DEPARTMENT OF
AEROSPACE ENGINEERING AND MECHANICS

COLLEGE OF Science & Engineering
UNIVERSITY OF MINNESOTA

Department Update - Winter 2020

SOCRATES Takes Off

Kyle Houser and Jenna Burgett (pictured right) can now say their names are written in the stars—etched on the access panels of a small satellite in space, that is. The two College of Science and Engineering students are project leaders in the University of Minnesota's Small Satellite Research Group, an interdisciplinary team building small satellites sponsored by NASA and the U.S. Air Force Office of Scientific Research.

On November 2, the team's CubeSat, SOCRATES (Signal Opportunity CubeSat Ranging and Timing Experiment System), successfully ascended to the International Space Station on an Antares rocket (pictured below), and it will be released into Earth's orbit in February 2020. SOCRATES is the first small satellite built at the University of Minnesota Twin Cities to go into space.

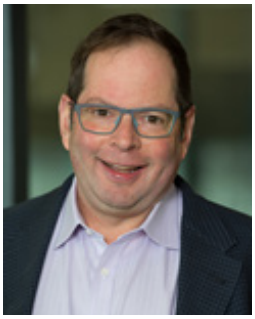
SOCRATES has two missions as it soars among the stars. The first is to demonstrate the operation of an X-ray spectrometer in orbit, which can be used to demonstrate a new method of navigation (X-ray navigation or XNAV, an alternative to GPS). The second mission is to record spectra from x-rays coming from solar flares. This will be used to investigate electron acceleration mechanisms in solar flares, which can better inform models of solar weather.

Once SOCRATES is in orbit, the team will try to make contact from ground stations across the United States—including one in northern Minnesota—with hopes of gathering six months of continuous data from the CubeSat.

Antares CRS-12 ©NASA HQ PHOTO

What's Inside...

FROM THE DEPARTMENT HEAD



Dear Friends,

As we begin another decade, we are constantly reminded of the rapid changes science and technology have made in our lives. We see headlines about advancements ranging from artificial intelligence to autonomous vehicles to space exploration to climate change. The challenges of the new decade reinforce my belief that the mission of our Department, College, and University to advance research, teaching and outreach, is more important than ever.

Our students, alumni, and faculty have accomplished much in the past year, and I am pleased to feature some highlights in this newsletter. We were excited to celebrate the launch of the Minnesota Small Satellite group's CubeSat, called SOCRATES, to the International Space Station in November. We were also thrilled to welcome AEM alumna Michele Brekke back to campus as Homecoming Grand Marshal in October.

Our research stories focus on the increasing role of drones in the department. Our Aeromechanics Lab course, AEM 4602W, now includes a drone flight experiment designed by Professor Derya Aksaray and others, in the new drone lab in Shepherd Laboratories. We also have a story about how Professor Demoz Gebre-Egziabher and co-workers use drones to track and map invasive species and insects. Finally, we feature the research of one of our newest faculty members, Professor Ryan Caverly.

We want to extend our gratitude to Professor Tom Shield, who retired after 29 years at the University of Minnesota. Tom played an enormous role in building our undergraduate curriculum and setting up our undergraduate advising processes, and he was also one of my closest research collaborators.

As always, I thank our alumni and friends for your support. Your generosity helps us support all of our students in their education and training, and is vital to maintaining our exceptional environment for education and research.

Perry Leo
Department Head

Did you know we're on Twitter?
Look for **@UMNAEM** or visit **cse.umn.edu/aem** for more information.

Professor Thomas Shield Retires

Professor Thomas Shield retired this year after 29 years of teaching at the University of Minnesota.

Shield came to Minnesota as an Assistant Professor in 1990. He received his undergraduate degree at the University of Illinois in 1982, and then went to the University of California at Berkeley where he received his M.S. and Ph.D. in Mechanical Engineering in 1984 and 1988 respectively. He was a post-doctoral research associate at the University of Illinois and Brown University before joining the department.

Shield's research focused on experimental characterization of the mechanics of materials. He had particular interest in how microstructures in modern materials affect their mechanical properties. Shield's work on shape-memory materials, magneto-elastic materials and copper-based alloys, often in collaboration with Professors Leo and James, led to many important advances in the understanding of the interactions among microstructure, phase change, plasticity, and fracture. The basic understanding developed by Shield's work has led to improved materials and more reliable design of actuators, sensors, and other devices that employ active materials.

Shield served as a member and Associate Editor of the American Society of Mechanical Engineers (ASME) for a number of years. He received a NSF National Young Investigator Award and the University of Minnesota McKnight Land-Grant Professorship for his research.

Shield also had enormous influence on the undergraduate program in Aerospace Engineering and Mechanics. He served as Director of Undergraduate Studies from 1998-2017, and was the lead in transitioning the curriculum from quarters to semesters. Shield served as adviser to hundreds, if not thousands, of students, and genuinely cared that they receive the best possible education. He also wrote the department's courses and advising database, which has become an asset not only to the department, but also to the college and university.

According to AEM Professor and Head Perry Leo, "Tom Shield has had an enormous impact on making AEM's undergraduate program truly outstanding, on making our student advising strong and on setting up the program for continued success. He was also a great research collaborator and a true friend. I miss having him in the department and wish him the best in his future endeavors."

Professor Maziar Hemati Receives NSF Award

Professor Maziar Hemati has received the National Science Foundation CAREER award for his research in "Controlling nonlinear flow interactions to suppress transition to turbulence."

Professor Hemati's research focuses on using theory and principles from the robust control community to model and control complex fluid dynamical systems. Specifically, his CAREER proposal is based on studying how complex, nonlinear flow interactions can be manipulated to suppress laminar transition to turbulence and, hence, achieve drag reduction. Hemati and his research group will use computer simulations of a channel flow with wall-based sensing and actuation of the flow to demonstrate how the transition can be delayed.

New Directors of Graduate & Undergraduate Studies

Professor Ryan Elliott is the new Director of Graduate Studies. He has been with AEM for 14 years and researches stability and instability problems related to structures, materials, and microstructured materials.

Associate Professor Yohannes Ketema is the new Director of Undergraduate Studies. Professor Ketema has been with the department for 26 years and researches broadly in the area of dynamics.

Science Court Results

Students in the Fall 2019 Science Court, designed by AEM professor Ellad Tadmor, deliberated on the pros and cons of nuclear power. Nuclear power, which is a clean and highly efficient source of energy, is underutilized in the United States. Students debated whether the U.S. government should increase funding for the development and construction of nuclear power plants with the aim of significantly increasing nuclear power use. After a thrilling 3 hour deliberation, the "pro" team won in a 10-5 vote.
Learn more at scicourt.umn.edu

AEM Annual Career Panel

AEM students had the opportunity to listen to professionals in the aerospace field and participate in an informal networking session at the AEM Career Panel. The event began with a panel discussion called, "Insights on Successful Careers in Aerospace," where students gained valuable advice about career skills from professionals in the aerospace field. This year's panelists included: Lisa Graham, from Collins Aerospace; Jason Graham, from Collins Aerospace; Jan Fransen, a research librarian at UMN; and Karim Alame, a graduate student at UMN. Professor John Weyrauch served as panel moderator. Following the event, a reception was held and students were encouraged to network with the panelists.

This annual event allows students to hear from industry professionals, ask insightful questions about working in the field, and gain valuable career advice, such as how to job search effectively and how to break through in the aerospace field. Thank you, panelists and volunteers, for helping make this year's career panel successful!

Drones Take Flight

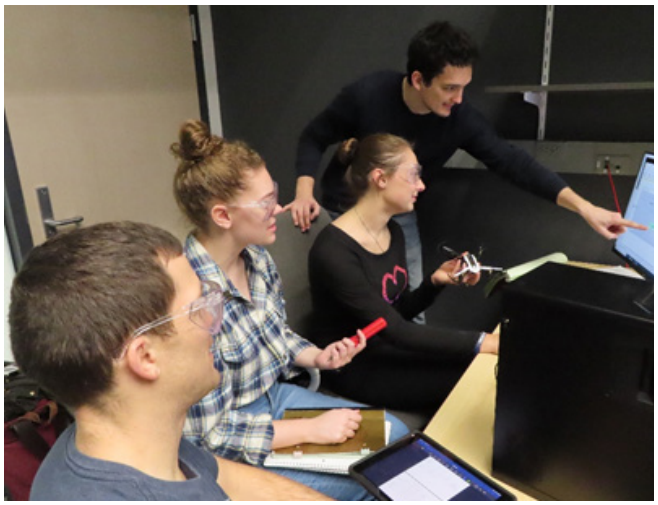
From light shows to combatting invasive species, drones have become an increasingly important part of society. As technology continues to improve, innovative research with drones has become a focus for many, including the professors and researchers in AEM. Our students have the opportunity to tackle drone research in various courses, but recently, they've been able to test and fly drones in AEM 4602W, Aeromechanics Laboratory.

The new drone experiment was designed by AEM Professor Derya Aksaray, in collaboration with Professors Peter Seiler, Ryan Caverly, and Yohannes Ketema, as well as Lab Coordinator Kale Hedstrom, and Caverly's students Casey Carlson and Robert Halverson. Students in AEM 4602W worked with the Parrot Mambo drone and investigated the influence of the controller parameters on drone's dynamical behavior. The goal was for the drones to maintain a desired position and attitude, while subject to various disturbances in flight.

Professor Aksaray explained that stability is an important system behavior. A stable system tends to return to its original position after a disturbance. Nonetheless, a stable system can return to its original position in various ways. For example, there could be a smooth return to the original position, or there could be oscillatory behavior while the drone attempts to return to its original position. As Aksaray notes, "… all these different types of behaviors can be generated by different control gains that we use in the controller."

Typically, many undergraduate courses focus on theoretical aspects such as how to design the controller, how to pick a gain, what kind of behaviors might be observed, or how to simulate the behavior. The purpose of the lab is to take those theories and actually experiment with how the drones will react when using different gains. "In a nutshell," Aksaray said, "we designed an experiment where this drone is supposed to go to a specific altitude… then hover there for a while before it lands." The experiment made use of the new drone lab in Shepherd that houses the Minnesota Robotics Institute. "The Shepherd lab space is a new indoor flight facility which has a high ceiling, sufficiently large area that makes it ideal for this experiment," she said.

Students in the class spent several weeks in lecture learning about the dynamical system and its response, how to design a PID controller, and related topics. The experiment consists of flying drones under different conditions and collecting data on their response. The discussion then



focuses on how to interpret the data and how to write a formal report on their findings. Professor Aksaray noted that it is important that the experiment includes critical thinking and data interpretation, as this will assist students in their future jobs.

Plans for the Future

Future students in AEM 4602W can look forward to more drone experiments. Professor Aksaray is already working on improvements to this year's experiment. "This is like the base experiment," she explained, "Our goal is to continue this experiment series in the following years and… improve it based on the experience we gain, and based on the feedback we receive from the students. Hopefully, in following years, we will evolve the experiment and make it include other aspects."

> *"I'm really happy to be in this course, and I'm also very excited by having this experiment in the department and hopefully making [it] better and better every year."*

The department shares Professor Aksaray's excitement and looks forward to the development of more drone experiments.

UAVs Combatting Invasive Species

Professor Demoz Gebre-Egziabher spoke at the Minnesota Invasive Terrestrial Plants and Pests Center drone symposium on how the AEM UAV research group is helping combat invasive plants and insects. The symposium presented scientific solutions to protect Minnesota's natural landscapes using Unmanned Aerial Vehicles (UAVs).

Presenting ideas at the symposium were AEM alumni Todd Colten, the chief aerospace engineer and co-founder of Sentera, Greg Emerick, the director or New Strategic Ventures and co-founder of Sentera, and Monika Chandler, research scientist from the Minnesota Department of Agriculture.

> *"We will not have forests if we have oriental bittersweet infestations."*
> *- Chandler*

UAVs have been chosen as an effective method for this issue because they are capable of detecting invasive plant species from the air, which will support human teams on the ground. The current projects focus on studying crop eating insects such as brown-spotted drosophilia and soybean aphids, as well as invasive plant species such as palmer amaranth and oriental bittersweet.

Professor Gebre-Egziabher commonly uses UAVs as tools for his research in navigational hardware and guidance systems, and to collect data from the air.

Curtis Olson, AEM UAV researcher, said, "In addition to directly detecting invasive plants or insects, current aerial maps and imagery can be useful in documenting infestations and communicating between the team members addressing specific infestation sites. A current and detailed map can help to understand how the infestation started and spread, it can help with follow-up in subsequent years, and can assist team members who haven't yet visited the site."

The drones used for these projects operate with a unique fixed wing system built by the UAV lab rather than the traditional fixed wing system.

"For ultra-high resolution imaging, we have assembled our own fixed wing system in-house based on the X-UAV Talon airframe, combined with our in-house 'Goldy3' flight controller, and an off the shelf Sony a6000 camera (+ 30mm prime lens). We have added a DJI Phantom 4 with a sentera multispectral camera for the palmer amaranth project," Olson said.

Researchers are hoping that these projects will allow them to better understand how invasive species behave and how to contain and eliminate them.

A fixed-wing UAV is deployed over the landscape for invasive species imaging. (Image credit: UMN Extension)

William Elke lll Awarded NASA Fellowship

Ph.D. student William Elke III was awarded a prestigious NASA Fellowship. Elke was one of 19 students nationwide to receive it.

His proposal, "Launch Vehicle Control Design on a Quad-copter Testbed," pursues designing and utilizing a system that allows for end-to-end testing of flight controllers and new launch vehicles at a lower cost and level of risk. "I'm tremendously excited for the opportunities that come with this fellowship and I cannot wait to get started. I am looking forward to working closely and learning from my advisers," says Elke.

I am also looking forward to working with NASA during both the academic year and during the summer at NASA Langley Research Center."

Professors Demoz Gebre-Egziabher and Ryan Caverly will serve as Faculty Advisors and Principle Investigators (PI) for the duration of Elke's fellowship. Both will oversee and help advance Elke's proposal. In addition, a NASA Technical Adviser will be assigned to mentor him.

Geoffrey Magda Honored for Internship

Geoffrey Magda is one of 32 students to be awarded a 2019 Prix du Stage de Recherche in Mechanics for his internship work in Professor Ryan Elliott's research group. Magda is an undergraduate student from the Ecole Polytechnique in France studying mechanics.

While in Minnesota, Magda worked to develop an understanding of the mechanics of architected materials. Recent developments in additive manufacturing techniques have revitalized interest in the behavior of the mechanical behavior of materials with engineered (periodic) microstructures. Architected materials are commonly constructed of a series of beam-like struts connected by joints to produce a porous, lightweight, and strong material such as a honeycomb. The results of his work show that there is a clear connection between the joint geometry and the critical buckling mode of the architected material's behavior.

"In the short few months that Mr. Magda was in my research group, he made impressive progress," said Elliott.

These results add to a growing understanding (developed in part by Elliott's group) of failure in architected materials, and will eventually lead to a set of design principles/guidelines for this growing and important class of advanced materials.

Luci Baker Accepts Silberman Fellowship

Ph.D. student Luci Baker received the Edward Silberman Fellowship. The Edward Silberman Fellowship is an annual award that was established to honor Professor Edward Silberman, and provide fellowships to students in the St. Anthony Falls Laboratory for outstanding research. Baker received the award for her Ph.D. work with Professor Filippo Coletti on experimental investigation of inertial particles in turbulent shear flows.

According to Baker, "the aim of my research is to study the interaction between fluid and inertial particles in turbulent shear flows and to investigate how the particle shape, size, buoyancy, and concentration affect the fluid-particle interaction. I use experiments to investigate the dynamics of both spherical and non-spherical particles in a turbulent boundary layer and in a natural stream environment (the Outdoor StreamLab at St. Anthony Falls Laboratory). This research will help us understand the behavior of sediment and microplastic particles in many natural and industrial environments."

2019-2020 AEM Undergraduate Scholarships

Congratulations to all the following students.

AEM Strategic Initiatives Fund
Sophia Vedvik
Keegan Bunker

Richard D. and Wyona R. Bartsch AEM Scholarship
Hannah Reilly

Boeing Scholarship
Emma Lenz
Sylvia Griffitt
Patrick Collins
Alexander Baum

Glenn E. Bowie Educational Fund
Joseph Moynihan

Richard G. Brasket AEM Scholarship
Jacob Meiners
Connor Keech

CSE Oswald Award
Jonathan Siles Garner

Richard & Shirley DeLeo Scholarship & Engineering Fund
Campbell Dunham
Ellis Syke

Chester Gaskell Aeronautical Engineering Scholarship
Isaiah Patton
In Kyu Lee
Anna Bialke

Lawrence E. Goodman Scholarship in Theoretical and Applied Mechanics
Vinh Le Ngyuen

The Eric W. Harslem Scholarship for Aerospace Engineering
Emma Krieg

Robert H. & Marjorie F. Jewett Fund within AEM
Emma Zeller
Donald Rowell
Joshua Graeler

John and Robert McCollom Memorial Scholarship
Nathan Noma
Nikolas Pardoe

Rose Minkin Aerospace Engineering Scholarship
Nathan Pharis
Maxwell Lindstrom
John-Paul Heinzen

Louis R. and Dona S. Wagner Aerospace Engineering and Mechanics Scholarship
Albert Unruh

2019-2020 Graduate Fellows

Kenneth G. & Rosemary R. Anderson Fellowship
Nia Allen

College of Science & Engineering Fellowship
Cooper Gray

CSE Grants to Advance Graduate Education
Nia Allen

Doctoral Dissertation Fellowship
Eduardo Vitral

NASA Fellowship
Olivia Schroeder

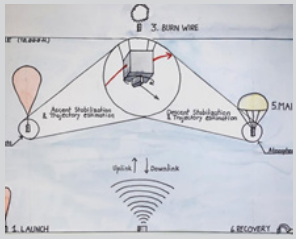
National Science Foundation Fellowship
Jordan Hoyt

Swaminathan & Garg AEM Fellowship
Nia Allen

Peter J. Torvik Fellowship
Ariel Ibarra Pino
Nia Allen

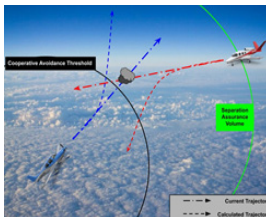
Fall 2019 Capstone Design Projects

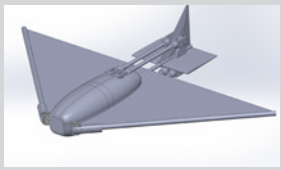
5G Navigation in the NAS
Sponsor: Honeywell, Plymouth MN
Goal: Design a navigation system that will rely on 5G signal for low altitude urban flight.



CubeSat Sonde
Sponsor: U of M Prof. Gebre-Egziabher
Goal: Validate avionics systems intended for CubeSat systems on a weather balloon experiment.

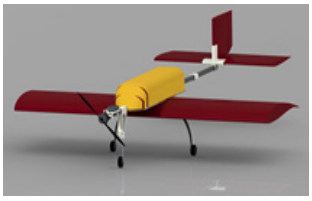
Safe Autonomous System for GA
Sponsor: Cirrus Aircraft
Goal: Create a suitable Detect and Avoid (DAA) system for Cirrus Aircraft for Autonomous General Aviation Aircraft.

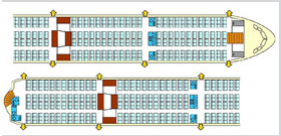




CanSat
Sponsor: American Astronomical Society
Goal: Design a CanSat that will consist of a container and a science payload, which will be a delta wing that will

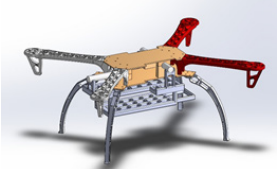
AIAA Design, Build, and Fly
Sponsor: AIAA
Goal: Build a solid, reliable 'bush plane' capable of towing a banner and carrying passengers.



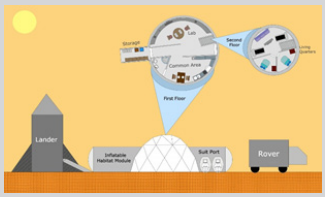


Boeing Large Transport
Sponsor: Boeing
Goal: Design an aircraft that can be competitive with and improve upon Airbus' largest aircraft, the A380-800.

Convertible sUAV
Sponsor: Sentera
Goal: Design UAV with a system that can be exchanged between the versatility of a quad rotor and the efficiency of a fixed-wing aircraft.

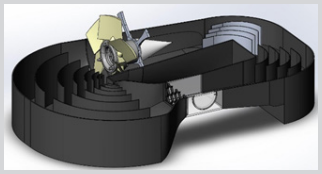


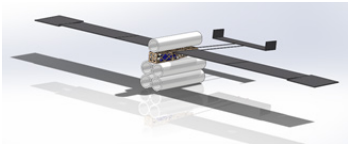
NASA RASC-AL
Sponsor: National Institute of Aerospace
Goal: Design 1 rover and 3 landers capable of sustaining a crew of 4 astronauts on Mars for 30 days.



Hybrid to Battery Regional Aircraft
Sponsor: NASA Armstrong
Goal: Create a proof design for conversion to a fully electric aircraft.

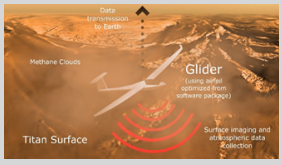
Desktop Wind Tunnel
Sponsor: Collins Aerosapce, Burnsville MN
Goal: Design and build a portable wind tunnel for Collins Aerospace to better demonstrate their products for trade show and educational purposes.





SAE Micro
Sponsor: Society of Automotive Engineers, Aerospace Division
Goal: Design and build an aircraft that minimizes empty aircraft weight and maximizes ability to carry payload.

Titan Aerial Research Vehicle
Sponsor: Aster Labs
Goal: Create software package and design a wing optimized in the Titan environment for maximum endurance.



UAV Anti-countermeasures
Sponsor: Boeing
Goal: Create an operational UAS able to defeat acoustic detection, LASER, and RADAR capabilities of the C-UAS mechanisms.

(left to right) Nick Conlin, Devin McGee, Machlen Polfliet, Nick Pahl, and Andrew Van Gerpen

Rocket Team Wins 2019 Bayer Alka-Rocket® Challenge

A student team from the University of Minnesota College of Science and Engineering rocketed their way to victory and a $25,000 prize in the annual Bayer Alka-Rocket Challenge at Kennedy Space Center Visitor Complex.

The Minnesota team launched an Alka-Seltzer powered rocket they designed to an altitude of 535 feet – a height that, along with a safe recovery, earned them the top score in the competition and the cash prize. Their win was confirmed by a panel of judges, along with a GUINNESS WORLD RECORDS™ Adjudicator. The Golden Gophers, however, did not break the GUINNESS WORLD RECORDS title earned at last year's Challenge with an 883-foot launch by a rocket team from Brigham Young University (BYU).

"We built off our mistakes in previous years to make this year's rocket lighter, stronger, and more reliable," said Machlen Polfliet, a junior majoring in aerospace engineering and mechanics and leader of the University of Minnesota Alka-Rocket Challenge team. "We were definitely pleased when our rocket won."

Dr. Mae Jemison, former NASA astronaut and the first woman of color in space, was part of the event. According to Dr. Jemison, "As in years past, this annual competition has been a blast – for these students, myself and my fellow judges, and everyone else involved. The creativity, engineering prowess, execution and commitment of each team to develop their Alka-Rockets is an inspiring demonstration of how STEM education is alive and well across the country."

She added, "We're certain that each of these students will make their mark in science, engineering or innovation – the areas that are extremely critical for our country's success."

Breaking Through the Aerospace Industry

AEM alumna Michele Brekke returned to the University of Minnesota in October as the 2019 Homecoming Grand Marshal. Brekke received her Bachelors of Science in 1975, and her Masters of Science in 1977 from the UMN AEM department. During her time at UMN, she worked closely with Professor Helmut Heinrich, starting as his secretary and eventually working her way up to a research assistant in the wind tunnel lab testing parachutes. Brekke also played on the University's volleyball team and competed in two national championship tournaments during her collegiate career.

After graduation, Brekke began her career in NASA's Mission Control Center in 1977. Brekke would go on to become the first woman flight director at NASA, and hold various roles throughout the agency for 37 years before retiring. Currently, Brekke works as a flight manager for Boeing's Starliner, which is a part of NASA's Commercial Crew Development program.

Brekke held a meet and greet in the Balas Atrium on Oct. 4, where she answered questions and spoke about her experiences in the aerospace industry. She shared her story and gave students advice on balancing career and family. Brekke said, "I get to write a page in the history books every day I go to work. I just love that I get to be a part of the next new thing."

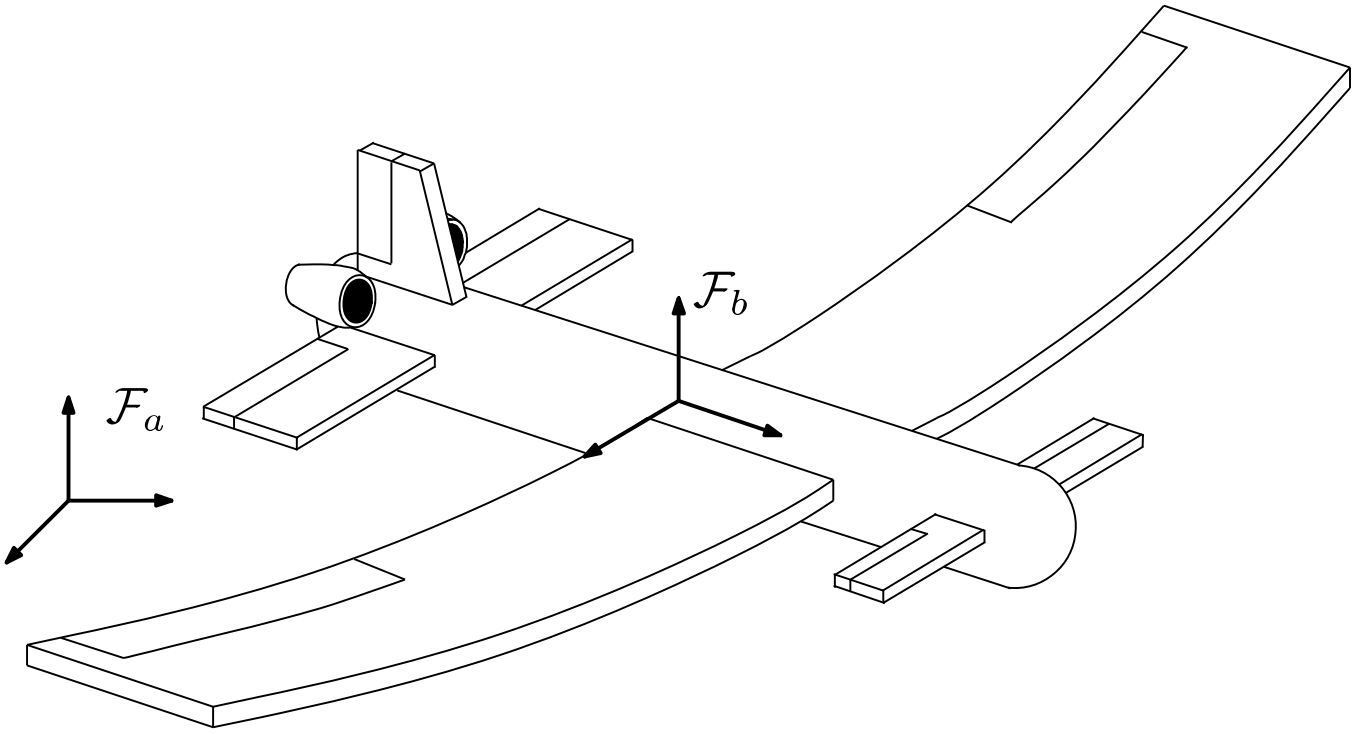
When asked about her success, Brekke said, "All it takes is all you got. Because when you go into this field, it is not a cakewalk. People aren't going to just give you opportunities, you have to work really hard. But if you want something badly enough, you will find a way." She also commented, "Trust your gut--because it never lies."

Anil Bajaj Receives Caughey Dynamics Award

AEM alumus Professor Anil K. Bajaj of Mechanical Engineering at Purdue University received the 2019 Thomas K. Caughey Dynamics Award from the American Society of Mechanical Engineers for his expertise in nonlinear dynamics. He was presented with the award at the AMD Honors and Awards Banquet in Salt Lake City during the 2019 ASME International Mechanical Engineering Congress and Exposition.

Bajaj graduated from the University of Minnesota with a Ph.D. in Mechanics in 1981, and promptly joined the faculty at Purdue. He is currently the Alpha P. Jamison Professor of Mechanical Engineering. Bajaj has held numerous leadership positions during his career, including Department Head from 2011 to 2019.

Bajaj said, "My interests in nonlinear dynamical systems and its applications to structural stability and multi-physics systems developed in Doctoral Studies under AEM Professor Patarasp R. Sethna. He was very passionate and intellectually curious about uncovering complex dynamic phenomena in nonlinear systems. I see reflected in me his influences, not only about research but also about academic integrity, interactions with colleagues as well as mentoring students."



Caverly's team controls flexible robotic and aerospace systems by leveraging fundamental input-output system properties

Why flexible systems?

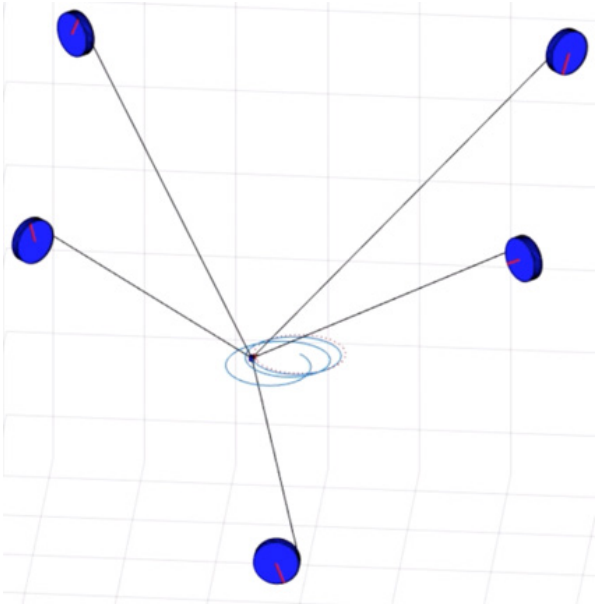
Flexible structures are found in many robotic and aerospace systems, including aircraft wings, spacecraft booms, and robotic manipulator links. These structures are often designed to be lightweight, which intuitively has performance benefits, but can greatly complicate the control of these systems. For example, a poorly designed feedback controller may cause resonance of the flexible structure, de-stabilize the system, and result in worse performance than the uncontrolled system! To make matters worse, it is often difficult to obtain models that accurately capture the structural properties of the flexible structure, further complicating the control design process. These limitations impact the achievable performance of flexible systems, such as an aircraft's fuel efficiency or a spacecraft's maximum slew rate.

Is there alternative system information that can be used when designing feedback controllers for flexible systems? The answer is yes! The relationship between the system's inputs (actuators) and outputs (sensors) can be identified and used to target suitable feedback controller designs.

Modular Dynamic Modeling of Flexible Multi-Body Systems

Although dynamic models of flexible systems are inherently uncertain, they still contain useful information regarding the system's dominant features and provide a means to perform numerical simulation. AEM Professor Ryan Caverly's group focuses on deriving the equations of motion of individual system components that make up the flexible system (e.g., aircraft fuselage or wing, spacecraft hub or flexible appendage) and kinematically constraining the components together to form a model of the complete system. This results in a modular approach to dynamic modeling, where only the kinematic relationships between components need to be re-derived. Moreover, the individual component models can easily be adjusted depending on the desired model fidelity. For example, can we approximate a structure to be rigid? How many modes of vibration do we want to capture?

Caverly and graduate student Alex Hayes have made use of this approach to model cable -driven parallel robots (CDPRs). Their modular simulation code can

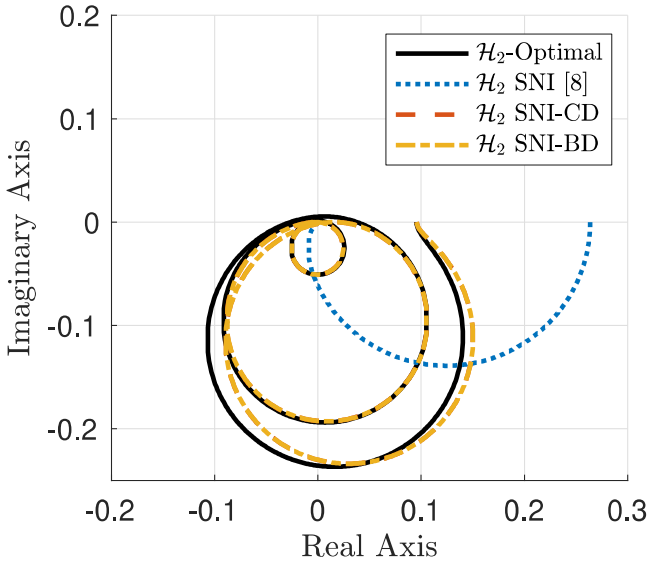


Simulation of a a cable-driven parallel robotic system tracking adesired payload trajectory.

accommodate CDPRs with three to eight cables and different cable models that can be chosen based on the CDPR configuration and simulation purpose. This simulation environment will provide a means to test novel input-output control strategies developed by the team.

Input-Output Control Design

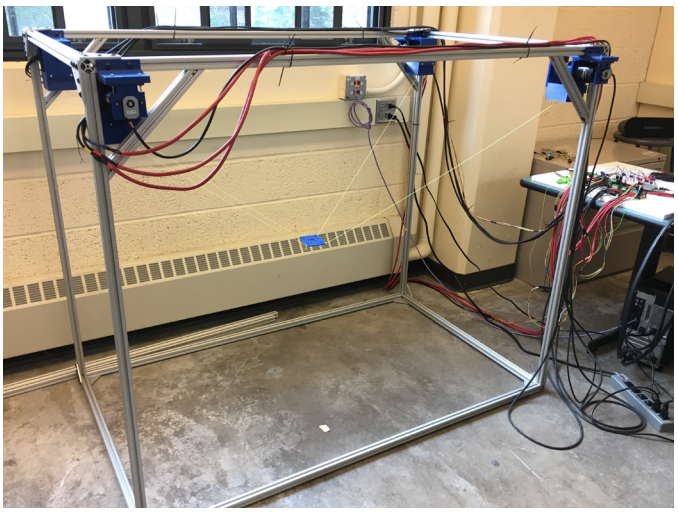
Although it may be difficult to determine an accurate mathematical model of a flexible system, it is often possible to find the system's input-output properties. For example, flexible structures that are equipped with actuators and sensors that are physically collocated (e.g., a motor with a built-in encoder or a piezoelectric actuator/sensor pair) often feature a passive input-output relationship. Passivity is a fundamental input-output property of these systems that holds for wide ranges of model uncertainty. A dynamic system may have other input-output properties, including negative imaginary, dissipative, or interior conic. Once an input-output property of the system is determined, there are input-output stability theorems that can be used to determine the input-output properties of the feedback controller that will robustly stabilize the system.



Caverly and graduate student Manash Chakraborty are developing methods to design robust and optimal feedback controllers that leverage input-output stability theorems and the known input-output properties of flexible systems. They have successfully derived convex-optimization-based methods to design optimal strictly negative imaginary (SNI) controllers, which were shown to be effective in suppressing the transverse vibrations of a beam. The team is now extending these methods to develop improved control strategies for hard disk drives.

Moving Forward

Caverly's team plans to continue developing novel input-output control techniques that leverage the input-output properties of flexible systems and begin to validate their approach through experiments. Caverly's research lab features three robotic systems that are used for this purpose, including a custom-built CDPR. The team is hopeful that their control methods will enable exciting new robustness guarantees and performance capabilities in the control of flexible systems.



Prototype of cable-driven parallel robotic manipulator in Prof. Caverly's research lab.

AEM Alumni After 50 Years

In addition to the CSE 50-year Reunion, the AEM class of 1969 gathered to celebrate their reunion and the first moon landing. Alumnus Gary Ashley organized the weekend on July 19-20, 2019. They toured campus and visited the wind tunnel facility in Akerman as well as other research spaces, including the department's Unmanned Aerial Vehicle Lab.

They spent time reminiscing and enjoying the longevity of their friendship and positive opportunities that came from their days at the University of Minnesota in the then Department of Aeronautical Engineering. The graduates went on to be successful at a variety of companies such as Boeing, TRW Inc., and many others.

George Ceman, one of the reunion participants, said, "We had an excellent curriculum and preparation. The skills we learned at the University of Minnesota allowed us to stand up in the world. We've all had successful careers and most of us have had interesting accomplishments as well. And we always have good stories to share!"

In Memoriam: J. Leonard Frame

J. Leonard Frame, alumnus and longtime donor to the Department of Aerospace Engineering and Mechanics, passed away on Sept. 21, 2019.

Frame graduated with a bachelor's degree in Aeronautical Engineering at the University of Minnesota in 1943. Frame was an expert in the field of wind tunnel technology, and founded and became president of FluiDyne Engineering Corp., which had a position of international preeminence in the field of aeronautical testing, serving most of the airframe and propulsion industries in the U.S. After selling Fluidyne, Frame founded and led Phoenix Solutions Co. Frame's achievements in engineering and business were recognized by the University with the prestigious Outstanding Achievement Award in 1969.

From the Development Office:

Thanks to the many alumni, friends, and companies who gave so generously to the Department of Aerospace Engineering and Mechanics in calendar year 2019. These annual gifts are instrumental in supporting our students, faculty, and enhancing the academic program. Your support has been instrumental in helping the department continue attracting and admitting the most talented students into our undergrad and graduate programs.

The need for support for the college and the AEM department has never been greater. Gifts of all sizes are making a difference in the lives of our students. Support from our alumni, faculty, staff, friends, and industry ensures that our students will continue to be leaders in shaping the future of aircraft and spacecraft design, research and development, biomedical and computer engineering and education, thanks to the education they receive in our department.

We thank you for your support and encourage you to continue helping us prepare the next generations of engineers. Your gifts are making a difference.

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College of Science and Engineering

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Professor Emeritus Garrard on Apollo 11

AEM Professor Emeritus William Garrard was interviewed by the Twin Cities ABC affiliate about the role of local companies on the historic first moon landing. Garrard noted that companies across the nation collaborated with NASA to make this incredible feat happen, including companies from Minnesota. He pointed in particular to Honeywell, which was based in Minneapolis in 1969, and designed and built key components for the Apollo spacecraft. The company's contributions included vehicle stabilization and control systems, making it possible to maneuver the spacecraft from launch to touchdown on the moon. Honeywell also developed environmental controls providing oxygen and drinking water for the astronauts.

"I think it's absolutely astounding, yeah. The more I think about it in later years," Garrard told ABC. "Honeywell played a very major role. Honeywell was a leader in design of control systems and those were very, very important for the flight of Apollo."

Apollo 11 ©NASA HQ PHOTO

The department will now also be publishing an electronic newsletter. If you wish to be added to the mailing list, please email aem-dept@umn.edu.