 2017. This method provided a powerful and flexible way to impose 6-DoF constraints (incorporating both attitude and translation) on spacecraft maneuvers.

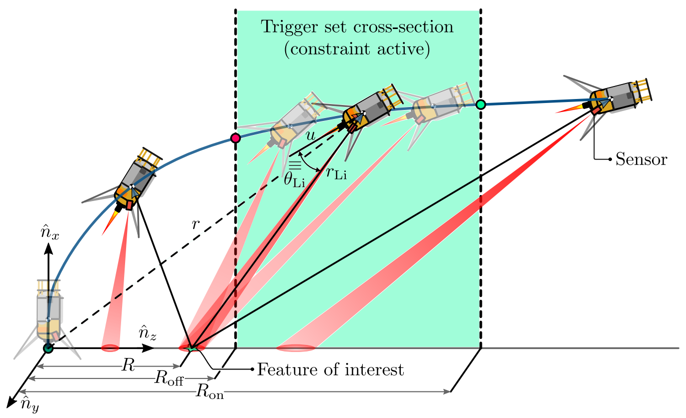
The need for a 6-DoF approach became more prominent as modern planetary landing missions began to demand "terrain-relative navigation" and "hazard detection and avoidance.” Elango explains, “The 3-DoF approach worked well enough in landing scenarios where precision was not important. But now as we’re trying to land with high accuracy at designated sites with unknown terrain, we are using cameras or LiDAR to focus

CONTINUED NEXT PAGE

ONBOARD **DECISION-MAKING** RECORD

on the landing sites in real-time to inform the spacecraft about safe regions. This capability requires high-fidelity modeling of the spacecraft's attitude as well as translation."

To meet this challenge, then-A&A doctoral students Taylor Reynolds, Michael (Miki) Szmuk, and Danylo Malyuta developed the dual quaternion-based 6-DoF powered-descent guidance (DQG) algorithm. This algorithm effectively handles state-triggered constraints (conditional constraints that activate only when specific conditions are met) and is suitable for real-time implementation on computationally limited flight hardware. NASA chose this algorithm for PDG in its SPLICE program.



With state-triggered constraints, when the rocket is inside the trigger window, the body-fixed sensor – a LiDAR or a camera — points towards a feature of interest on the surface to guide it to a safe landing.

The breakthrough: Achieving sub-second onboard decisions

While the DQG algorithm exhibited impressive capabilities, it faced two significant challenges: a large code size and slow execution time. The existing NASA solver, co-developed by A&A researchers, had a large codebase exceeding 600,000 lines and executed slowly on the flight computer. This was not ideal for real-time safety-critical applications.

To address these issues, the A&A research team, led by Kamath and Elango, developed the sequential conic optimization (SeCO) framework. This innovative framework combines sequential convex programming and first-order conic optimization, eliminating the need for matrix factorizations and inversions. By utilizing the proportional-integral projected gradient (PIPG) solver and exploiting the structure of trajectory optimization problems, the SeCO framework achieves significantly faster execution times.

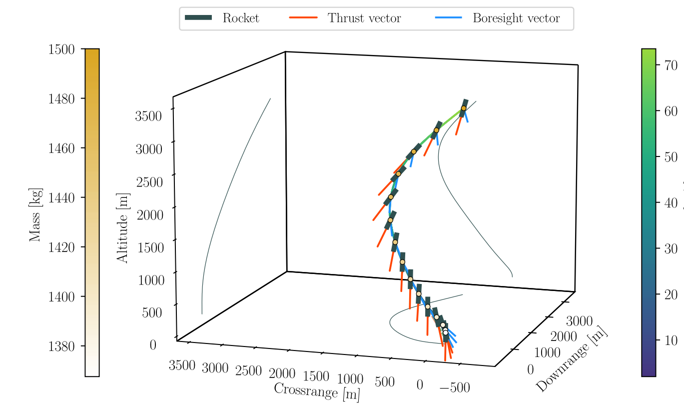
The SeCO solver is capable of solving optimal control problems in milliseconds, exceeding the speed of existing solvers. In onboard tests with NASA's SPLICE flight computer, the algorithm successfully broke the one-second barrier, meeting NASA's requirement for real-time precision landing. The reduction in execution time by over 5x and the decrease in code size by two orders of magnitude make the SeCO framework a transformative advancement in rocket landing guidance.

NASA plans to conduct flight tests of this algorithm in a closed-loop fashion onboard the Astrobotic/Masten Xogdor rocket in 2025 as part of the SPLICE flight campaign. These tests will further validate the effectiveness and reliability of the SeCO framework in real-world scenarios.

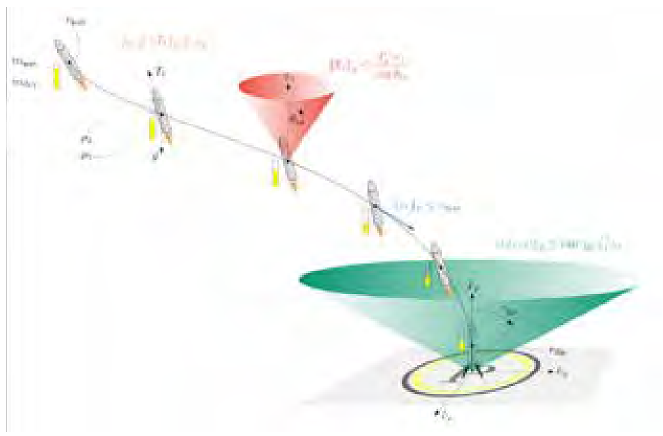
Reflections on the achievement and future implications

Professor Açıkmeşe acknowledges the team's achievement, stating, "With the successful execution of onboard spacecraft decisions in less than one second, we have not only broken the barriers of powered-descent guidance but also paved the way for landing on uncharted celestial bodies. This groundbreaking achievement is a testament to the relentless pursuit of innovation and excellence by our team, and it is an honor to receive the 2023 AIAA Guidance, Navigation, and Control Best Paper Award for our efforts."

Access the full-length version of this story and the AIAA-winning paper as well as other primary sources.

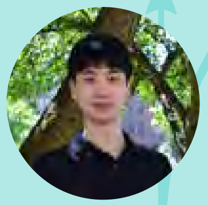


The 3D landing trajectory obtained via the SeCO solver in real-time.



A depiction of the rocket landing guidance problem with basic constraints that can now be executed on-board with split-second decision-making.

See our visualization of 3-DoF versus 6-DoF.



*"The most compelling aspect of this research to me is how it encompasses both the layer of high-level trajectory optimization by SCP and that of the low-level convex optimizer by PIPG. It is the effective combination of both layers that I believe is key to break the barrier of 1-second." **- Taewan Kim***

*"The success of the solver shows how an innovation in mathematical optimization and solutions leads to groundbreaking technologies in space systems. It tells a simple yet powerful message: engineering breakthroughs often come from bridging the gap between theory and application. Contributing to this project is undoubtedly my proudest achievement as an aerospace engineer." **- Yue Yu***

*"Sequential convex programming applied to real-world problems has changed the game for trajectory optimization due to its speed and reliability. This work to harness the real-time potential of these algorithms through customization of the solver pushes the limit on what is possible for embedding instantaneous constraint information in the mission planning process." **- Skye Mceowen***

*"Our ability in formalizing complex constrained guidance problems in six degrees of freedom, and then solving them using highly efficient algorithms developed by our team, open up an unprecedented capability for the conception, design, and development of current and future lunar and planetary missions. I am so proud of how our UW team has put its significant marks on the development of this critical space systems technology." **- Professor Mehran Mesbahi***

revolutionizing space rendezvous

Researchers in our Nonlinear Dynamics & Controls Lab test a precision tool for Blue Origin.

Main photo courtesy of Blue Origin.
All other photos by Kenn Curry.

A tool for precise remote rendezvous

Docking or approaching another spacecraft in orbit is an incredibly challenging task. With both spacecraft traveling at approximately 16,000 miles per hour, even the slightest error in relative position and speed could lead to a catastrophic collision in space. However, the real-time control and monitoring required for such maneuvers become even more difficult due to the vast distances between the mission control on Earth and the remote rendezvous point.

To overcome these challenges, A&A doctoral student Nick Andrews is spearheading groundbreaking research at the Nonlinear Dynamics & Controls Lab for Blue Origin under Professor and Chair Kristi Morgansen. Andrews explains, "Our ultimate objective is to develop a control system capable of utilizing camera sensing for visual tracking, enabling two spacecraft in low Earth orbit to locate each other and autonomously dock."

Andrews' research team is studying the functionality of "AprilTags,'' a type of visual fiducial markers that look a lot like QR codes. These tags are specifically designed to enable the calculation of the position and orientation of objects in space and are even visible in low light, making them particularly useful for space applications.

Harry Furey-Soper, another A&A student involved in the project, highlights the importance of AprilTags in space orientation. He says, "In space, you can't rely on the ground or horizon for orientation, and determining the distance between objects becomes challenging. Being able to measure and identify relative navigation and positioning on board using AprilTags is an invaluable tool."

A&A undergraduate work sets the stage

Four undergraduate researchers laid the foundation for this project. Furey-Soper and Joshua Cheng, who are now A&A graduate students, played a crucial initial role by 3D-printing spacecraft models and setting up mounted cameras and AprilTags for experimentation. Their efforts created a tabletop testbed equipped with robotic arms, which served as the centerpiece of their Junior Capstone project.

Then, Kaylee Hudson, an electrical and computer engineering student, collaborated with Furey-Soper on a Washington NASA Space Grant Summer Undergraduate Research Program (SURP) project in 2022. Building on this work, Osvaldo Aldaz continued the project's development as his 2023 SURP project.

Creating table-top simulations

Andrews is leading the analytical phase, while the remaining team members focus on demonstrating the results with hardware. The initial stage of their work involves recreating the outcomes through a tabletop experiment. Using robotic arms modified to hold 3D-printed spacecraft models, the team simulated docking maneuvers guided by cameras focused on the AprilTags. This setup replicates an in-space docking scenario, providing a representation of an encounter in space. Through this setup, the researchers can validate algorithms and assess results on a smaller scale.

Using MATLAB, they analyzed the effectiveness of AprilTags under various distances and orientations, discovering that the tags' efficacy decreased as the distance and orientation angle increased. However, they also found that while a larger tag can sometimes make the system more effective, it can also make the system less robust because it takes up a significant amount of surface area that may be better utilized with a series of smaller diverse tag sizes. They will be testing the effect of curvature because data only exist for flat tags, but in-space vehicles are cylindrical which may affect their performance with such precise maneuvers.

The value for Blue Origin and students

The ultimate objective is to deliver valuable data to Blue Origin from these demonstrations and work with the company on iterative research that tests real usage of AprilTags and ensures they are not intruding on any constraints. The team will have the opportunity to compare actual flight data from a future Blue Origin launch with their analytical and table-top experiment results.

Professor Morgansen emphasizes the value of this project, "For our students, this research has honed their hands-on experience and analytical skills and contributed to the forefront of space exploration. By collaborating with Blue Origin, we are revolutionizing space missions, developing a control system that enables autonomous docking and paving the way for a safer and more efficient future in space."

Top right inset photos: Furey-Soper and Cheng (right) and Hudson (left) set up the table-top robotic arm that replicates an in-space docking scenario.

At left: The robotic arm is ready for testing while Furey-Soper and Andrews demonstrate the controls. Right: Furey-Soper, Cheng and Hudson with the 3D-printed spacecraft models used for AprilTags experimentation.

When aeronautical engineering was almost exclusively male-dominated, three women from the University of Washington's aeronautical engineering department (now our William E. Boeing Department of Aeronautics & Astronautics) charted new courses in the field.

Rose Lunn, Eleanor Dickson and Luella Armstrong not only excelled in their studies and careers but also paved the way for future generations of female engineers. With the recent passing of Luella Armstrong in 2023, this is a fitting time to reflect on and honor the contributions of these pioneering women who helped shape the aerospace industry.

These trailblazers share remarkable commonalities being the only women in their graduating classes and all working at the University of Washington Aeronautical Laboratory (UWAL), where their work with wind tunnels laid the foundation for their careers.

HONORING THREE TRAILBLAZING women of aerospace

Clockwise from top left: Eleanor Dickson, Rose Lunn, and Luella Armstrong

Rose Lunn: The first to soar

(Class of 1937)

Rose Lunn made history as UW's first female aeronautical engineering student. From a young age, Lunn had set her sights on studying at the Massachusetts Institute of Technology. Her dream began to take shape when she enrolled in the UW in 1933.

In 1937, Lunn graduated at the top of her class, becoming the University's first female aeronautical engineering graduate. Her academic excellence, honed through work in the original wind tunnel, earned her a scholarship to MIT, fulfilling her childhood ambition. At MIT, Lunn completed a three-year-long master's degree in aeronautical engineering and became the first recipient of Zonta International's Amelia Earhart scholarship award — a $4,000 grant that allowed her to continue her doctoral studies.

Lunn's career took off during World War II, a critical period for aerospace advancements. She initially joined Curtiss-Wright in Buffalo, New York, where she set up a Flutter and Vibration Group. However, her most significant contributions came during her 22-year tenure at North American Aviation (NAA). At NAA, Lunn established another Flutter and Vibration Group and added a Vibration Laboratory for ground and flight testing, an acoustical group, and an analog computer facility.

Lunn's expertise was crucial in the development of the X-15 rocket plane, pushing the boundaries of hypersonic flight. When concerns arose about mounting the X-15 on the B-52's wing, Lunn, whose judgment was well-respected among colleagues, expressed reservations. Her expertise led to a detailed study to ascertain the full extent of engine vibration effects on the X-15, showcasing her indispensable role in aerospace innovation.

Eleanor Dickson: Winds of change

(Class of 1949)

Eleanor Griffin Dickson's fascination with aviation began early. As a 10-year-old, she was already building model airplanes and dreaming of designing real ones. After graduating from Seattle's Queen Anne High School in 1945, Dickson enrolled in the department.

In 1949, Dickson embarked on a 38-year career at Boeing in Seattle. She became a pioneering "aerodynamicist," a term used for wind tunnel testing engineers — a role rarely held by women at the time. Her expertise in wind tunnel testing, developed during her time at the UW, contributed to significant advancements in aircraft design.

Dickson's work on winglets for large airliners improved fuel efficiency and performance. Her innovative use of local wind tunnels in aircraft design processes helped refine and optimize aircraft configurations. Throughout her career, she traveled to wind tunnels around the country to direct tests and gather data. On being one of the first female engineers at Boeing, Dickson said she didn't notice; she just "did the job."

Luella Armstrong: Breaking the mold

(Class of 1951)

Luella Armstrong continued the legacy of breaking barriers. Her exceptional work at the UW Aeronautical Laboratory so impressed Boeing engineers that she was guaranteed a position upon her graduation from the department in 1951.

Armstrong began her Boeing career in aircraft structural dynamics, working on complex projects, including airplane landing loads and flutter analysis. Her initial focus was on payloads in the Air Tunnel, and she later discovered her work contributed to the Boeing B-50D airdrop of a nuclear weapon.

Reflective of the discriminatory practices of the time, Armstrong was dismissed due to pregnancy after working at Boeing from 1951 to 1956. During her 22-year hiatus from Boeing, she focused on raising her three children while also teaching herself computer coding skills.

When she returned to Boeing in 1979, Armstrong's self-taught knowledge of computers proved invaluable. She met with the head of Boeing's CAD/CAM division and quickly gained a reputation for being able to bridge the generational gap between younger and older employees at the company. This unique ability, combined with her engineering expertise, made her an asset in a rapidly evolving technological landscape.

Armstrong's innovative research and development on B-52 updates earned her Boeing's Medal of Recognition, extending the iconic aircraft's capabilities. Her contributions to the field were significant. In 2019, her pioneering spirit and career achievements were further honored with the prestigious Museum of Flight Pathfinder Award.

Throughout her career, Armstrong paved the way for women in engineering, serving as a role model and mentor for young women pursuing STEM education. In 2016, the Seattle Times amended a 1951 front-page story about her, originally titled "One Girl in Air Engineers Graduates with 174 Men." The correction acknowledged Armstrong's statement: "I was a woman. I wasn't a girl." This update highlighted the progress in recognizing women's contributions to engineering over the decades.

A legacy of innovation

These three women — Lunn, Dickson, and Armstrong — not only excelled in their field but also opened doors for future generations of female engineers.

A&A Professor and Chair Kristi Morgansen says, "As the first female faculty member and now chair of this department, I stand on the shoulders of these women. Their groundbreaking achievements not only advanced aerospace engineering but also opened doors for countless women in STEM. We're still working on what they started — making engineering a field where women aren't the exception, but the norm."

The UW Aeronautical Laboratory, featuring a 3x3 wind tunnel built in 1917, and the Kirsten Wind Tunnel, constructed in 1936, were at the forefront of aeronautical research. Both facilities continue to operate today, playing a vital role in advancing academic and industry research.

A&A's Design Build Fly team soars to new heights with historic 3rd place finish

An innovative aircraft designed for both urban transport and emergency reponse pays off in this past summer's annual AIAA competition.

A&A's Design Build Fly (DBF) team reached unprecedented heights, securing an impressive 3rd place finish at the 2024 AIAA DBF Competition in Wichita, Kansas, with their aircraft "Orca." This remarkable achievement marks the team's best performance to date and serves as a testament to their dedication, innovative thinking, and collaborative spirit.

Building upon their success from 2023's 5th place finish, the DBF team approached the 2024 challenge with renewed vigor and a steadfast commitment to excellence. A&A senior Jevoni Sykes, the team's chief engineer, described the mission as developing "an urban air mobility aircraft" with two distinct configurations: a taxi and an ambulance.

The taxi configuration required the team to optimize for passenger capacity, energy efficiency, and speed, while the ambulance configuration focused on accommodating medical personnel and equipment while prioritizing swift response times. Sykes expressed immense pride in the team's performance, stating, "We did phenomenal in all aspects of this year's competition, we were a top-ten report (8th), we scored the most points in our ambulance mission, and would have scored the most points in the taxi but the loss of a fuse and a wing strike cost us our flight attempt, and mission time, respectively."

Sykes attributed the team's success to the innovative risks they took and the lessons learned from previous years. "The Orca had some new features. This was our first year implementing retractable landing gears which decreased our drag and made us faster than most other teams," he explained. "We developed and used control surfaces like Fowler flaps and slotted flaps and ailerons, which were entirely new to the club. And we took lessons learned from last year like our monocoque fuselage and expanded and optimized them like decreasing the weight by using thinner Nomex honeycomb core and lighter weight carbon fiber as well as implementing the sandwich structure into our wings which we have never done before."

The team's growth and success can be traced back to the transformative efforts initiated a few years ago with Ethan Uehara (A&A '21) and Daniel Moore (A&A '22) playing pivotal roles in rebuilding the team and implementing a structured organizational framework. This foundation enabled the team to handle explosive growth, with over 70 active members last year, and fostered an environment conducive to the team's motto of "educate and compete."

Sykes praised the team's collaborative spirit and dedication. He commended manufacturing lead Kaleb Shaw, saying, "Kaleb absorbed every bit of information like a sponge — from aerodynamics and avionics to structural design and manufacturing. His dedication earned him the role of manufacturing lead and next year's technical director." Sykes also highlighted Kai Tom and Ken Chen, noting, "Without Kai, our next structures lead, and Ken, our amazing pilot, we couldn't have designed, built or ultimately flown this plane."

The DBF team's success would not have been possible without the support of their sponsors, including Boeing, Janicki, T-Motor, and many others, as well as the guidance of industry mentors from companies like SpaceX and the Marymoor Radio Control Club. As the team looks ahead to the next competition, Sykes is brimming with confidence, "I am very excited to see what the team does next year, and I think this club is more than capable of taking home the gold with next year's leadership team and returning members."

Left: Design Build Fly's team victory image after placing 3rd in their competition.

This year's structures lead Kai Tom with the award-winning plane.

DBF manufacturing lead Kaleb Shaw (right) with the "Orca" at the AIAA competition.

Jevoni Sykes with the "Orca" in Wichita.

Kai Tom, on the DBF community

"I truly believe DBF would not be successful without the memories created as a team. One of the most electrifying memories was watching the plane fly for the first time. I was sitting on the damp grass with my colleagues full of nervous adrenaline. Twenty seconds later, I heard the motor whine overhead as the carbon fiber aircraft zoomed by. At that moment I just thought, wow, we as a team made that thing fly! That is pretty cool. In that moment I looked back at all the persistence that took us to this point. All the meetings and discussions that seem to mimic a working environment. All the hours in the shop that brought us closer as a group. I truly appreciated having a community around me that understands the frustrations and glories that come from making something so special. We could not have been successful without everyone."

A NOVEL APPROACH TO REDUCE NOISE POLLUTION

Sunflowers architecting sound

NSF funds research on nature-inspired materials for superior noise control and acoustic wave absorption.

A joint team of researchers from the University of Washington (UW) and State University of New York (SUNY) at Buffalo has received over $500,000 from the National Science Foundation (NSF) to develop innovative patterned structural designs for noise reduction, inspired by the Fibonacci spiral arrangement of sunflower seeds.

Led by A&A's Assistant Professor Ed Habtour, the project aims to deepen our understanding of how geometric patterns affect wave dynamics. The research seeks to create new design principles for irregular geometric patterns in acoustic meta-materials, -structures, and -surfaces, potentially revolutionizing how we control and absorb sound waves.

"Recent studies in biology revealed that sunflowers distort their floret patterns to attract pollinators and avoid pests. By mimicking their distorted pattern designs, we can achieve two things current regular designs can't: better control of properties of the wave dynamics and reduction of acoustic noise over wider frequency ranges," explains Professor Habtour.

The research team, which includes SUNY Associate Professor Mostafa Nouh, Professor Edmund Seto from the UW School of Public Health, and Assistant Professor Tomás Méndez Echenagucia from the UW Department of Architecture, will develop models and prototypes to understand how these natural patterns can be applied to engineered multifunctional structures that can attenuate acoustic waves while meeting the structural durability objectives.

Focusing on practical applications, the researchers will be targeting noise in the 200-2000 Hz range, which is known to harm human hearing and health. This includes sounds from highways traffic, aircraft, trains, and construction activities. They will create demonstration prototypes of indoor and outdoor acoustic attenuation panels designed for integration into buildings and vehicles.

Beyond the scientific work, the project has a social justice component. Habtour and Seto will work with schools in disadvantaged communities that are disproportionately affected by noise pollution, especially near airports and airfields in Washington state. They will demonstrate how communities can create their own affordable, non-toxic alternatives to current noise-reduction products.

The researchers hope their work will lead to a new generation of materials that can reduce noise pollution more effectively, while also empowering communities to adopt and benefit from these innovations early on. This research could potentially extend to other applications involving electromagnetic and light waves in the future.

Go to the source: Access an original research paper on this topic in the *Journal of Exposure Science & Environmental Epidemiology* (June 2024) by Lauren M. Kuehne, Ed Habtour, Tomás Méndez Echenagucia and Steven J. Orfield.

Main image: A close-up of a sunflower's center, showcasing the intricate Fibonacci spiral pattern of its seeds. Inset photos, left to right: Assistant Professor Ed Habtour, Assistant Professor Tomás Méndez Echenagucia and Professor Edmund Seto.

Uncertainty no more

Mohammad Al-Jarrah merges math and machine learning for safer autonomous systems.

Mohammad Al-Jarrah, an A&A doctoral student, is tackling the "nonlinear filtering problem" — determining the true state of a system when relying on imperfect information. Al-Jarrah's research is especially important for autonomous systems, which need to safely navigate uncertain real-world situations. Examples of these systems include self-driving cars managing traffic, smart energy grids adapting to weather, and robotic surgical assistants responding to unexpected events.

He notes, "The evolution of aerospace technologies underscores a growing reliance on uncertain sensory data and deployment in uncharted environments. This matters because as aerospace systems grow in complexity, mastering the art of navigating uncertainties becomes crucial for safety and innovation."

Al-Jarrah's approach combines machine learning with optimal transport theory. He explains, "Optimal transport theory gives us a sophisticated way to work with probability distributions. It introduces concepts such as the Wasserstein metric, a way to measure how similar or different two distributions are while taking into account the underlying data geometry."

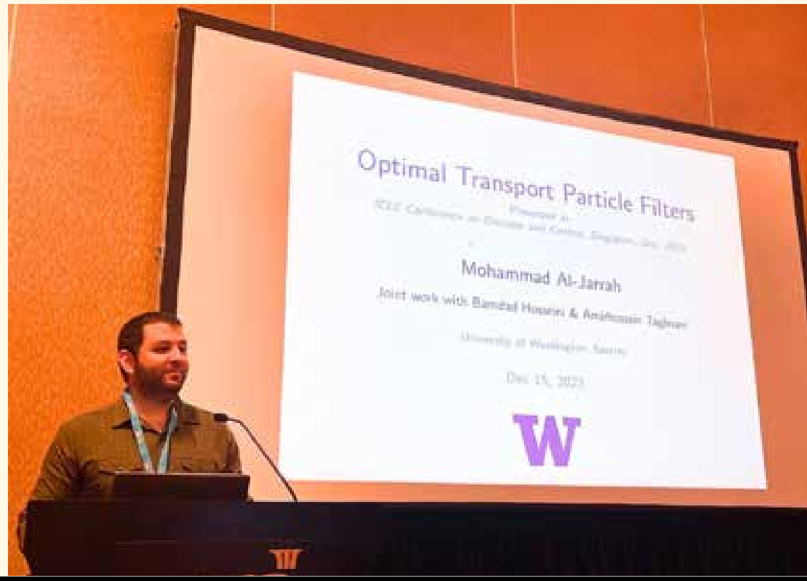
While optimal transport theory provides a solid mathematical foundation, it is insufficient for real-world autonomous applications. Machine learning, particularly deep neural networks, is needed to approximate the optimal transport map, enabling the transformation of probability distributions based on incoming data. This allows Al-Jarrah's approach to manage multi-modal and high-dimensional uncertainties that previous algorithms could not handle.

Al-Jarrah's research, funded by the National Science Foundation, seeks to create scalable and adaptable nonlinear filtering algorithms that make autonomous systems more resilient. This could lead to optimal and energy-efficient sensing strategies that reduce uncertainty in real time when unexpected situations arise.

Developing these innovative algorithms presents computational and theoretical challenges, requiring careful design of neural networks, training procedures, and rigorous mathematical error bounds. Al-Jarrah and his faculty adviser, Assistant Professor Amir Taghvaei, are working on algorithm design, neural network parameterization, and training using advanced optimization techniques like stochastic gradient descent. They are also conducting extensive evaluations against practical benchmarks to ensure the algorithms' reliability for real-world use.

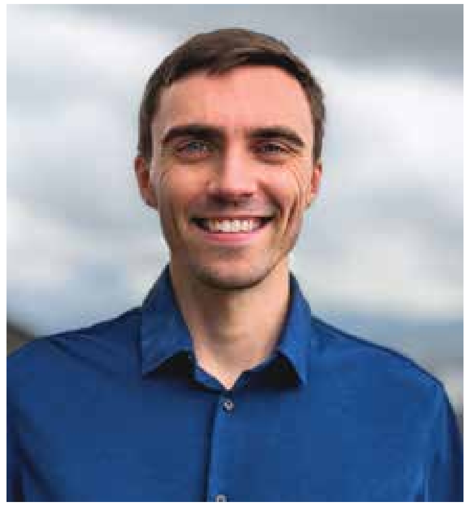
Taghvaei comments on Al-Jarrah's research, stating that "It's an ambitious undertaking, but one that could pave the way for a new era of safer autonomous technologies. Mohammad's research aims to enhance the resilience of autonomous systems, potentially revolutionizing fields from transportation and energy management to healthcare and beyond."

Go to the source: Access the full-length version of this story and several published research papers on this work.



Al-Jarrah presenting at the 2023 IEEE CDC Conference in Singapore.

A&A welcomes three new faculty members, boosting space systems capabilities



Photos left to right: Charlie Dorn, Martin Nisser, and Avin Vijay

We are excited to announce the addition of three new assistant professors to our faculty. Charlie Dorn, Martin Nisser, and Avin Vijay will join our team, bringing fresh perspectives and cutting-edge expertise to our space systems engineering program. These appointments strengthen our department's capabilities, particularly in the structures discipline, with Professor Nisser also contributing to our autonomy expertise. Their collective experience spans computer science, materials and aerospace engineering, reflecting the interdisciplinary nature of modern space systems engineering.

Charlie Dorn

Assistant Professor Charlie Dorn joins us from ETH Zurich, where he just completed his postdoctoral fellowship. Dorn received his PhD in space engineering from the California Institute of Technology. His research focuses on active and programmable structures, ranging from morphing origami-inspired structures to wave motion in mechanical metamaterials. Dorn's work combines theory, computation, and experimentation to develop structures with innovative properties such as wave steering and reconfigurability. His expertise in multiscale modeling and inverse design of structures and metamaterials will significantly enhance our department's research in advanced materials for space applications.

Martin Nisser

Assistant Professor Martin Nisser comes to us from MIT, where he completed his PhD in the Computer Science and Artificial Intelligence Laboratory. Nisser's research centers on developing new fabrication methods for creating customizable hardware, from robots to space structures. His work spans applications from in-space manufacturing to personal fabrication, with a focus on automated digital fabrication and assembly procedures. Nisser brings valuable experience in computational fabrication, programmable materials, and modular robotic platforms for in-space assembly, having led multiple parabolic flight campaigns and contributed to MIT's Extrusion Project on the International Space Station.

Avin Vijay

Assistant Professor Avin Vijay arrives from the University of Michigan, where he served as a research faculty after completing his PhD in aerospace engineering there in 2021. Vijay's research focuses on leveraging structural mechanics and numerical tools for the Design for Additive Manufacturing of composites and 3D-printed plastics used in aircraft and spacecraft structures. His expertise also includes mechanics of carbon fiber laminates and the application of machine learning in the mechanics and manufacturing of aerospace structures. His work on In-Space Assembly and Manufacturing of ultra-large space structures will contribute significantly to our department's capabilities in advanced space structure design.

Remembering Anita Gale: A life dedicated to aerospace and education

The A&A department mourns the passing of Anita Gale (1951-2024), the 2020 Distinguished Alumna and a trailblazing figure in the aerospace industry. Gale leaves an inspiring legacy of innovation, mentorship, and unwavering dedication to space exploration and education.

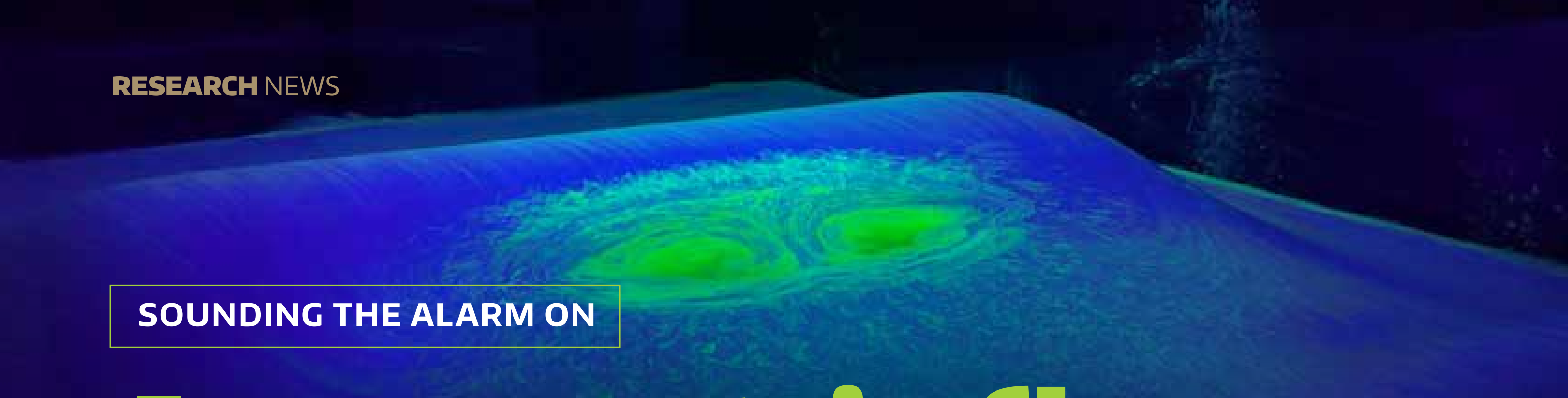
Gale's passion for space began in her youth, fueled by the launch of Sputnik and the excitement of the Mercury missions. She entered UW Engineering in 1969, the same year as the Apollo 11 moon landing, as the only woman in her A&A cohort. After earning her bachelor's and master's degrees in 1973 and 1974, she embarked on a career in the Space Shuttle Program.

Starting at Rockwell International in 1974, she played a crucial role in the shuttle's development, specializing in payload and cargo integration. Her work resulted in three U.S. patents for technologies that significantly reduced vehicle processing costs and schedules. Throughout her career, Gale excelled in roles of increasing responsibility at Rockwell, Aerojet Electro-Systems, and Boeing, where she finished her industry career with the Commercial Crew program in 2016.

Gale's impact extends far beyond her engineering achievements. In 1984, she co-founded the Space Settlement Design Competition, a program that has since reached over 1,000 high school students annually across six continents. What began as a small project with her husband and a colleague grew into a global phenomenon, inspiring countless young minds to pursue careers in aerospace and engineering. A&A Professor and Chair Kristi Morgansen reflected on Gale's impact, stating, "As a woman in aerospace, I have long looked to Anita, who was a pioneer in the U.S. space program and an inspiration to the women in the field after her."

Gale's leadership was also evident in her active involvement with the American Institute of Aeronautics and Astronautics (AIAA) and the Society of Women Engineers (SWE). In 2021, she was elected CEO of the National Space Society, a position she held until her passing. Under her leadership, the organization opened a new headquarters at the Kennedy Space Center and secured significant funding for space education initiatives.

Anita Gale's life and career will continue to inspire generations of aerospace professionals and students. As a passionate engineer and educator, she left an indelible mark on the A&A department, the aerospace industry, and countless young minds worldwide. Her unwavering dedication pushed boundaries, both in space and on Earth.



SOUNDING THE ALARM ON

Asymmetric flows

Associate Research Professor Owen Williams is raising concerns about a phenomenon known as asymmetric flow, urging the aerospace community to acknowledge and address its implications for flight safety.

Asymmetric flows, characterized by unexpected and unpredictable airflow patterns around symmetrical objects, have long been dismissed as experimental errors. However, Williams and his collaborator, Professor Alexander Smits of Princeton, argue in an upcoming paper for the Annual Review of Fluid Mechanics that these occurrences are far more prevalent and significant than previously recognized.

These unpredictable flows, often emerging at the limits of an aircraft's operational range – known as the flight envelope – can lead to dangerous situations. Williams paints a stark picture: "Imagine a pilot executing a tight turn, only to have the aircraft roll unexpectedly – the consequences could be catastrophic."

What makes these flows so difficult to predict is their extreme sensitivity to seemingly insignificant factors. Minute variations in an object's geometry, surface imperfections, or even the presence of dust particles can trigger persistent asymmetric behaviors under specific conditions.

Williams' research, partly funded by Boeing, has focused on examining airflow separation over smooth, curved surfaces like aircraft wings, a phenomenon notoriously challenging to predict. Using the University of Washington's 3'x3' wind tunnel, the team discovered that the flow separating over these surfaces exhibits far more dynamic and erratic movement than conventional design tools can predict. This unpredictable behavior has significant implications for both the efficiency and control of aircraft.

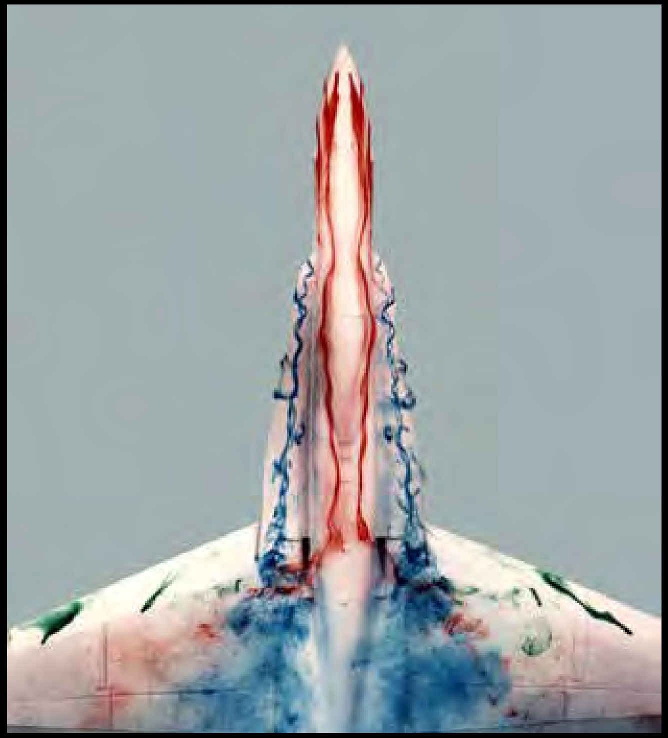
The research suggests that asymmetric flows arise from complex interactions between instabilities, bifurcations, and the inherent sensitivity of these flows to small disturbances. Bifurcations, in this context, refer to points where even minor changes in conditions can drastically alter the flow's behavior.

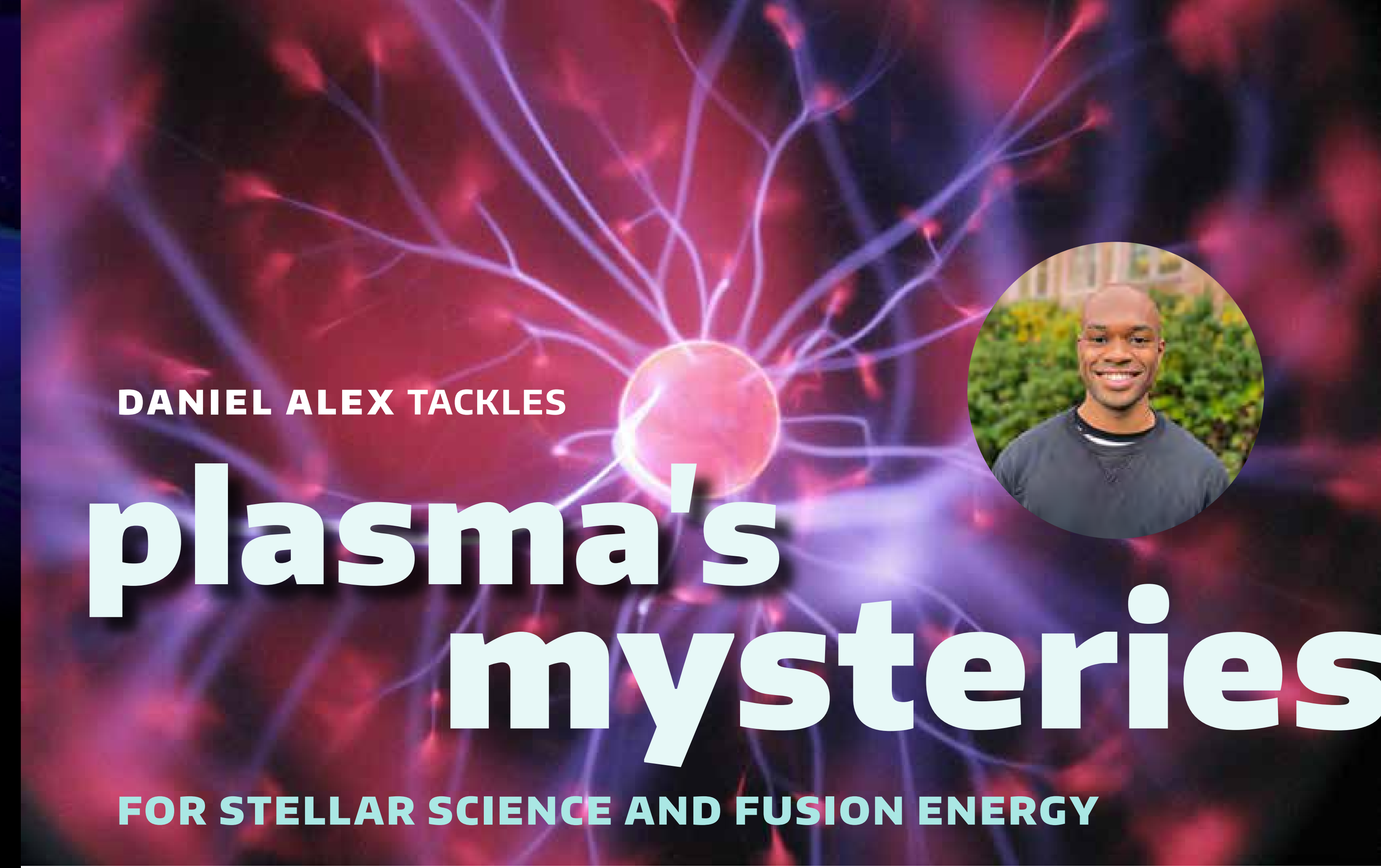
Williams believes that a reluctance to report these "unexpected" asymmetries has hindered progress in understanding them. He emphasizes the need for more open discussion and reporting within the aerospace community to develop a unified theory for predicting these behaviors.

Looking ahead, Williams is exploring how artificial intelligence and machine learning can improve the modeling of turbulent separated flows over high-lift wings. This research, also funded by Boeing, aims to enhance our understanding of the complex, multi-scale phenomena underlying turbulent flows, ultimately leading to better aircraft designs.

As the aviation industry strives for greater performance and efficiency, recognizing, understanding, and mitigating the risks posed by asymmetric flows becomes increasingly critical.

Go to the source: Access the full-length version of this story and the original research paper.





DANIEL ALEX TACKLES

plasma's mysteries

FOR STELLAR SCIENCE AND FUSION ENERGY

Daniel Alex, a doctoral student in A&A's Plasmawise Lab, is using complex computer simulations to help unlock the future of clean energy through nuclear fusion. His research, conducted under the guidance of Professor Bhuvana Srinivasan, focuses on one of fusion energy's greatest challenges: understanding and controlling the unpredictable behavior of plasma.

Plasma, often called the "fourth state of matter," makes up over 99% of the visible universe. While it holds the key to potentially limitless clean energy, its inherent instability makes it difficult to harness for practical applications.

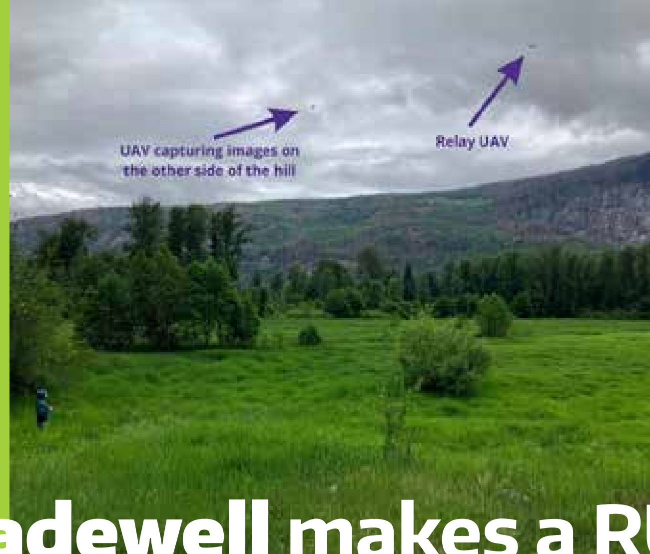
One of the key challenges Alex is addressing is turbulence during the fusion process. He explains that at facilities like the National Ignition Facility (NIF) at Lawrence Livermore National Lab, where he conducted research, scientists are working to achieve fusion by compressing tiny pellets of hydrogen isotopes. "When we fuse these isotopes, we get helium and energetic neutrons. If we can heat the plasma enough to achieve fusion, we can use the heat from those reactions to sustain additional fusion reactions. This process is called ignition."

A significant obstacle to achieving ignition is a phenomenon known as the Rayleigh-Taylor instability, which occurs when fluids of different densities mix. This instability creates chaotic mixing, similar to what happens when water is poured into oil. Alex's simulations are helping researchers understand how this instability impacts fusion experiments.

Perhaps the most intriguing aspect of Alex's research involves the discovery of incredibly strong magnetic fields that spontaneously emerge within the plasma. These self-generated fields, reaching magnitudes of 11,000 tesla in his simulations, are far stronger than those produced by MRI scanners or even ITER, the world's largest planned fusion experiment. These magnetic fields aren't just scientific curiosities – they appear to be making the turbulence worse. His research suggests that these fields contribute to cooling and low-pressure regions within the plasma, further accelerating the mixing process.

Professor Srinivasan emphasizes the significance of Alex's work: "Daniel's insights into turbulence and magnetic field generation aren't just theoretical advances. They could help solve some of the major roadblocks in fusion energy research." She also highlights the broader scientific implications of this research, noting that the same fundamental physics governing plasma instabilities are at play in both distant stars and laboratory fusion experiments.

Go to the source: Access the full-length version of this story.



Evelyn Madewell makes a RUCKUS in search and rescue

Evelyn Madewell, an undergraduate researcher in A&A's Control and Trustworthy Robotics Lab (CTRL), is leading the charge in enhancing drone-based wilderness search and rescue.

Her innovative system, the Reliable Uninterrupted Communications Kit for UAV Search (RUCKUS), offers a solution to the limitations of traditional drones in challenging terrains. Madewell recently presented her research on RUCKUS at SciTech 2024.

RUCKUS is a portable and self-contained system designed to enable UAVs to operate beyond the pilot's visual line of sight (BVLOS). This is a critical advancement for search and rescue missions in areas where obstacles, such as dense forests or mountainous terrain, obstruct the pilot's view.

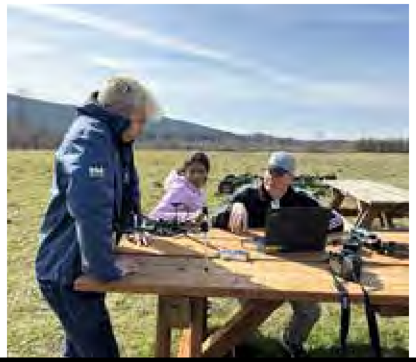
The system comprises three key elements: a search UAV equipped with cameras, a ground control station for the operator, and a relay UAV strategically positioned to maintain communication between the search UAV and the ground station. This setup not only extends the operational range of the search UAV but also allows it to function effectively even when obstacles interrupt the line of sight.

Madewell's inspiration for RUCKUS came from direct conversations with search and rescue teams, including the Chelan County Sheriff's Department. These teams highlighted the crucial need for BVLOS capability in their operations. Recognizing the importance of practicality and accessibility, Madewell and her team engineered RUCKUS to be self-contained, modular, and affordable.

The self-contained design enables rescuers to carry all the necessary equipment in a backpack, facilitating rapid deployment in remote and often inaccessible locations. The system's modularity allows for seamless integration with existing equipment, reducing costs and enhancing its versatility. Most importantly, the affordability of RUCKUS ensures that this life-saving technology is accessible to volunteer organizations and government agencies often operating with limited budgets.

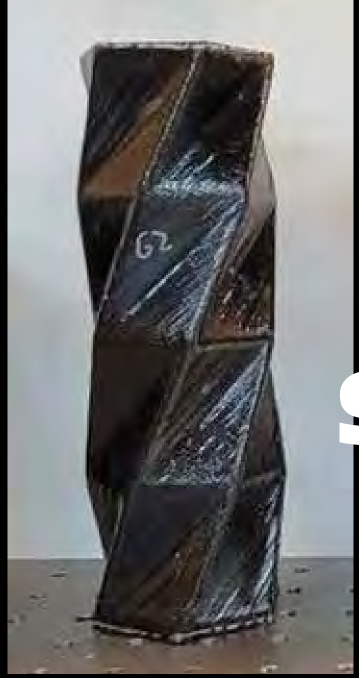
A key feature of RUCKUS is its ability to provide real-time video feedback and dynamic updates to the operator. This immediate information flow is vital for efficient search efforts and can be the difference between life and death in time-sensitive rescue operations.

To validate the system's efficacy, Madewell and her team conducted rigorous experimental flight tests. These tests focused on measuring signal strength over long distances and verifying the system's ability to maintain a stable connection and transmit video even when obstacles obstructed the line of sight. The results confirmed RUCKUS's effectiveness in maintaining communication and transmitting critical visual data in challenging environments.



Go to the source: Access our full interview with Madewell and the team's research paper.

Above left to right: Professor Emeritus Juris Vagners, Paul Gray (owner of the flight test site), Sanghamitra Johri, Danny Broyles, Evelyn Madewell, Assistant Professor Karen Leung, Helen Kuni, and Matthew Keene stop for a photo during RUCKUS testing; Madewell test-pilots a drone with the RUCKUS system; Evelyn Madewell. At left: Eli Pollack, Sanghamitra Johri and Daniel Broyles discussing the system; Pollack, Madewell and Helen Kuni take a break during flight testing.



JIMMY O'NEIL'S ORIGAMI MANUFACTURING TECHNIQUE LEADS TO BREAKTHROUGH FOR softer impacts

Doctoral student Jimmy O'Neil has been adapting origami tubes for softer impacts, and his innovative manufacturing is solving a significant industry challenge.

O'Neil's research focuses on the use of Kresling origami for crash resilience. Kresling origami is a foldable thin sheet connected by parallelograms and triangles. Attaching the ends creates a Kresling unit cell. His research aims to overcome the limitations of modern-day vehicle crash boxes by introducing these folds that combine compression with twisting, creating a smoother collapse during impact.

Traditional crash boxes have straight wall geometries, resulting in harsh initial impact peaks for passengers. By incorporating creases and folds that act as geometric imperfections, O'Neil discovered a way to optimize the collapse of structures, reducing the intensity of impacts.

O'Neil's research demonstrates that Kresling origami tubes provide compression advantages over straight-walled cylinders and square tubes. He conducted compression tests on five different shapes of tubes and measured the force for each shape. The tests confirmed that Kresling tubes absorbed energy more gradually, creating a smoother and safer experience during impact.

However, implementing origami principles in engineering has been challenging due to the manufacturing process. Structural materials are difficult to fold and shape into complex origami geometries. O'Neil proposes filament winding as a solution. Filament winding is a common manufacturing process for composite cylindrical tubes. This approach merges the advantages of origami with carbon fiber reinforced epoxy resin materials, which offer weight-saving benefits over metals.

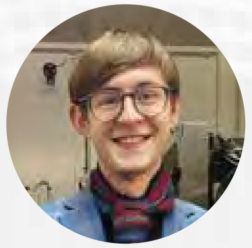
O'Neil's research on impact mitigation with origami has the potential to improve safety in various fields, including vehicles and rocket landings. Professor Marco Salviato emphasizes the importance of this research, noting that O'Neil's approach to using origami architecture to enhance energy dissipation in composite structures "can be a game changer."

While O'Neil's manufacturing process currently requires significant effort, filament winding machines will enhance efficiency and make it a viable option for industry applications. His research paves the way for safer and more efficient structures by adapting an ancient art to solve modern engineering challenges.

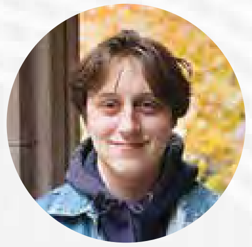
Go to the source: Access the full-length version of this story with accompanying video, more technical information, and a published paper on this origami tube research.

2024 A&A UNDERGRADUATE SHOWCASE WINNERS

1st Place / People's Choice Award
Yeongjun "Marvin" Bok



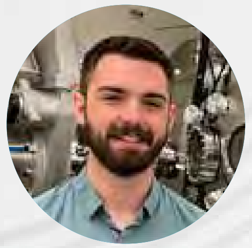
2nd Place
John Michael Racy



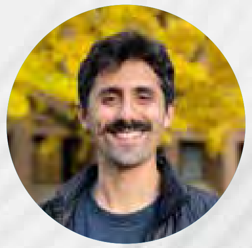
3rd Place
Jasper Geldenbott

3rd Place
Annika Singh

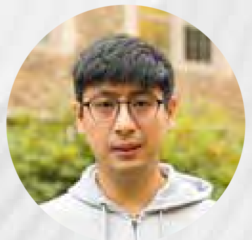
2024 A&A GRADUATE RESEARCH SHOWCASE WINNERS



1st Place
Landon Bevier



2nd Place
Paul Medina

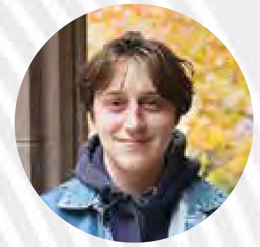


3rd Place
Jiacheng Chen

3rd Place
Collins Davis

People's Choice
Thijs Masmeijer

2024 A&A STUDENT EXCELLENCE AWARDS



Undergraduate Research Excellence
Jasper Geldenbott

Master's Research Excellence
Matthew Nuss

Doctoral Research Excellence
Mohammad Al-Jarrah

Undergraduate Teaching Excellence
Colin Baxter

Graduate Teaching Excellence
Oliver Sheridan

Undergraduate Service Excellence
Jevoni Sykes

Graduate Service Excellence
Landon Bevier

Every day the future is expanding in our labs. From the development of advanced unoccupied aerial vehicles to new aerodynamic techniques and unconventional space propulsion concepts, the faculty and students of UW Aero & Astro are honing the cutting edge of tomorrow's technologies.

UNDERGRADUATE AWARD

Sigma Gamma Tau Award for Western Region
Lillie LaPlace

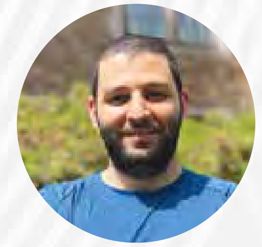
GRADUATE AWARDS

NSERC Fellowship
Kevin Manohar

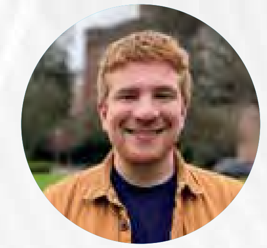
Varanasi Endowed Fellowship
Mira Tipirneni

Condit Dissertation Fellowship
John Berg

CONFERENCES



Outstanding Paper
Mohammad Al-Jarrah*



Best Student Paper
Spencer Kraisler

2024 IEEE CONFERENCE ON DECISION AND CONTROL

Best GNC Graduate Student Paper
Skye Mceowan

2025 SCITECH

** Additional awards: Sarchin Fellowship, ACE Fellowship*

HIGHFLIGHT
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Professor Bhuvana Srinivasan receives nation's highest early-career scientific honor

A&A's Professor Bhuvana Srinivasan has been named a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honor bestowed by the U.S. government on outstanding scientists and engineers beginning their independent careers.

The award, announced by President Biden, recognizes Srinivasan's groundbreaking work in computational plasma physics, particularly her research advancing fusion energy concepts and plasma-based propulsion systems. Her selection stems from her NSF CAREER Award achievements in developing high-fidelity models for plasma dynamics.

As director of our PLASMAWISE Lab, Srinivasan leads research crucial to the future of both space exploration and sustainable energy. Her work spans from studying plasma-material interactions in thrusters and fusion devices to investigating instabilities in high-energy-density fusion and astrophysical plasmas.

"Professor Srinivasan exemplifies the innovative spirit and scientific rigor that drives our department forward," says Professor Uri Shumlak, who served as Srinivasan's Ph.D. advisor before becoming her colleague. "Her return to UW as a faculty member, now earning this prestigious recognition, showcases not only her exceptional talents but also her dedication to pushing the boundaries of aerospace engineering. Her work is instrumental in advancing both fusion energy and space propulsion technologies."

Srinivasan joined our faculty after serving as associate professor at Virginia Tech, where she held the Endowed Crofton Faculty Fellowship in Engineering. Her research has garnered support from numerous prestigious institutions, including the National Science Foundation, Department of Energy, and Air Force Office of Scientific Research.

The PECASE award, established by President Clinton in 1996, recognizes scientists and engineers who show exceptional leadership potential in their fields. This year, nearly 400 researchers received this distinguished honor across 14 federal agencies.