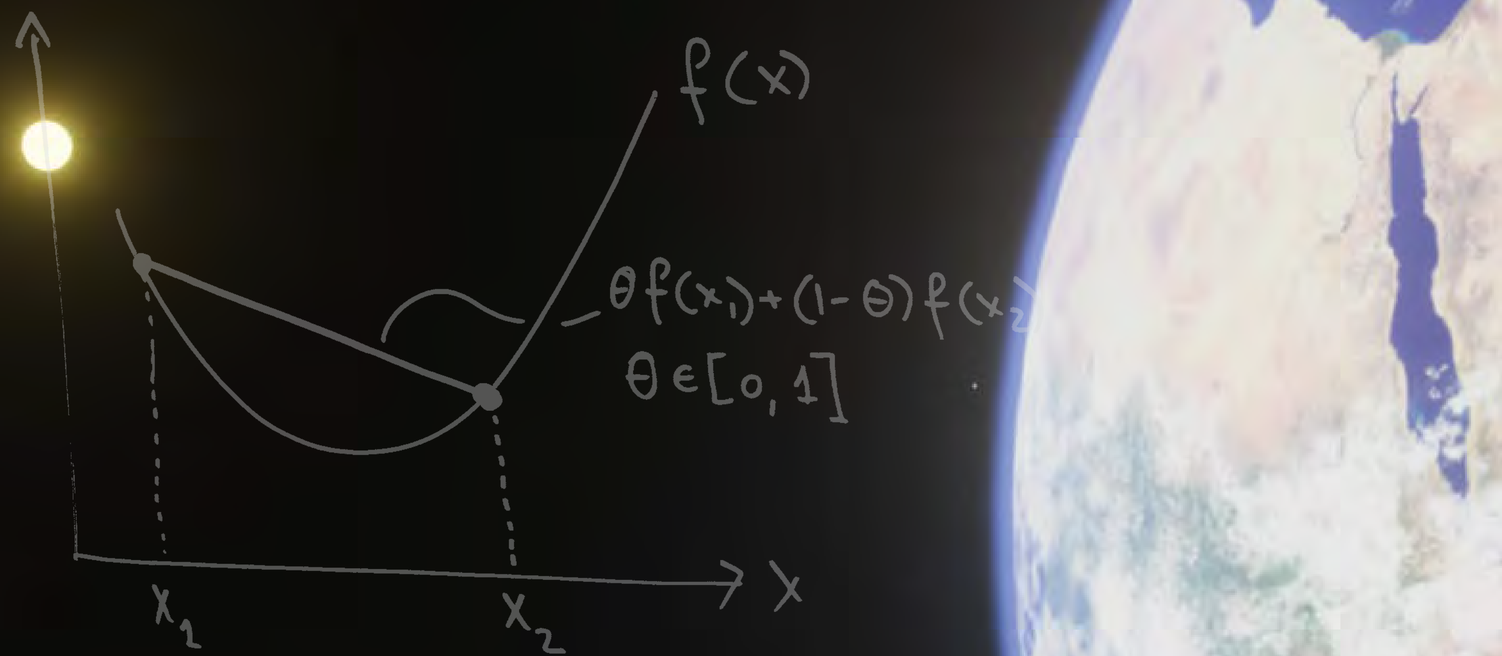
HIGH**FLIGHT**

WILLIAM E. BOEING DEPARTMENT OF AERONAUTICS & ASTRONAUTICS



2020 IN THIS ISSUE

MESSAGE FROM THE CHAIR

Dear A&A Alumni and Friends,

We are in quite a moment for the world and for aerospace in particular. It's been challenging. Our graduating seniors are still waiting for their moment to walk with their friends at the department graduation. We have been not only dealing with the COVID-19 pandemic, but also with our understanding of endemic, systemic racism and how we can effect real change as an institution and as individuals. Not being together in person is a real loss, but as I look at the state of our department, I cannot help but feel inspired and hopeful about this community.

What am I seeing? We are advancing marine energy through our fluids research, locating people lost in the wilderness by training drones to see people, helping the world's corals recover, developing new data science methods, analyzing Mars missions, unraveling the mysteries of detonation engines and applying controls algorithms to track COVID-19. We're doing all of this and more.

In addition, we are welcoming two new faculty members into the department. Ed Habtour comes to us from Sandia National Laboratories as he comes on board as an assistant professor in Structures, and Erik Hurlen comes from San Diego State University as he joins us as an associate teaching professor. Erik has been coordinating sending junior lab kits to our students at home and mapping out how to teach such a hands-on course remotely.

And that's exactly our wheelhouse in A&A. We are engineers specifically trained to make things that work remotely. While we are missing the in-person banter and collaboration, we are rising to the challenge of figuring out how to make it work. Aerospace engineers send innovations far into the oceans, the skies and space – places we may never individually go in person. This year is not lost. It is a challenge that we will master and come out more clever, more agile, and more grateful to be back together when we can.

Kristi A. Morgansen
Professor and Chair

Kristi A. Morgansen, Professor and Chair

HIGHFLIGHT 2020

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An electronic copy of Highflight will be posted on our website.

Kourosh Hadi

named A&A's Distinguished Alumnus 2020

Kourosh Hadi (BS '82, MS '87) has been named the 2020 A&A Distinguished Alumnus. Hadi has made major contributions to the field of aeronautics through his many leadership roles at Boeing as well as his work with the A&A department, starting with his time as an undergraduate on the Kirsten Wind Tunnel crew to his current work as the department's Boeing executive focal.

Since 2012, Hadi has been responsible for development of all new and derivative Boeing airplanes. He oversees advanced concepts, technology integration and competitor airplane analysis. Hadi also serves on the Board of Directors of HRL Laboratories (formerly Hughes Research Laboratories). In his years of different leadership roles in Boeing Commercial Airplane Product Development, he has led the preliminary design and successful launch of many significant programs including 787, 777x, 737-10, 767 Tanker, 747-8, 777 Freighter, 747 Dreamlifter, and 767-400ER.

Before his current position, he was the Boeing 767 Chief Program Engineer including for the KC-46 tanker. He was responsible for leading the program, and maintaining technical integrity and quality engineering design, certification and safety.

Hadi served as deputy Chief Program Engineer and integration leader for 747-400, integration leader for 747-4000ER, and was 767-400ER wing leader. He was promoted into management in the Airplane Configuration and Integration group in 2000, leading product development programs for 747, 767, 777 and new airplane programs. He began with Boeing as a noise research engineer in 1985.

Since 2007, Hadi has been working directly with the A&A department as both the Boeing executive focal and as a member of the Visiting Committee. In these roles, he has worked toward enhancing A&A's excellence in education, research, and experimental capabilities. In particular, he has strengthened the links with Boeing to align research in the department with cutting edge developments in the aerospace industry, work he continues today.

Kourosh Hadi at the UW centennial for aeronautics instruction in 2018. Photo credit: Matt Hagen.

Aerospace turns the tide on MARINE ENERGY

By Andy Freeberg and Amy Sprague

Unique challenges of marine energy

Mechanical engineering Ph.D. student Abigale Snortland is eager to get back to UW's Harris Hydraulics Lab and its Alice C. Tyler flume, a long, fast-flowing channel of water that simulates river flows and tidal currents. Her team's turbine research informs how to draw renewable energy from river, tidal and ocean currents.

These kinds of marine-generated energy have huge potential. Two other main sources of green energy, solar and wind, depend upon clear skies and consistent wind, which have significant downtimes. But marine energy benefits from steady and reliable water flows.

Despite this potential, marine energy projects have been hard to implement. Flowing water, with its forces, turbulence, sediments, salinity and algae, is tough on equipment. Maintenance may need to be done underwater during slack tides, the narrow window of time with weak tidal currents. Snortland's work, for which she was recently awarded a prestigious National Science Foundation Graduate Research Fellowship, will apply aeronautics techniques to boost the performance of marine turbines and inform industry standards that reduce the overall challenges of such systems.

Simpler turbines, not-so-simple physics

Snortland specifically researches how water moves through cross-flow marine turbines, which are different from the more familiar axial turbines, the structure of the common wind turbine. While axial turbines look like windmills, cross-flow turbines are structured more like a whisk, and, due to their relative mechanical simplicity, they provide some advantages in the harsh water environments.

She explains, "We are looking closely at cross-flow turbines because they have few moving parts and connections that could get corroded underwater. Unlike axial turbines in water, they don't need to rotate to follow the direction of the changing tides and currents. They work regardless of which direction the tide is flowing. Even in wind, there are some applications where cross-flow turbines may be preferable to axial turbines."

"Part of the reason that most wind turbines look alike is because there is an established theory for how wind moves around the blades, which helped the industry converge on a design. No equivalent theory yet exists for cross-flow turbines because we still have a lot to learn about how fluids move around those blades."

Abigale Snortland and Greg Talpey observe a cross-flow turbine in the Alice C. Tyler flume in the UW Harris Hydraulics Lab as part of a research collaboration among the Departments of Mechanical Engineering and Aeronautics & Astronautics and the Pacific Marine Energy Center.

"Part of the reason that most wind turbines look alike is because there is an established theory for how wind moves around the blades, which helped the industry converge on a design. No equivalent theory yet exists for cross-flow turbines because we still have a lot to learn about how fluids move around those blades."

ABIGALE SNORTLAND

While simpler for the corrosive waters and the variable directions of tides, the physics of these turbines are far less tidy, making it challenging to build a standard model. For a simple two-bladed spinning cross-flow turbine, one blade is moving with the flow while the other blade is going against it. This constant fight between the upstream and downstream blade results in strong moving vortices, a mess of turbulence and unsteady performance.

Brian Polagye leads the Pacific Marine Energy Center and co-advises Snortland. He says, "Generally, we have been able to make advances in performance through trial and error. But that can only get us so far. To advance the theories around turbine performance," he continues, "we need to understand what is happening on each blade through Abigale's experimental data."

Apply aerospace

To get beyond trial and error, Polagye teamed up with aeronautics and astronautics professor Owen Williams to co-advise Snortland. Williams is one of the UW's leading experts in wind tunnel testing. He manages the UW aeronautics laboratory, one of two experimental wind tunnels on campus and has also built a small-scale supersonic wind tunnel in his lab in the bottom floor of Guggenheim Hall, which draws air from the large-scale Kirsten Wind Tunnel next door.

Williams has extensive experience with particle image velocimetry (PIV), a method of inserting small particles into a flow, lighting them with a laser and using a high-speed camera to photograph and chart the trajectories and speeds of those particles to map flows.

While it may seem counterintuitive to bring an aerospace expert into a marine energy project, water and air are both fluids, and the methods and principles of studying hydro- and aerodynamics are remarkably similar. Wind tunnels and water channels play by the same rules.

With Williams' guidance, Snortland set up an experimental cross-flow turbine in the water flume and has been using PIV to analyze how the water is coming off the blades. She explains, "During a turbine rotation, the blades reach a certain angle to the incoming flow, and it causes little swirls that stay with the blade for a little bit and then drop off. This separation causes a dip in performance. Until now, we haven't been able to see exactly what is happening on the blade. As we get more data, we can finally explain why small changes we make in the turbine setup affect performance."

Data from Snortland and her team won't just make turbines better; it'll also make them smarter. Significant energy can be gained by improving the controls on the turbines, using knowledge of hydrodynamics to predict when to boost a turbine to keep it from stalling out or dampen it to keep from spinning too fast.

The goal: Remote energy systems worth the investment

The most immediate application of this research is to improve the prospects of self-contained remote energy systems. These systems could persistently and renewably power scientific equipment in the ocean or remote coastal villages. ME alumnus Ryan Tyler is an engineer at Ocean Renewable Power Company which has deployed a pilot cross-flow turbine system in the remote village of Igiugig, Alaska.

Tyler notes that recent improvements based on hydrodynamic data, like what Snortland is collecting, has allowed them to double the output of their systems. Not only will Snortland's research further improve industry performance, but it will help inform and standardize the industry designs. "Ultimately," he says, "this data will advance the whole field by bringing down design and production costs while raising performance, like what we've seen for the wind industry. With cheaper manufacturing and higher energy output, the economics of marine energy fall into place."

A UW research team tests a cross-flow turbine in Lake Washington with Governor Jay Inslee (at right). These tests complement the on-blade hydrodynamics research in which Snortland specializes.

HIDE and Seek

A&A's Autonomous Flight Systems Lab builds a drone-based machine learning dataset to find those lost in the wilderness.

Training a drone to save lives

Jason Reinfeld, Chief of Special Operations in the Chelan County Sheriff's Office, reports that his office led 41 Search and Rescue missions to locate missing people in the county wilderness last year alone, which was a relatively "light" year. These searches involved volunteers, some out overnight, deputies earning overtime and helicopters operated at $525 per hour. While the costs of these missions varies widely, a typical search costs the department about $9000. These missions strain local law enforcement budgets and take a lot of critical time, maybe too much time, to locate a person to bring them home safely.

Reinfeld knows that drones can help his office save lives in his county, especially in extremely rugged areas like The Enchantments Wilderness. Rough terrain can easily hide lost or injured hikers. At its most basic, a drone can scan the landscape faster than searchers on foot. Reinhold reports that their use has been limited due to the vast areas that might need to be searched on any particular mission. He cites battery life, stability and the difficulty in scanning large areas as drawbacks. But researchers in A&A's Autonomous Flight Systems Lab (AFSL) know that their drones can do much better than that.

AFSL's Chris Hayner, a UW physics student pursuing an A&A minor, explains, "Human eyes have limitations. It's hard to know what you are looking at from drone footage, especially if the terrain is dynamic, and humans get tired and less effective the longer they are studying footage. We use object detection through machine learning to act as the eyes that never blink or tire."

Building the machine learning dataset

Object detection is one of the main areas of computer vision that detects or distinguishes objects in digital images. The methods of object detection include machine learning in which a statistical model is trained to detect or classify predefined features, in this case, a human form. The AFSL students, led by Director and A&A Professor Emeritus Juris Vagners, are working with a subdivision of machine learning called Deep Convolutional Neural Networks (DCNN), which trains the program to identify features through a large set of processed images.

Hayner says, "One of the challenges of training the DCNN model is that we don't have a large set of images to train the model off of. We are training it from scratch with photos we are taking. There are plenty of photo datasets of humans, but none of humans from a drone's point of view in wilderness environments."

AFSL's Echo Liu and Karina Bridgman prepare a drone for a "hide and seek" exercise to build the machine learning dataset and train the program to recognize humans in the wilderness.

These training sessions involved, up until the shutdown for the coronavirus pandemic, several Saturdays with about ten UW students headed out to various wilderness sites in Washington State where they have permission to fly drones. The students scatter in all directions to be captured in drone footage taken from above. Researchers will use the images from the footage from this high-tech game of "hide and seek" to train their program to identify humans in the wilderness.

Right now, AFSL has a dataset of about 29,000 pictures, taken exclusively by UW students from the lab's drones in these hide and seek games. This processed dataset is currently yielding an accuracy of finding humans in the wilderness of about 92 percent, with even better results when combined with thermal data. With more photos and training by UW students, this accuracy will continue to go up.

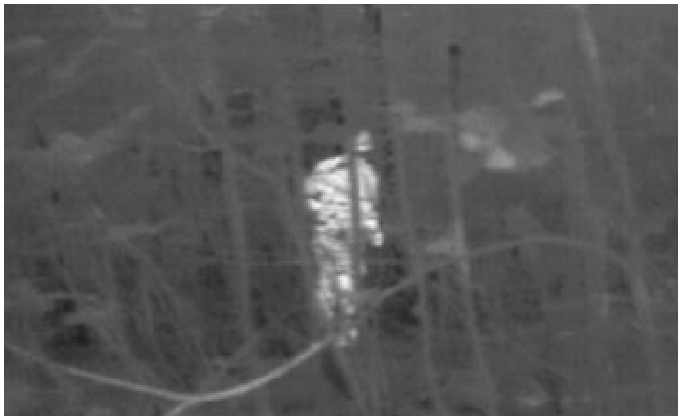
Interdisciplinary efforts for better results

Seeding the model for this DCNN method takes an interdisciplinary team. Echo Liu, an AMATH CFRM graduate student bringing expertise in statistical modeling to the project, says, "Images contain very high-dimensional data, and many statistical models suffer from this limitation. As we develop this DCNN, the model is able to learn various features of objects of interest from our image data. Ultimately, with practice, the model will get more accurate."

Practically speaking, the system is meant to work simultaneously with human operators looking at the live feed and the objects that are flagged to dramatically reduce the time and resources needed to locate a lost person.

From Chelan County, Reinfeld is looking forward to seeing how this research works out, "Decreasing the time it takes to locate someone is critical. Using an enhanced drone system instead of a helicopter would help us deploy faster, reach people faster and manage our financial resources better."

The machine learning program, combined with a thermal detection system represented in this image, produces very high accuracy in locating humans over large areas of wilderness.



Modeling COVID-
APPLY AEROSPAC

A&A alum Dan Klein draws on his controls training to model the transmission of COVID-19 in King County.

Not many A&A alums pursue a career to track and reduce world disease as part of the United Nation's Sustainable Development Goals. But Dan Klein (A&A Ph.D. 2008) has adapted his training in control theory to model transmission rates of diseases, including malaria, polio, tuberculosis, HIV, pneumonia and typhoid. Now, his group at the Institute for Disease Modeling, based in Bellevue, is tracking transmission rates of COVID-19 in King County, Washington.

We asked Klein about his career path into disease modeling and his research on COVID-19 transmission.

Were you interested in disease modeling when you started your studies in A&A?

When I started A&A, I had a keen interest in robots, and I still think robots are the coolest thing in the world. I had just completed a B.S. in mechanical engineering, but I wanted to work on the mathematics of robot brains - that's what brought me to control theory. My Ph.D. adviser, Professor Kristi Morgansen, was building these amazing free-swimming fish robots and the nonlinear theory to go with them, and I knew that's what I wanted to do! The coolest part is that we had several of these fish robots, and so I got to play with the early mathematics of multi-agent control systems and learn about schooling behavior from biologists.

What was the inspiration for you to pursue this work?

In infectious disease modeling, we use mathematics, programming and supercomputing to improve lives around the world. These models inform data needs and policies, thereby leading to burden reductions and hopefully disease eradication. The most inspiring part of this work is visiting the field to see the impact of these recommendations on the lives of real people.

Can you tell us about a field experience that has really impacted you?

One of the most cost-effective and long-lasting interventions against HIV is voluntary medical male circumcision (VMMC). The efficacy of VMMC in reducing HIV incidence in men is about 60% (really good)! We modeled the impact of increased VMMC programs in Zimbabwe, Kenya, and Uganda, and I was in Kenya presenting the simulation results to the country decision makers when they asked if I'd like to do a field visit. SURE!

We traveled to a rural clinic where a group of about 20 school boys had volunteered to come in. The visit started with counseling on safe practices - wow, I hadn't appreciated the impact of these messages. Long story short, I ended up being handed a surgical gown and hair net before being pushed into the operating room. I'm a doctor, but not that kind! Anyway, opportunities like these really bring the numbers in our simulations to life. These brave boys now have an increased chance of avoiding HIV due in small part to our modeling work.

19 transmission:

E

What is unique about modeling for COVID-19?

Before COVID-19, IDM focused almost exclusively on low and middle-income (LMIC) settings in Africa and South Asia. While we're modeling COVID in those settings today, we're also focusing right here on Washington State. It's likely that we won't have a COVID vaccine for over a year, so the big question right now lies in balancing health and economic outcomes. As we learn about physical distancing, contact tracing and case isolation towards reopening the economy, we're asking how these ideas could be deployed in LMIC settings.

One challenge in LMIC is that COVID-19 is just one of many infectious diseases. We have to take a holistic view to ensure the COVID response doesn't trigger a massive reversal of decades-long progress in reducing the burden of malaria, HIV, polio and many other preventable diseases. So in many ways, we've come full circle and are using the math and models we've spent years developing to reinterpret the landscape in light of COVID.

What was your path to the Institute for Disease Modeling?

After A&A, I joined the Center for Control and Dynamical Systems at the University of California, Santa Barbara as a postdoctoral scholar. While there, I worked on a sensor network question in which information spread like a disease - that's what led me to join IDM in late 2010. I stepped away from IDM for a one-year sabbatical at the Bill & Melinda Gates Foundation, where I led various data science and strategic initiatives in the Strategy, Data and Analytics team. Now I'm back at IDM leading the Computational Sciences Research team, although I spend most of my time on COVID modeling these days.

How did your research at A&A prepare you for this area?

While robots and infectious diseases may seem worlds apart, they actually are quite similar when you look at the underlying theory. Both are dynamical systems, and in each case we begin by building a simplified model, e.g. using ordinary differential equations (ODE). The foundation of mathematical models in epidemiology is the simple susceptible-infectious-recovered "SIR" ODE, much like the ones I had studied in A&A.

My initial work at the IDM was to build a model of HIV. In HIV, there's within-host viral dynamics and between-host contact networks. It looks a lot like a school of robotic fish if you squint hard enough!

How would you advise students interested in this kind of modeling to make the transition?

It's likely that many facets from your work will translate, even if it's just knowing how to learn! So master your core discipline, but also show curiosity and seek answers more broadly. It might feel out of your comfort zone at first, and it does take time, but it's worth it. There are great textbooks and resources online, and the UW has some fantastic courses in mathematical biology. For those looking to take the next step, IDM has summer intern and postdoc programs.

FEATURE STORY

Updating Apollo 11

“This is an important design tool to give engineers a target to shoot for, especially as we seek to fly more difficult missions to the Moon, Mars, the moons of Jupiter and beyond.”

DANYLO MALYUTA

What we gain by applying optimization algorithms to the iconic mission.

The 1969 Apollo 11 mission to the Moon is providing lasting impacts beyond the inspiration and wonder it inspired. It is still, fifty years later, providing valuable research data. Researchers from A&A’s Autonomous Control Lab and RAIN Lab accessed its trajectories and fuel usage data to validate the use of convex optimization algorithms in planning future spaceflights.

Specifically, they analyzed a thirty minute segment of the flight called the “transposition and docking” maneuver, which was the separation of the Command and Service Module from the Saturn V rocket. This maneuver extracted the lunar module in preparation for the moon landing by astronauts Neil Armstrong and Buzz Aldrin. During the historic mission, this maneuver burned through 50 kilograms of fuel.

NASA engineers in 1969 did not have the computing capability to apply convex optimization to make maneuvers more efficient. Today, however, A&A researchers, led by Ph.D. student Danylo Malyuta, took the opportunity to validate the use of such algorithms in spaceflight planning by applying them to this critical segment of the Apollo 11 mission.

In a paper that won the AIAA SciTech 2020 award for best graduate paper in Guidance, Navigation, and Controls, results showed that applying convex optimization algorithms to the targeted maneuver would save over 90 percent of fuel, bringing the fuel spent down to only seven kilograms.

We recently spoke with Danylo about the research, the results and the implications of this research.

First of all, what is convex optimization?

Convex optimization is a special method for arriving at the best decision when operating with conflicting constraints. You’re essentially trying to minimize some function that describes what you want, subject to a number of constraints that you must satisfy. In convex optimization, the function that you are trying to minimize looks like a parabola. Basically, the function “smiles” at you on a graph.

We start by entering constraints into a computer program and defining what is to be solved. Then, the program does the work for us, if it is convex, that is. But not every problem is convex. And it turns out that calculating the Apollo 11 trajectory is not convex, but we have a workaround. We use an iterative method called “successive convexification” which solves a number of convex optimization subproblems, maybe ten to twenty, in order to arrive at the solution.

How is it applied to space missions?

A common task in space mission design is to calculate the planned route, including any maneuvers, to the destination. This is known as trajectory design.

The proposed trajectory would have to satisfy certain constraints like the limits on how fast the craft can shift and rotate while keeping the cargo and systems safe and functioning. Another important constraint is the maximum and minimum allowed thrust from the engines. Then, a planned trajectory must minimize some variable, in this case fuel consumption.

During Apollo 11, digital computing was still in its infancy and was unable to handle computationally demanding tasks like optimization. Today, however, we can optimize difficult tasks very quickly. For our research on Apollo 11, we took into account constraints on spacecraft rotation, engine firing duration, and exhaust streams on the lunar module, all while seeking to minimize the fuel consumption.

Why is this research significant?

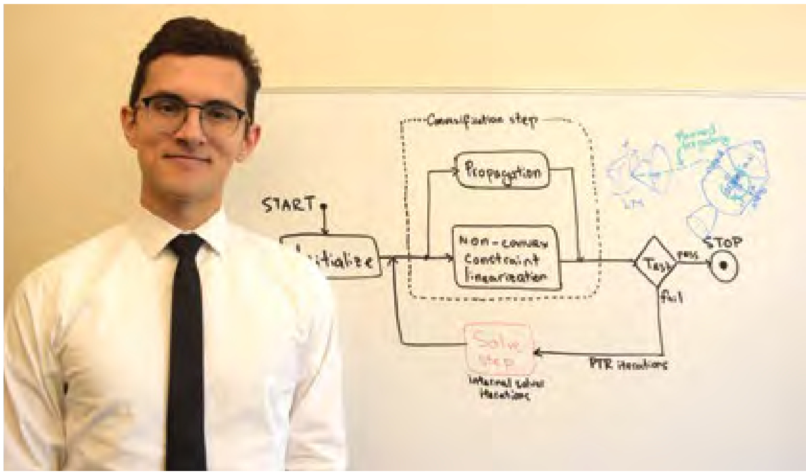
Right now, a lot of trajectory design at NASA and many of the space companies is done manually. By using convex optimization to create targets for this human design, we will be able to get closer to the ideal for safety, speed, efficiency, cost, and other constraints.

Computing an “optimal” trajectory helps engineers have a target to aim for even if manual operations will be in effect. So if the manually plotted trajectory is way off from what the algorithms are suggesting, we know we need to go back to the drawing board.

This is an important design tool to give engineers a target to shoot for, especially as we seek to fly more difficult missions to the Moon, Mars, the moons of Jupiter and beyond. Many of these missions will not be crewed, so our use of algorithms needs to be even more robust to adjust to many unforeseen conditions.

Our algorithms in this research told us that the part of the Apollo 11 mission that we analyzed could have been 90 percent more fuel efficient. If NASA engineers in 1969 knew this, they could have reworked their mission plan. Thanks to decades of computer and optimization advancement since Apollo, it is something we can do today.

This research is published as “Fast Trajectory Optimization via Successive Convexification for Spacecraft Rendezvous with Integer Constraints” by Danylo Malyuta, Taylor Reynolds, Michael Szmuk, Behçet Açikmeşe and Mehran Mesbahi



Danylo Malyuta, lead author of the award-winning paper that applied convex optimization to the transposition and docking maneuver of the Apollo 11 mission.

SARP wins
SPACEPORT America Cup

A&A's Skyler DelaTorre and Mechanical Engineering's Holly Gummelt carry the rocket to the launch rail. Photo credit: Jess Grant.

The Society for Advanced Rocket Propulsion (SARP), the UW rocketry club, clinched the top spot as the 2019 Judge's Choice and Overall Winner in the Spaceport America Cup.

The Spaceport America Cup is the world's largest collegiate rocketry competition, with over 120 teams competing in the New Mexico desert outside of Las Cruces. The SARP team spends the entire academic year building a rocket from scratch to compete in this competition.

In addition to its first place overall win, the UW team also scored first in the 30,000 feet, student developed hybrid-liquid propulsion category. The SARP team distinguishes itself by creating a hybrid motor, used by only a few teams due to its complexity in both design and operation.

Why would the team follow this hybrid model? SARP's Chief Engineer Jess Grant reports, "It is more interesting because of its complexity in building it from scratch, and it produces a safer rocket. These hybrids can sacrifice altitude, but advancing this technology is a lot more rewarding and this hybrid category is the most technically challenging of the competition."

SARP, which has grown to around 150 active members, builds heavily off of past SARP designs, iterating on some subsystems and redesigning others. The team is divided into subsystems: structures, avionics, recovery, propulsion, business, and, for the first time this year, payload. While the team has high representation from the aeronautics and astronautics department at the UW, the team also draws from across not only the engineering and STEM departments, but also business and other disciplines.

Grant points out that the approximately 25 students who travel to New Mexico have the privilege of representing this colossal effort of such a great team.

Aqil Khairi, Jimmy Ragan, and Jess Grant complete the rocket assembly the day before launch. Photo credit: Ben Yan.

A&A CubeSat secures exclusive **NASA spot**

Four CubeSats after release. Photo: NASA.

Four CubeSats after release. Photo: NASA.

A&A's CubeSat Team, launched only in 2018, has secured one of only 18 spots for its "SOC-i" CubeSat in the NASA CubeSat Launch Initiative (CSLI). As the team's co-founder Charlie Kelly explains, "This award is equivalent to a monetary value of $300,000. NASA will provide all of our launch integration services and effectively guarantee SOC-i a ride to space between 2021 and 2023."

A CubeSat is a small, standardized spacecraft about the size of a loaf of bread which carries research projects into space. NASA will assign each selected CubeSat to a planned spaceflight mission. After launch, the CubeSats will be released into orbit from the launch vehicle or from the International Space Station.

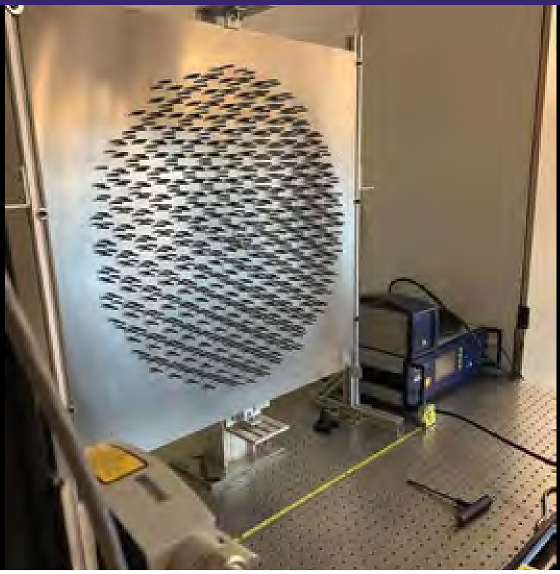
This first A&A CubeSat, the Satellite for Optimal Control and Imaging, dubbed "SOC-i" with a nod toward the Pacific Northwest salmon, will have a specific mission to demonstrate the ability to satisfy two constraints with its orientation control and imaging systems. SOC-i's on-board software will orient its navigation sensors toward the sun at all times for accurate positioning while its cameras must never face the sun to avoid damaging its lens.

Taylor Reynolds, the team's other co-founder, says, "While SOC-i is the first A&A CubeSat, the team's objective is to lay a foundation for long-term satellite engineering projects at the UW through providing students with this inspiring opportunity to work with spaceflight hardware and software."

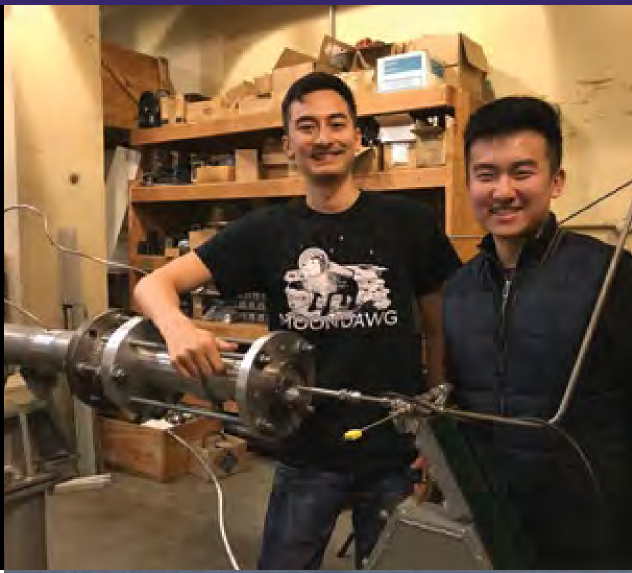
NASA's Sam Fonder, program executive for the Launch Services Program, describes CSLI as "the perfect win-win" for educational institutions and NASA: "Developers get a chance to build and test small spacecraft for research in space. NASA can use this research to assist in accomplishing its mission objectives."

Kelly and Reynolds emphasize how much work the team contributed to apply for this award. Reynolds says, "The team leads submitted over 200 pages of material for the application, in addition to the full year of design and prototyping behind that. The reward is that our A&A CubeSat team has gone from zero-to-accepted satellite with this huge financial and logistical boost in a little over a year's time. Even though some of us will have graduated by the time SOC-i launches, this achievement alone is a lot to be proud of."

SOC-i is supported by the UW College of Engineering and the Aerojet Rocketdyne Foundation and is advised by A&A professors Mehran Mesbahi and Behçet Açıkmeşe.



A&A researchers created a precise pattern of bolts to direct the paths of mechanical waves into a confined area of the metal plate.



Good vibrations

A&A's Chun-Wei Chen contains energy for better structures, smoother rides, and higher efficiency.

A&A researchers in the Laboratory for Engineered Materials and Structures (LEMS) led by Chun-Wei (Ethan) Chen created a metal plate with a precise geometric distribution of bolts. The goal is to see how vibrations diffuse through the structure to see if they could be confined to a small section of the plate. The results did not disappoint.

Chen explains, "By showing that we can isolate and contain this kind of energy – in this case, a mechanical wave – we are encouraged that in the future we can build structures and vehicles that not only reduce vibrations for comfort or structural integrity, but could potentially harvest those vibrations and convert this captured energy for additional power."

Jinkyu Yang, Chen's adviser and head of LEMS, is excited about the significance of these findings. "Ethan has actually observed in the lab what we had previously only demonstrated theoretically," Yang says. "The implications of being able to contain vibrations in a structure point to many potential future applications, such as smoother rides for airplane and automobile passengers with a potential to harness the vibration energy collected back into the system."

After additional study, researchers will move toward designing both materials and structures that will have an adapted pattern to create the map for vibrations to follow, isolating areas of machines, vehicles, buildings, and more, such as where humans or sensitive equipment would be.

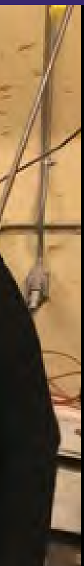
Chun-Wei Chen

Landing big on Mars

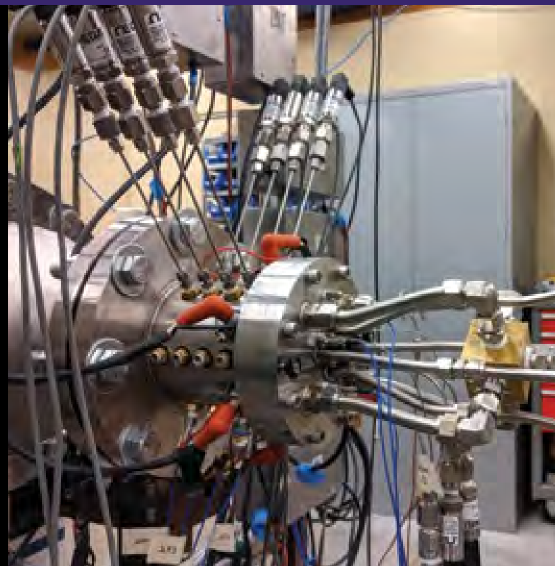
Xiuqi "Charlie" Yang (MS A&A '19) explains the challenges of landing a large craft on Mars: "So far, we've only been landing robots on Mars smaller and way lighter than a Mini Cooper. So we can do that. The capsule will slow down to the point of using a supersonic parachute to land them. But if we want to land something bigger like a crewed spacecraft, we can't do that yet. There's not enough Martian atmosphere for a parachute to work. Supersonic retropropulsion is our most promising technique to get there."

Under supersonic retropropulsion (SRP), the technique researched by Yang, Brenton Ho (MS A&A '19) and A&A faculty member Owen Williams, the vehicle slows down from supersonic speeds by firing its engines into the oncoming high-speed flow. The challenge is that this procedure may cause the air around the spacecraft to become unstable, potentially destroying the mission.

Figuring out what configurations, conditions, and contours would create this instability is a challenge. In the lab, they can generate 16 milliseconds of supersonic flow using a small-scale Ludweig tube, a type of simple wind tunnel. This flow simulates conditions of a landing spacecraft that has reached the lower portions of the Martian atmosphere. They



Brenton Ho and Charlie Yang show off the Ludweig tube wind tunnel and schlieren camera. These tools aid in the study of supersonic retropropulsion (SRP).



A&A researchers developed an experimental rotating detonation engine (shown here) where they could control different parameters, such as the size of the gap between the cylinders. The feed lines (right) direct the propellant flow into the engine. On the inside, there is another cylinder concentric to the outside piece. Sensors sticking out of the top of the engine (left) measure pressure along the length of the cylinder. The camera would be on the left-hand side, looking from the back end of the engine. James Koch/University of Washington

then use a schlieren camera to capture 75,000 frames per second to observe changes in flow density, such as those caused by shockwaves. The method will help them determine the sources and behavior of shockwave unsteadiness and suggest ways to mitigate it.

SpaceX uses supersonic retropropulsion to assist with reentry and landing of their Falcon 9 rockets, allowing their reuse. More research is needed to land larger and crewed spacecrafts on Mars with significantly less atmosphere. Photo credit: SpaceX.

Simple, fuel-efficient rocket engine could enable cheaper, lighter spacecraft

Originally reported by Sarah McQuate, UW News.

It takes a lot of fuel to launch something into space. Sending NASA's Space Shuttle into orbit required more than 3.5 million pounds of fuel, which is about 15 times heavier than a blue whale.

But a rotating detonation engine promises to make rockets not only more fuel-efficient but also more lightweight and less complicated to construct. There's just one problem: Right now this engine is too unpredictable to be used in an actual rocket.

Researchers at the University of Washington have developed a mathematical model that describes how these engines work. With this information, engineers can, for the first time, develop tests to improve these engines and make them more stable. The team published these findings Jan. 10 in Physical Review E.

"The rotating detonation engine field is still in its infancy. We have tons of data about these engines, but we don't understand what is going on," said lead author James Koch (A&A PhD '20).

To try to be able to describe how these engines work, the researchers first developed an experimental rotating detonation engine where they could control different parameters, such as the size of the gap between the cylinders. Then they recorded the combustion processes with a high-speed camera.

From there, the researchers developed a mathematical model to mimic what they saw in the videos. The model allowed the researchers to determine for the first time whether an engine of this type would be stable or unstable. It also allowed them to assess how well a specific engine was performing.

A&A professors Mitsuru Kurosaka and Carl Knowlen and AMATH professor Nathan Kutz, co-authored this paper. This research was funded by the U.S. Air Force Office of Scientific Research and the Office of Naval Research.

A Soyuz spacecraft launches from the Baikonur Cosmodrome in Kazakhstan in 2017 using a conventional, fuel-intensive engine. UW researchers have developed a mathematical model that describes how a new type of engine — one that promises to make rockets fuel-efficient, more lightweight and less complicated to construct — works. NASA/Bill Ingalls/Flickr

Yang part of $1.7M NSF grant to study corals

Originally reported by Sarah McQuate, UW News

An interdisciplinary team of researchers from multiple institutions, including the University of Washington, has received a two-year, $1.7 million National Science Foundation grant to study coral growth to help boost critical restoration efforts. The team includes A&A professor Jinkyu Yang.

“This project is a good example of how aerospace engineers, marine biologists, chemical engineers and computer scientists can work together,” Yang said. “Successful aerospace missions often rely on advanced materials, which can be used for other fields of studies. Likewise, materials — even living materials — in other fields can inspire the design of aerospace engineering materials.”

At the UW, Yang’s group will 3D print scaffolds to guide coral growth and look into new techniques to measure how well the corals grow.

Collaborating with Yang are Judith Klein-Seetharaman at the Colorado School of Mines, Hollie Putnam of the University of Rhode Island, Lenore Cowen at Tufts University and Nastassja Lewinski at Virginia Commonwealth University.

Photo above: An interdisciplinary team of researchers from multiple institutions — including the University of Washington — has received a two-year $1.7 million National Science Foundation grant to study coral growth. Photo credit: Michael Webster

Açıkmeşe leads $1.2M NSF grant to advance autonomy through Mars missions insights

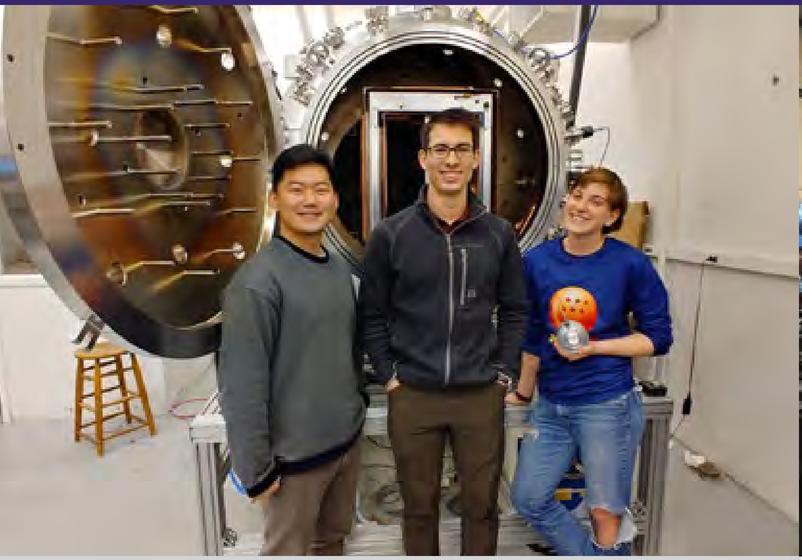
A research team spanning three universities led by A&A professor Behçet Açıkmeşe received a total of $1.2 million from the National Science Foundation to leverage insights from autonomous missions to Mars to advance humanitarian applications here on Earth.

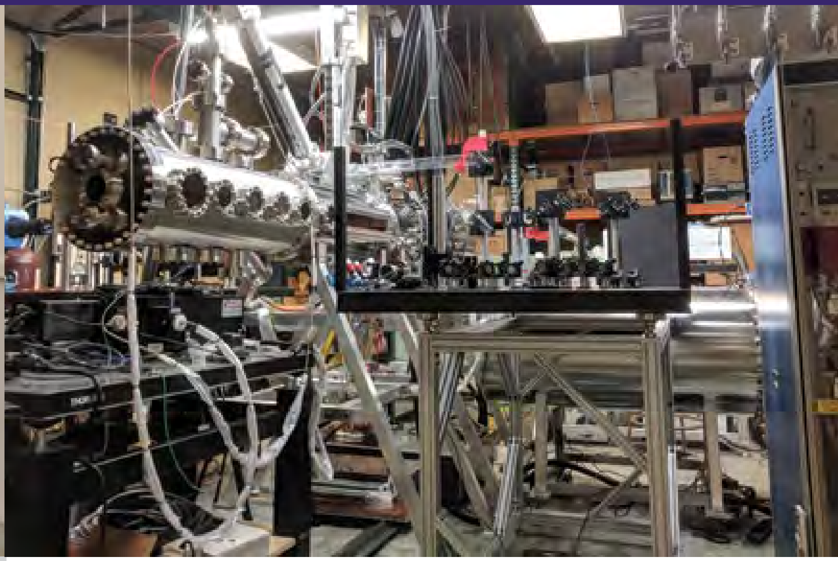
The UW, Stanford, and Johns Hopkins will collaborate, each bringing special expertise to the partnership. Açıkmeşe leads A&A’s Autonomous Control Lab and previously worked at NASA’s Jet Propulsion Lab where he developed guidance and control algorithms for the Curiosity rover landing in 2012. This experience put him in a unique position to apply insights from Mars missions to advancing autonomous control algorithms for challenging cases. At Stanford, professor Marco Pavone also worked on Mars missions with JPL, but with ground missions. At Johns Hopkins University, professor Marin Kobilarov brings his expertise with underwater autonomous vehicles to the partnership.

The project’s focus will be critical autonomous missions that have the potential to remove humans from harm in traditionally dangerous tasks. Applications include search and rescue, disaster relief, environmental monitoring and toxic spill clean-up.

The Autonomous Control Lab’s research includes this fleet of ground robots used to validate control algorithms for robotic swarms.

Professor Behçet Açıkmeşe with an experimental quad rotor in the Autonomous Control Lab.





Little to develop data science methods for plasma optimization

A&A professor Justin Little received a $450,000 Young Investigator Research Program (YIP) Award through the Air Force Office of Scientific Research. Little was one of only 40 scientists and engineers to receive the award nation-wide.

Little runs A&A's Space Propulsion and Advanced Concepts Engineering (Space) Lab which explores the plasma physics of electric propulsion systems for space travel. Little will use the YIP award to fund a Ph.D. student in A&A for three years to explore the intersection of data science and plasma physics. Specifically, the group will develop a method to rapidly optimize electric thrusters by taking data from high-speed plasma diagnostics and applying machine learning and data discovery algorithms.

Little notes, "Existing methods for optimizing electric thrusters rely on semi-empirical scaling laws and extensive experimental campaigns. In addition to being costly and time intensive, such methods are ineffective for new concepts with greater complexity. High-speed plasma diagnostics are commonly employed to understand electric thruster physics, however, the relationship between the resulting data and thruster performance is relatively opaque. Our aim is to see how emerging data science methods might be used along with high-speed sensor data to shed new light on the physics and performance of electric propulsion systems."

SPACE Lab's Sungyoung Ha, Curtis Promislow, and Anna Sheppard in front of the Space Test Facility, a key piece of equipment for plasma testing that will interface with data science methods under Professor Little's recent award.

A&A's fusion energy labs receive $3.5 million

A&A's two labs for advancing nuclear fusion research – the HIT Lab and the ZaP Lab – have recently received a combined $3.5M to advance two different strategies for compact, cost-effective fusion energy. The Department of Energy's ARPA-E program is dedicating $2.5M to these projects. DOE's interest in fusion is that a commercially-viable nuclear fusion breakthrough promises US energy security with no carbon emissions and no long-lived waste like current fission-based nuclear energy.

Though A&A's approaches through a spheromak in the HIT Lab and a Z-pinch in the ZaP Lab can lead to cost-competitive commercialization, further advances are needed. Plasmas need to be formed in specific shapes to stably undergo sustained fusion. Each lab's strategy involves a different shape for the magnetic fields and confined plasma. The HIT Lab takes advantage of the natural property of plasmas to self-organize and uses Imposed-Dynamo Current Drive to keep it going. In contrast, the ZaP Lab forms and compresses plasma in a 50-cm long column, the Z-pinch (pictured above), with plasma flowing along its length, which, in turn, stabilizes it – a technique developed by A&A Professor Uri Shumlak.

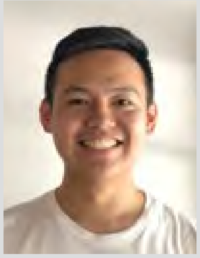
In addition to the DOE funding, the HIT Lab received an additional $1M in the gift of a set of switching power amplifiers from Eagle Harbor Technologies. The HIT Lab's Lead Scientist Christopher Hansen explains, "Our work involves a lot of power – we're talking 10-20 megawatts – that needs to be released very precisely on microsecond timescales in order to sustain the plasma in a controlled way. We have partnered with Eagle Harbor for many years on their development of precision high-power systems like these that benefit not only our lab but fusion labs around the world. The donation of these prototypes is a major enhancement of our lab."

STUDENT AWARDS

AIAA Region VI Student Conference Awards:

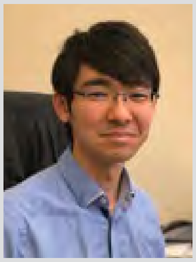
Second in team category for machine learning application


Jiacheng Chen


Casper Hsiao


Silas Chu


Elaine Xiong

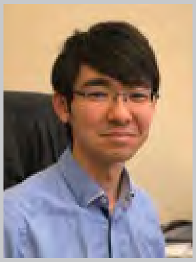

Yasuhiro Miyazawa

A&A Student Excellence Awards

Excellence in Doctoral Research


Yao Qiao

Excellence in Teaching


Yasuhiro Miyazawa

Excellence in Service


Kristina Dong


Eleanor Forbes


Hannah Schnelz

FACULTY AWARDS

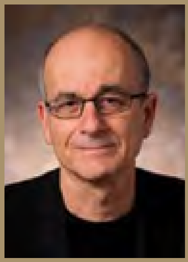
AFOSR Young Investigator Research Program Award


Justin Little

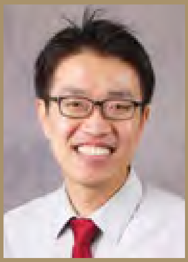
AIAA Aeroacoustics Award 2020


Robert Dougherty (affiliate)

AIAA Ashley Award for Aeroelasticity for 2021


Eli Livne

AIAA Associate Fellow


Jinkyu Yang

American Physical Society Fellow


Uri Shumlak

Third in undergraduate category for Ram Accelerator setup


Kristina Dong


Adrian Lo

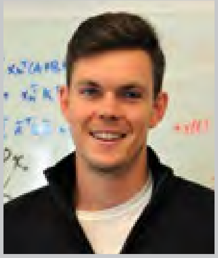
Brooke Owens Fellowship


Kristina Dong


Monica Kim


Anna Sheppard

Husky 100

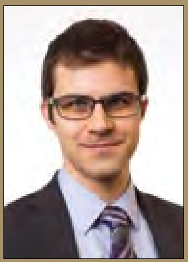

Taylor Reynolds

Society of Women Engineers Awards

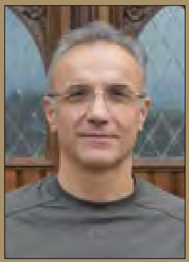

Jaspreet Kaur


Sarah Li

DEStech Young Composites Researcher Award of the American Society of Composites


Marco Salviato

IEEE's Control Systems Society's 2019 Technical Excellence Award in Aerospace Control


Behçet Açıkmeşe

HIGHFLIGHT

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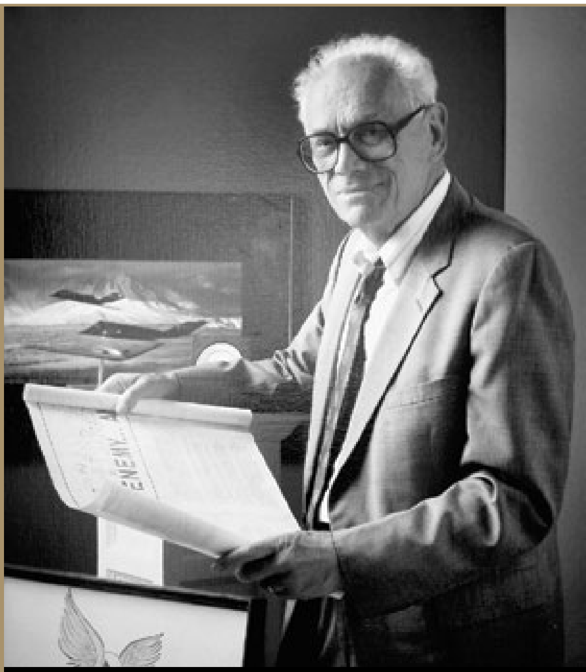
Estate gift from Richard Scherrer ('42) creates new faculty support fund

Richard Scherrer ('42) planned a surprise estate gift that will help A&A fill a priority need.

Last year, A&A Chair Kristi Morgansen received word that beloved alumnus Richard Scherrer (A&A '42) had sadly passed away. Scherrer was well-known to the department. Winner of the Distinguished Alumnus Award in 1995, his career highlights included Navy service, 13 years with NASA and 16 years as a lead aeronautical engineer with Lockheed Martin where he played a major role in the early development of the Northrop B2 Stealth bomber. Scherrer also spent several years working as a product design consultant for Disneyland. He famously developed the tracks and braking systems for the Matterhorn, Dumbo, Tea Party, Flying Saucer and Monorail rides. He was an associate fellow of AIAA and a member of the National Academy of Engineering.

And while the department treasured Scherrer, he clearly also treasured the department. Through his estate, he planned a surprise, unrestricted $100,000 gift. Morgansen, who has been working with the department leadership team to secure new funding to recruit, support and retain faculty talent, saw this gift as a wonderful opportunity.

Morgansen explains, "Faculty support funds help us attract the best and brightest educators and researchers to the UW as we compete in the market with the top aerospace programs. I can't emphasize enough how grateful we are to create the Richard Scherrer Endowed Fund for Faculty Support in Aeronautics & Astronautics. We are thrilled to honor Scherrer's legacy and generosity with this named fund that will help advance teaching, research and leadership in our department."



The William E. Boeing Department of Aeronautics & Astronautics has dedicated a limited pool of matching funds to encourage the creation of other new endowed faculty support funds. If you would like to learn more about supporting this critical funding priority through philanthropy, please contact Kaitlin Colleary, Associate Director of Advancement for A&A at kaitcoll@uw.edu or 206-685-6192. Kaitlin is also available to assist alumni working on estate plans.